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Contemporary Issues in
Economy and Technology

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PAPERS



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Track 1

Accounting
and Finance

CORPORATE SOCIAL ACCOUNTING AND CONTROL: THEORETICAL AND PRACTICAL CONSIDERATIONS

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Abstract. Business is essentially a socio-economic activity that adheres to a specific logic and is planned, reported, evaluated, and controlled. The paper focuses on the accounting of socio-economic activities, particularly social and environmental accounting, which has become essential in business management. Enterprises must incorporate social and environmental accounting into their reporting to adapt to the evolving environment. Contemporary managers understand the significance of this decision and are seeking practical solutions in this regard. Social accounting involves revealing the social and environmental impacts of a company's economic activities to specific stakeholders and society in general. Corporate social accounting gradually developed a methodology and tools for consistent reporting to stakeholders. Corporate social accounting involves providing information for impact assessment and monitoring and evaluating accounting and control systems. New areas of corporate accounting and control are currently under development. They are committed to integrating information on strategy, performance, and enterprise development in a manner that connects economic, social, and environmental indicators. Studies indicate that social accounting is increasingly playing a significant role in the advancement of models for strategic analysis and internal control systems within enterprises. Yet, many countries have not thoroughly examined the practical aspects of corporate social accounting or adapted models for strategic management and control. This paper focuses on accounting, internal control, corporate social accounting, and their relationship with business strategy. The study aims to explore ways to enhance the involvement of accounting in utilizing strategic models to analyze and oversee environmental and social aspects integrated into business strategies.

Key words: *strategic management, corporate social accounting and control*

1. Introduction

Business, in all its forms, is a part of our everyday lives. In practice, it is a socioeconomic activity with a predetermined logic that is planned, reported, analyzed, and controlled. This paper focuses on the accounting of this socioeconomic activity, specifically on the so-called social and environmental accounting, which are now considered essential components of business management. The changing environment necessitates the adoption and integration of social and environmental accounting concepts into corporate reporting. Modern managers recognize the importance of such a way of thinking and are seeking practical solutions in this area.

Social accounting is commonly linked to the practice of revealing the social and environmental impacts of a company's economic activities to particular stakeholder groups and the broader

society. Social accounting is widely regarded by contemporary managers as an initial measure towards fostering corporate social responsibility. Various enterprises have undertaken efforts to gather dependable data for the purpose of evaluating social impact. Gradually, social accounting developed a systematic approach and a set of tools for consistent reporting to stakeholders.

In addition to facilitating impact assessment, social reporting encompasses the monitoring and evaluation of reporting and control systems. Within this particular framework, novel forms of corporate accountability and control have emerged. This concept is associated with the integration of data pertaining to strategy, performance, and business development, with the aim of establishing connections between economic, social, and environmental indicators. Accounting plays an increasingly significant role in the provision of comprehensive information, including its registration, reporting, and analysis of business performance. Additionally, it encompasses costing and cost analysis based on economic factors, with a particular focus on social responsibility objectives.

In contemporary times, social accounting has become an integral component of corporate annual reports. Studies indicate that social accounting is playing an increasingly important role in the advancement of strategic analysis models and internal control systems within businesses. Nevertheless, the pragmatic elements of social accounting have not been adequately investigated, and numerous models have not been modified for the purpose of strategic management and control. SDG (Sustainable Development Goals), ESG (Environmental, Social, Governance), and ESRS (European Sustainability Reporting Standards) are key concepts that create the conceptual framework of the paper. Research methodology is connected with analysing and interpretation of standards, documents, literature and previous studies.

This publication primarily examines the domains of accountability and control pertaining to corporate social responsibility, within the context of enterprise business strategy. The purpose is to examine and assess the potential for enhancing the involvement of accounting in the implementation of strategic models for evaluating and managing environmental and social factors integrated into enterprise strategies.

2. Specifics of social accounting in enterprises

Social accounting has been defined differently by different researchers, which broadens and enriches the scope of this field of accountability. Most commonly, social accounting is thought to be an application of double entry bookkeeping to socio-economic analysis (Chavda & Acharya, 2022; Mihaylova & Papazov, 2021). It is also widely believed that this type of accounting is a process of collecting, collating, preparing, and publishing social and environmental information in the form of various social and environmental accounts (Contrafatto & Rusconi, 2005). In addition to social accounting, green accounting has also been mentioned in theory in recent times.

Similar to social accounting, green accounting is a systematic approach that acknowledges, quantifies, documents, condenses, and communicates environmental, social, and business activities and occurrences, leading to an accounting data set that supports operational, tactical, and strategic decision-making. Green accounting refers to the systematic practice of documenting business transactions while explicitly considering and incorporating environmental considerations. The integrated approach entails the collection of accounting information to enable stakeholders to assess and execute business and non-profit decisions, while also considering the environmental consequences associated with these decisions.

Green accounting for businesses is linked to the implementation of corporate social responsibility. This is the enterprise's responsibility for the overall environmental impact of its operations (Prahara and A'yuni, 2021). Green accounting is the process of preparing financial statements that reflect environmental costs. The latter are done to mitigate the effects of environmental impacts as well as the costs of addressing environmental damage in the future. In other words, the use of green accounting in businesses improves environmental cost management, particularly in industrial enterprises. The goal is to achieve greater environmental efficiency (Anggraeni and Dewi, 2022). Social accounting incorporates environmental accounting.

Irrespective of the diverse interpretations of corporate social reporting, the primary objective is to assess, document, compare, and ultimately enhance the social and ethical performance of companies by implementing suitable strategies. The primary objective of this study is to examine the interplay between corporate social accounting, internal control, and strategic management. The utilization of a more comprehensive interpretation of social reporting involves the systematic gathering, organizing, organizing, and disseminating of social and environmental data through diverse social and environmental narratives.

Before delving into the practical aspects of the issues, a general comparative table can be presented that highlights the key differences between financial reporting and corporate social reporting (Table 1).

Table 1. Main differences between financial accounting and social accounting

Indicator	Financial accounting	Social accounting
Information mainly produced for	Shareholders	Stakeholders (local communities, customers, government)
Purpose of information	To record the financial performance in a period and the financial position at the end of that period	In addition to financial factors, it integrates social factors, eco-factors, etc.
Legal requirements	Mandatory for companies	Not mandatory but disclosure of Corporate Social Responsibility activities has been mandated for a certain class of enterprises
Nature of information	Financial	Financial and non-financial
Formats	Financial accounts to reflect a true and fair view must follow accounting standards and company law	No specified format
Time period	Historical perspective	Historical as well as future
Limitations	Absence of full disclosure of facts	Financial analysis is not used much

Source: Adapted from (Khatabook, 2024).

Social accounting offers a comprehensive view of financial and non-financial performance, enabling accurate and long-term decision-making at the tactical and strategic levels. Modern accounting frequently plays an important informational role in business management, and

accountants are becoming an important and active member of the management team at various levels (Pepur, Kukuz & Hrga, 2022; Mihaylova & Papazov, 2018).

According to Papazov and Mihaylova (2023), there is a logical connection between strategic, tactical, and operational decisions inside of an organization. Therefore, the development of social accountability is reflected in all three types of decisions, beginning with the operational ones, and progressing all the way up to the strategic ones. The following is a condensed version of some of these directions of accountability and control:

- accounting for reductions in harmful gases and emissions;
- accounting for waste reduction;
- accounting for energy effects of management decisions;
- accounting for water use and water treatment measures;
- optimizing information flows;
- performance evaluation;
- integrated management control.

The aforementioned areas can be comprehensively examined and interconnected with the analytical reporting of the enterprise. Consequently, this can act as the basis for social accounting and the formulation of tactical and strategic decisions. Based on empirical evidence, it is evident that energy consumption, water utilization, and waste management constitute a substantial proportion of operational expenditures, particularly within the industrial domain. Accurately quantifying these expenses is a logical approach to effectively administer savings, formulate investment strategies, and evaluate societal ramifications. These concerns ought to be effectively tackled by means of corporate social responsibility reporting and internal control mechanisms.

Enhancing environmental performance within businesses necessitates more than mere allocation of tangible resources. Impacts in this domain can be attained through the substitution of specific materials, implementation of technological advancements, reduction of scrap and waste during production, and other related strategies. Energy, water consumption, and waste production are all substantial factors that contribute to costs within the industrial sector. Consequently, a methodical approach to monitoring, recording, and managing costs is necessary. Effective accounting, especially in the analytical component of business reporting, results in investments in energy-efficient machinery, thereby enhancing energy efficiency. Additionally, it facilitates the implementation of technology for material recycling and reuse, waste reduction, and the establishment of smart buildings (Stoencheva, 2020).

This illustration showcases the interconnection between operational (cost management decisions), tactical (investment decisions), and strategic (enterprise technology decisions) aspects of corporate social accounting. Within this framework, accountants, especially those working in small and medium-sized enterprises, are required to consistently examine energy consumption records and aid managers in evaluating energy utilization. Additionally, this aids in maintaining internal control over this particular category of expenses. Accountants should ensure that their work is structured in a consistent manner for various tasks such as water management, waste management, occupational accidents and injuries resulting from occupational diseases, and analysis of staff sickness and absence. This matter can alternatively be conceptualized as an exploration for pragmatic resolutions that enhance the professional conduct of accountants and managers within the context of small and medium-sized enterprises.

3. Practical aspects of corporate social accounting and control

The practical aspects of corporate social accounting and control are also linked to the implementation of the European Sustainability Reporting Standards (2024). ESRS-1 specifies the mandatory concepts and principles to be used in sustainability reporting and requires businesses to disclose sustainability information such as strategy, risk management, and impact opportunities, as well as climate change indicators and targets. Sustainability information can influence stakeholder decisions, so companies should identify their two main stakeholder groups, i.e.:

- affected stakeholders – individuals or groups whose interests are or may be affected by the enterprise's activities, including through its value chain.
- stakeholders with an interest in the enterprise – major users of financial reporting, such as existing and potential investors, credit institutions, insurance companies, other users, including business partners, trade unions and social partners, civil society organizations, and non-governmental organizations, among others.
- ESRS-2, the second standard, focuses on sustainability reporting and accountability by outlining the specific requirements for transparency in sustainability reports. This encompasses the fundamental attributes of the enterprise and a comprehensive summary of its operations, along with detailed information regarding the strategy and business model, the importance of the entity's effects, potential risks, and prospects for long-term viability.
- The practical aspects of corporate social accounting and control are also linked to thematic standards for disclosing environmental, social, and governance issues, regardless of economic sector. Thematic standards require:
 - reporting on identifying and assessing significant impacts, risks, and opportunities;
 - managing related policies, objectives, action plans, and resources; and
 - establishing indicators and targets for specific topics.

These requirements are practically applied in addition to cross-cutting standards such as:

- environmental standards. Environmental standards determine disclosure requirements for companies related to climate change, pollution, water and marine resources, biodiversity and ecosystems, and resource use and circular economy.
- social standards. Social standards outline a framework for businesses to consider issues related to their workforce, workers in their value chains, communities, consumers and end-users of their products or services affected by their actions.
- governance standards. A governance standard sets out disclosure requirements related to improving users' understanding of an enterprise's strategy, and processes, procedures and performance in relation to its business conduct.

From a practical point of view, the enterprise needs to describe the relationships between the different elements of information. This may require linking non-financial management, strategy and risk management information to relevant metrics, financial indicators, and targets. For example, an enterprise may explain the impact of its strategy on the financial statements or financial plans, or explain how the strategy has impacted sustainability-related metrics and targets, etc. When monetary amounts or other quantitative data that are presented in the financial statements are included in the sustainability report (there is a direct link between the information disclosed in the sustainability report and that in the financial statements), the enterprise shall include a reference to the relevant financial statement line item where it can The sustainability

report may include monetary amounts or other quantitative data that are indirectly related to the financial statements and the sustainability report.

In practice, corporate social accounting aims to identify material environmental and social costs that can be reduced. The identification of such costs is preceded by an analysis of the actual data in the accounts (at the synthetic and analytical levels), an analysis of supply and sales transactions, and an analysis of the manufacturing process. From a practical standpoint, cost analysis by activity in the enterprise is useful for tracking key processes and their compliance with standards, internal and external regulations, established industry practices, and so on.

The first step in organizing social accountability in enterprises is to define procedures for measuring costs, identifying savings, and raising revenue from all activities related to the enterprise's social responsibility. An important next step is to track analytical accounting data in natural measures. Enterprises that use materials to produce products must maintain separate analytical accounts for the material flows acquired by the enterprise and consumed for specific products, as well as the waste generated during production. Analytical reporting can be separated at the process level. This makes it easier to identify opportunities for cost savings. Furthermore, actions involving process changes to reduce consumption and account for resource savings can be identified more easily.

In terms of enterprise social reporting, analytical reporting can be organized for money paid for sick leave and work accidents, litigation costs for work accidents, costs paid for work accident insurance, costs for additional personnel insurance, and so on. For example, under Bulgarian law, employees who are required to have compulsory insurance for the risk of an accident at work are determined by the employer in writing after consulting with the occupational health service and the working conditions committee based on the risk assessment. A protocol must be used to certify the consultations, and a collective agreement may also designate employees who are required to be insured against the risk of a workplace accident if the need is proven and the risk is recognized.

Rapid technological and economic development has caused the emergence of new risks and influenced the change in the frequency and effects of already known ones (Stanković, Tomić & Stanković, 2020). Changes in the environment also require changes in the internal controls and accountability of enterprises (Angelova-Stanimirova, 2023; Liao & Khan, 2022; Kirova, 2018).

In order to determine how stakeholders (such as investors, lenders, customers, suppliers, employees, and so on) view an organization, the quality of the reporting is of the utmost importance. As a result of internal control, the quality of the reporting is affected. The complexities of social relations have invariably led to changes in control activity, as well as its improvement and development, as is evident from a review of the academic literature, which reveals that these changes have occurred simultaneously. With this information, it appears that controlling is an activity that is able to adjust to changes in the surrounding environment. In accordance with this line of reasoning, it is possible to propose, from a pragmatic point of view, an improvement in the extent of internal control that businesses have in the area of social accountability.

In practical terms, the internal control activity is related to the establishment of adequate information systems and given the social accountability in enterprises, the following is necessary:

- defining the information needs on the status of the counter-controllable parameters that are related to social accountability and sustainability;
- identifying sources of information on the meanings of the controllable parameters related to corporate social responsibility and sustainability;
- specifying data collection methods;

- selection of the form of storage of the collected data;
- provision of methods for processing the information, analyzing, and identifying relationships and dependencies.

This technology must adhere to a clear and understandable logic, allowing the control influence to be directed toward synchronization with the established goals and objectives. The logic of the technological implementation of the control activity is also linked to the new standards for a more responsible and sustainable business, which will eventually become mandatory for most organizations, as well as funding opportunities.

4. Conclusion

Corporate social accounting refers to a comprehensive method of collecting both financial and non-financial data to assess and execute business and non-profit choices, while also considering the environmental consequences of these choices. Irrespective of the different interpretations of corporate social reporting and the numerous global regulations, its fundamental purpose is to assess, communicate, compare, and ultimately enhance companies' social and ethical performance by implementing a suitable business strategy. The subject at hand remains relatively nascent within the realm of business operations, prompting companies to seek pragmatic resolutions and frameworks.

This paper aims to examine and evaluate the potential for enhancing the involvement of accounting and control in the context of environmental and social factors integrated into corporate strategies, as facilitated by the concept of sustainability. Based on the conducted analysis, it can be inferred that a diverse range of tools and models (cost analyses, relative advantage matrix, etc.) have demonstrated their efficacy in the realm of organizational management, particularly in the domains of financial and management reporting. This has generated considerable interest among researchers, who are keen on adapting and effectively implementing these tools and models for the purpose of social reporting.

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COMPARISON BETWEEN PENSION SYSTEMS IN AUSTRALIA AND CROATIA

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Abstract. The focus of every individual and also of every developed society is the financial future of pensioners. Responsibility for future retirement income lays upon state, retirement funds, but also upon individuals. Different social contexts have created different platforms for the development and growth of pension systems in Australia and Croatia. Roles of responsibility and their fulfilment differ between the two nations. Financial literacy - or lack of it - represents another lens for future expectations of retirement income. With positive trends in life expectancy, the sustainability of existing pension models is becoming uncertain. Aging of nations as well as changes in working contingent are also challenges that have to be taken in consideration when analysing future predictions for pension system efficiency. The focus of this paper is banking-orientated system of Croatia and market-orientated system of Australia. By comparing two opposing models, the one in Australia and the one in Croatia, we will try to answer the question of what improvements are possible. For the comparison, and in order to benefit from the diversity of issues that these countries face, taken demographical data, data concerning financing the pension system, historical data on establishment and current challenges in both countries have all been taken into consideration. Many of the variables which are important for the success of a pension system, and what future expectations are, will be presented and discussed in this work. Based on the findings, recommendations will be provided in conclusion.

Key words: *pension system, life expectancy, financial literacy, retirement income*

1. Introduction

The pension system has very different, demanding and complex tasks. The most important one is securing residents who pay pension insurance contributions during their working life so that they are entitled to receive, at the time of retirement, monthly pensions, so that they will not become poor. (Bejaković, 2019, 37) With demographical changes that have taken place in the last 3 decades, financing of a sustainable pension system has become one of the most challenging issues worldwide. Pension systems are in constant flux, and their reforms are driven by shifting objectives, moving reform needs, and changing enabling environments. (Holzmann, 2012, 21)

Contemporary existing pension systems can be classified based on different criteria. Pension systems can be classified according to three dimensions (Feldstein and Liebman, 2002). First, by structure they can be systems of generational solidarity (pay-as-you-go, PAYG) or fully capitalized systems. Secondly, pension systems can be structured as defined pension systems or defined contribution systems. Third, pension systems may be closer to the Beveridge or Bismarckian model. (Hachon, 2008, 342)

It is very important to take in consideration all important variables that can influence the effects of reforms. One of the most important variables is demographical trends. It is customary, when demographic data is taken into consideration for the purposes of economic forecasts, that the valorisation of changes comes down to looking at two trends. One is the increase or decrease in the number of inhabitants in a certain territorial area, and the other is the increase in life expectancy.

Reforms of pension systems took place in countries all over the world in an attempt to make them more sustainable. Requirements for efficient implementation of reformed systems vary between nations but one that is common for all countries that aim to make positive changes is a high level of financial literacy within its population. OECD performs surveys on financial literacy on a yearly basis and record improvements in several key competencies: financial knowledge, financial behaviour and financial attitudes. Financial literacy levels can and must be improved to support sound financial decisions in challenging economic contexts. Results from this latest coordinated measurement exercise reveal that there is room for improvement in financial literacy competencies: the overall average financial literacy score across all participating countries and economies is 60 points out of 100 points. (OECD, 2023, 56)

Societies are in constant change and pension systems need constant evolution in order to meet new challenges. The aim of research performed in this paper is to investigate and compare pension system in one post-communist country which is bank orientated and one overseas market-orientated country. Research will show pension systems from the period of their establishment to some future predictions.

2. Past, present and future of Croatian pension system

The Republic of Croatia, with land area of 56 594 km², is situated in the south-eastern part of Europe, surrounded by Alps in the west, Sava and Drava rivers in the north and east and the Adriatic Sea in the south. According to the 2022 mid-year population estimate, this area was populated by 3.8 million inhabitants with an average density of 68.1 inhabitants per km².

In last decade Croatia has faced a lot of demographical changes which had negative impact on sustainability of pension system. Main changes are shown in table 1.

Table 1 Natural changes and migrations in Croatia from 2013 until 2022

<i>Year</i>	<i>live births</i>	<i>died</i>	<i>immigrated</i>	<i>displaced</i>	<i>TOTAL</i>
2013	39 939	50 386	10 378	15 262	-15331
2014	39 566	50 839	10 638	20 858	-21493
2015	37 503	54 205	11 706	29 651	-34647
2016	37 537	51 542	13 985	36 436	-36456
2017	36 556	53 477	15 553	47 352	-48720
2018	36 945	52 706	26 029	39 515	-29247
2019	36 135	51 794	37 726	40 148	-18081
2020	35 845	57 023	33 414	34 046	-21810
2021	36 508	62 712	35 912	40 424	-30716
2022	33 883	56 979	57 972	46 287	-11411

Source Croatian Bureau of Statistics, various statistics, Retrieved from February until April, 2024, from <https://dzs.gov.hr/en>

Natural changes - difference between number of inhabitants that have passed away and live births - has been continuously negative. The only positive change is visible in immigration however it is too early to establish a trend.

The number of inhabitants is not giving us a completely clear picture on the implications of several decades of negative trends on pension system. For this purpose, we need to check what is going on with age structure. At Figure 1 we can observe the age pyramid change for Croatia from 2011 to 2021.

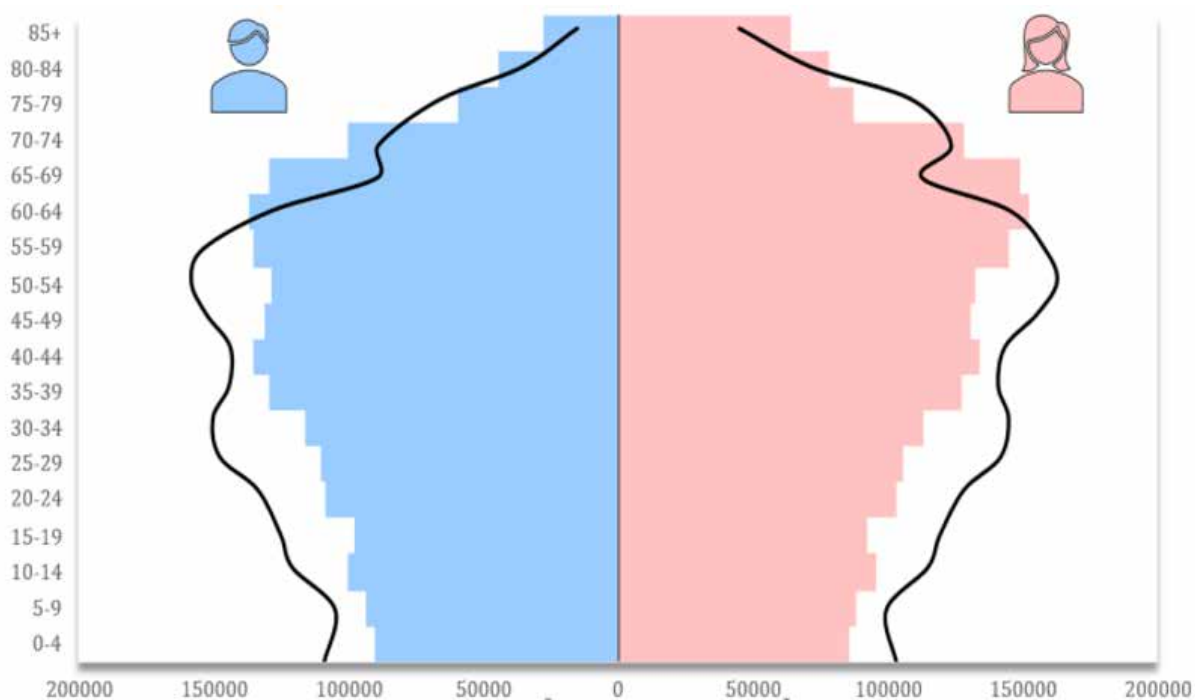


Figure 1 Age pyramid in Croatia 2011 and 2021

Source Središnji državni ured za demografiju mladih (2022.) Demografski godišnjak/ Demographic yearbook

From figure 1 it is visible that changes in the last decade are leading to a reduction of the labour force and potential labour force. Consequences are:

- the aging of the population determines a rather limiting framework for the formation of the working contingent, and thus the active population;
- by increasing the size of the elderly, mostly economically inactive population, personal and public consumption increases, especially in the domain of funds for health, social and pension care of the elderly. (Živić, 2003, 307)

In the described circumstances finding a sustainable model of pension system in Croatia presents a very impressive challenge.

2.1. Foundation of Croatian pension system

The Croatian pension system must be observed through general history due to the fact that Croatia gained its independence in 1991.

Before the first institutional form of organized pension system in Croatia we witnessed the formation of the first mining fraternity treasury in Croatia, founded in 1833 in Rude near Samobor. It was in Dalmatia in 1880 that a fraternal treasury was established in the mine Monte Promina (Siverić) near Drniš. (Puljiz, 2007, 166) One could point out many other examples of local associations of a that had a role in fulfilling the basic tasks of the pension system.

The first formal institution responsible for governing the pension system, the Croatian Pension Insurance Institute, began its activities as the Central Office for Workers' Insurance. It was founded and established by the Workers' Insurance Act on May 14, 1922. This Act represents the legal beginning of an organized pension system that would pass many changes in turbulent times which followed. The pension insurance providers have changed their names and internal organization, but the purpose of their existence has always remained the same - to provide workers' insurance, take care of the insured and benefit beneficiaries.

After the end of World War II, there was a merger of all existing holders of social insurance at that time, regardless of the branch of insurance and the coverage of persons for whom the insurance was provided. Instead of the Central Institute for Workers' Insurance, the Central Institute for Social Insurance with headquarters in Zagreb was established. Such an organization remained until 1971, when pension insurance was separated from health insurance.

Starting from 1972 until 1990, pension insurance was carried out in a self-governing community of interest, established for the territory of the whole of Croatia, based on a special law, by which Croatia regulated the original pension insurance, in accordance with the then constitutional amendments. It should also be noted that the 1970s and 1980s in pension insurance were characterized by the growth and development of the implementation of international agreements on social insurance, which to the greatest extent covered and protected Croatian workers abroad.

The past pension system in terms of relevant numbers of insured persons and pensioners is displayed in table 2.

Table 2 Number of insured persons and pensioners in the period 1950-1990

<i>Year</i>	<i>Number of insured persons</i>	<i>Number of pensioners</i>	<i>Ratio</i>
1950	593 102	67 771	8,75 : 1
1955	689 212	123 627	5,57 : 1
1960	912 290	176 978	5,15 : 1
1965	1 079 111	251 304	4,29 : 1
1970	1 116 088	340 134	3,42 : 1
1975	1 287 396	377 565	3,40 : 1
1980	1 518 049	438 133	3,46 : 1
1985	1 658 960	507 551	3,26 : 1
1990	1 682 971	594 339	2,83 : 1

Source Croatian Institute for Pension Insurance and its legal predecessors; annual reports HZMO (2002:207-208). Quoted according to Puljiz, V. (2007). Hrvatski mirovinski sustav: korijeni, evolucija i perspektive/ Croatian pension system: roots, evolution and perspectives. *Revija za socijalnu politiku*, 14 (2), 170.

In the observed period presented in Table 2 many changes occurred regarding different aspects of society. All these changes have influenced opening of new workplaces and growth in the number of people who obtained pension income rights. It can also be seen that the ratio between insured persons (those who pay contributions) and pensioners (beneficiaries of pension income) is decreasing. These figures in 1990 were already indicating the necessity of reform.

With the gained independence of Croatia, the Croatian pension insurance is about to meet new challenges. In the most dynamic period, during and after the homeland war, Croatian pension system needed reform in order to preserve sustainability. The war left its traces in the implementation of pension insurance. In the same time there was an increase of pensioners of

war and loss of working places (due to the wild privatisation that took place during the homeland war). At the same time, work on pension reform was initiated in 1998 with the adoption of the Law on Pension Insurance, which established the current Croatian Pension Insurance Institute.

2.2. Assessment of current pension system in Croatia

The reform of the pension system was carried out in Croatia in 1999 implementing a mixed model with three pillars.

The Pension Insurance Act (01.01.1999) induced a mandatory pension insurance model established through two pillars: intergenerational solidarity (pillar I) and individual capitalized savings (pillar II). In addition, the option of voluntary savings for old age was introduced (pillar III).

The law which regulates the system of general mandatory pension insurance is based on intergenerational solidarity, while the arrangement of two other pension pillars of the new pension system is arranged by special laws.

The reform was carried out in two directions:

1. adjusting the public pension system in 1999 (by tightening the conditions for acquiring the right to a pension with a transitional ten-year period, by lowering rights);
2. introducing mandatory II. pension pillar based on capitalized savings and voluntary capitalized savings for old age in III. pension pillar at the beginning of 2002.

The contribution for mandatory pension insurance is 20 percent of the worker's gross salary. For public pension system (pillar I) 15 percent is allocated, and for mandatory capitalized savings (pillar II) 5 percent. So, from the previous intergenerational solidarity system, 5 percent of the contribution was redirected to individual capitalized savings.

Current development of demographical changes has led to more difficult situations in terms of the sustainability of the pension system based on intergenerational solidarity as we can observe in table 3.

Table 3 Number of insured persons and pensioners in the period 1990-20200

<i>Year</i>	<i>Number of insured persons</i>	<i>Number of pensioners</i>	<i>Ratio</i>
1990	1 968 737	655 788	3:1
1995	1 567 981	865 769	1,81:1
2000	1 380 510	1 018 504	1,36:1
2005	1 498 877	1 080 571	1,39:1
2010	1 475 363	1 200 386	1,23:1
2015	1 413 637	1 135 166	1,25:1
2020	1 571 672	1 232 601	1,28:1

Source Croatian Pension Insurance Institute, various statistics

The data presented in table 3 underlines the importance of reform.

In figure 2 we can follow the success of funds that represent pillar II. Since 2014 the funds in pillar II have had 3 levels risk diversification. Funds A are investments with higher level of risk, B moderated risk and C funds are investments with the lowest risk. So we observe separately the income of A, B and C group of funds.

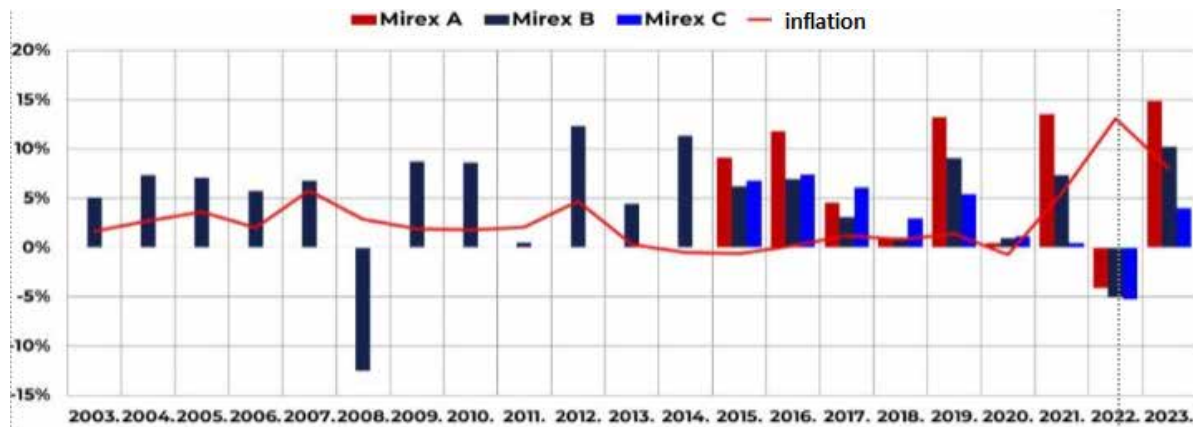


Figure 2 Income of obligatory funds (pillar II) 2003-2023

Source HANFA, www.hanfa.hr

Average yearly income of obligatory funds A is 7,36%, for funds B is 5,26 and for funds C is 3,30%. It is visible that only in years with extreme increases of inflation these funds failed to meet the challenge of generating income.

Citizens of Croatia still don't use in full the possibilities offered by the III pillar. Although government encourages investment in pillar III. giving state incentives in the amount of 15 percent on user payments, in the maximum amount of 99 euros per year, this type of capitalized savings has not yet reached its full potential in terms of the number of consumers.

This could be connected with lack of financial literacy which represents an obstacle for understanding of importance of saving for future.

2.3. Future of Croatian pension system

Although reform has started in 1998 (with legal framework in 1999) there are still things to be done. Without further changes expectations for the future don't look optimistic. Croatia has been following the basic reform trends in the EU, but in financial terms the system has remained strongly dependent on budget transfers, while pension adequacy has continued to deteriorate. The share of public pension expenditure in Croatia has stabilized over the previous decade at the level of slightly over 10% of the GDP, with fluctuations depending on the cyclical status of the economy (from 9.5% in 2007 to 11.6% in 2015) In figure 3 projections of future retirement income is presented based on data collected until 2019.

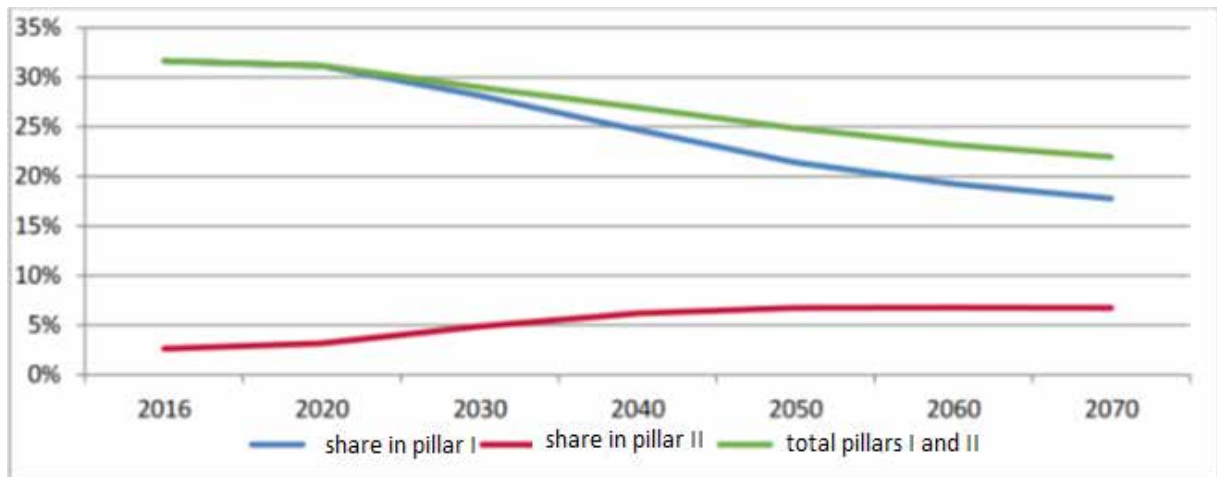


Figure 3 Projection of ratio between average retirement income and average salary until 2070

Source World bank (2019). Policy Note: Adequacy of Pensions in Croatia

Since predictions of future retirement income made by the World Bank didn't look very promising, especially from the source of intergenerational solidarity source (pillar I), it increased awareness of future retirement income gap.

Based on new data (Croatian Pension Insurance Institute, 2024) percentage of public expenditure for retirement in GDP in Croatia has been slightly decreasing and from 10,97% in 2020, to 9,81% in 2021, in 2022 it was 9,49% and latest data shows that in 2023 it was 9,43%. This trend will reflect positively on projections made in 2019, but still call for active monitoring and improvement of current policies.

3. Past, present and future of Australian pension system

The Commonwealth of Australia, with a land area of 7,688,287 km², is a large island surrounded by both the Indian and Pacific oceans. According to the most recent statistics from 2023, Australia has a population of 26,821,557 people, with this number only being projected to grow into the future.

Over the past several decades, Australia's population has been affected by many demographical changes, which naturally have tested the resilience of the nation's retirement income scheme and its ability to meet the needs of an aging population. Figure 4 highlights the significance of these changes.

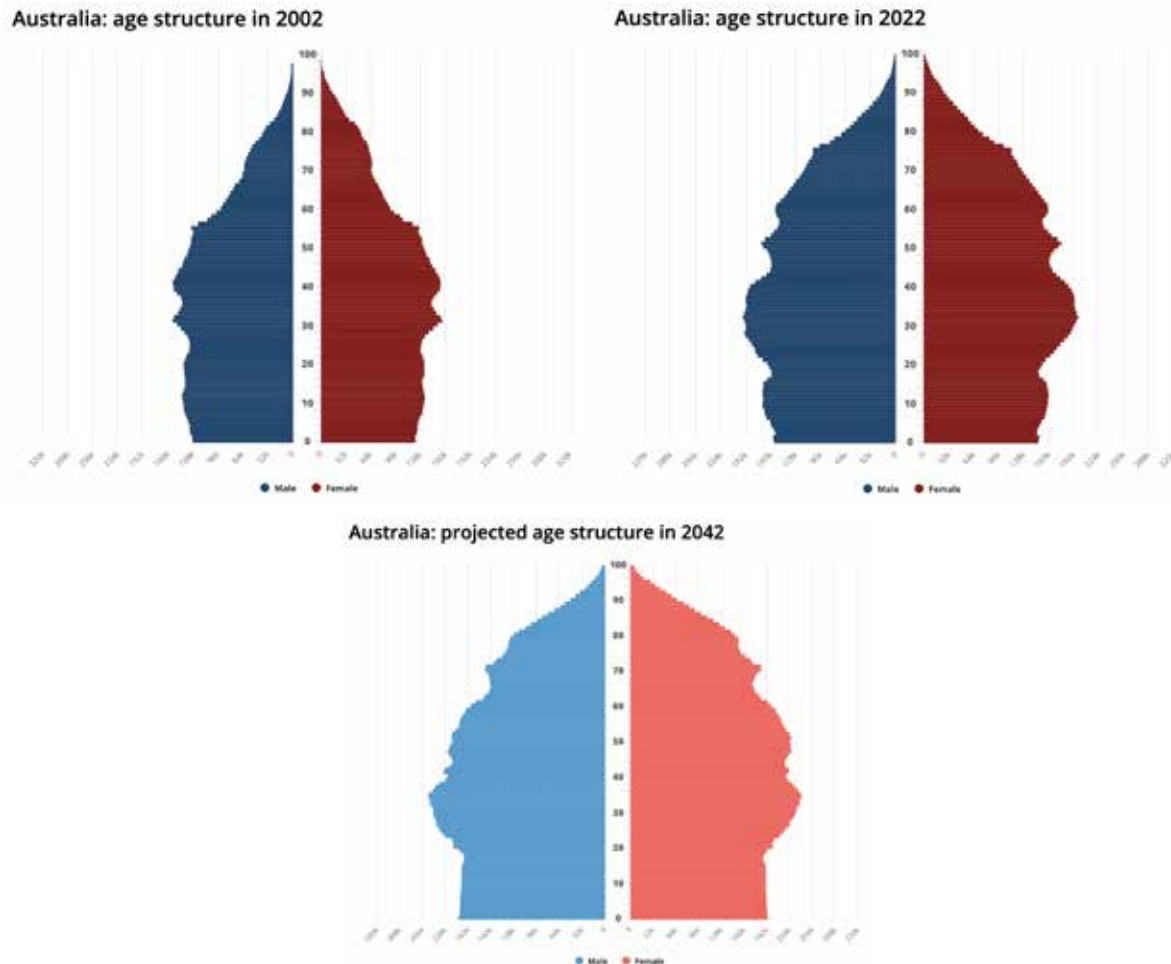


Figure 4 Age pyramid in Australia in 2002, 2022 and projection for 2042

Source Australian Bureau of Statistics

As it is clear to see, there has been huge growth in population, particularly skewed towards the older side of the age pyramid. This occurs due to a number of reasons, mostly due to the higher birth rate and decreased death rate with improvement of health care, as well as an influx of migration from overseas nations. Under the influence of declining fertility and mortality rates, countered to an extent by overseas migration, between 1980 and 2020 the share of Australia's population that is 65 years of age or older has risen from 9.6 to 16.3%. (Rice JM, Wilson T, Temple JB and McDonald P, 2022, 1). Given these circumstances, Australia's government has had to develop and reform a robust pension system to ensure this proportion of the population is well-funded for retirement.

3.1. Foundation of Australian pension system

The pension system in Australia has undergone several changes since its initiation in 1908. On 10 June 1908 the newly formed Commonwealth Parliament passed the Invalid and Old-Age Pensions Act. Prior to that, similar schemes had existed in some states, for example in New South Wales. New South Wales introduced legislation in 1900. Every person in the community who was above the age of 60 years, who had resided in New South Wales for 15 years and whose income did not exceed £50 a year would be entitled to a pension of ten shillings a week when single. Building on this model, the federal government was able to roll out a nation-wide system. It is important to remember the great difference in life expectancy between then and now. Only

four per cent of the population were over the age of 65.2, and men could expect to live 55 years, whereas women could expect to live for 59 years. This system was funded by tax, as it still is today. In contrast to most OECD countries, the age pension is financed from general revenues - no “social security tax”, or similar earmarked revenue collection device, exists. (Bateman and Piggot, 1997, 17) However, the burden of taxation is much more significant nowadays, due to the increased proportion of aged people in Australia’s population, mentioned beforehand.

The first major reform came in 1992, known as the Superannuation Guarantee (SG). Superannuation is a preferentially taxed investment vehicle, which has existed since the mid-nineteenth century. Investment earnings were not taxed when earned, only when withdrawn from the fund. This allowed another avenue for employees to fund their retirement. In 1992, following the government’s proposed budget the previous year, employers were required to make superannuation contributions on behalf of their employees. The mandatory contribution rate was 9% of employee ordinary time earnings from 1 July 2002 until 30 June 2013. On 1 July 2013, the rate increased to 9.25%, before increasing again on 1 July 2014, to 9.5%. The rate remained at 9.5% until 30 June 2021. From July 2022, the rate is progressively increasing by 0.5 percentage points each year until it reaches 12% on 1 July 2025.

Table 4 Superannuation coverage in Australia (percentage of employees covered)

Year	Full-time (%)	Part - time (%)	Total (%)
1986	46.5	7.0	39.4
1989	55.1	17.8	48.1
1992	88.0	54.1	80.3
1995	94.4	71.6	89.4
1999	96.9	76.3	91.0

Source Australian Prudential Regulation Authority (various years)

Following this reform, the Australian system had three main pillars: a means-tested Age Pension funded through general taxation revenue; the superannuation guarantee, a compulsory employer contribution to private superannuation savings; and voluntary superannuation contributions and other private savings.

Further reforms have been made to the Retirement Age. This is the age at which Australians are able to access the first pillar, the Age Pension. Due to an aging population, and a tendency for people to work longer and therefore have more personal savings, the age has had to be increased. This both reduces the financial burden and ensures the pension system can target those who need it most.

Table 5 Pension Age changes from 2017 to 2023

Period within which a person was born	Pension Age	Date pension age changes
From 1 July 1952 to 31 December 1953	65 years and 6 months	1 July 2017
From 1 January 1954 to 30 June 1955	66 years	1 July 2019
From 1 July 1955 to 31 December 1956	66 years and 6 months	1 July 2021
From 1 January 1957 onwards	67 years	1 July 2023

Source Australian Department of Social Services

These reforms have all been essential in making Australia’s pension system one of the most comprehensive and sustainable in the world, making it a model for other countries to take inspiration from.

3.2. Assessment of current pension system in Australia

One of the key benefits of Australia's pension system compared to those in other countries is that it is strictly means tested. This means that both assets and income are analysed, affecting how much an individual can receive from the tax funded Age Pension. Assets include any property or possessions owned in full, in part, or that the individual has an interest in. This includes both assets held outside Australia and debts owed to the retiree. Over time the means test has been adapted to become stricter, and include a variety of assets. When first established in 1908, only property and income were considered. Nowadays, assets include financial investments, home contents, vehicles, real estate, annuities, superannuation and private companies. Table 6 shows the lower limit for various cases, up until which the recipient will receive the full pension amount.

Table 6 Lower limit for assets test

Status	Homeowner	Non-homeowner
Single	\$301,750	\$543,750
A couple, combined	\$451,500	\$693,500
A couple, separated due to illness, combined	\$451,500	\$693,500
A couple, one partner, eligible, combined	\$451,500	\$693,500

Source Services Australia (2024)

Furthermore, income is tested to analyze whether or not an individual is able to receive the full age pension, a partial pension or ineligible to receive any support. Income also encapsulates wages, bonuses and commissions as well as other forms of income, such as real estate income and dividends. Figure 7 shows the lower limit of income one can receive before their pension is reduced, as of 20 March 2024.

Table 7 Lower limit for income test (individual)

Income per fortnight	Amount pension will reduce by
Up to \$204	\$0
Over \$204	50 cents for every dollar over \$204

Source Services Australia (2024)

Both of these means tests ensure that the Australian pension system only benefits those who need it most, whilst remaining affordable for the government.

Another key benefit is that the pension is constantly being indexed in order to account for inflation. Cost of living has become a serious crisis in Australia, particularly post-COVID-19. In order to counteract this, base pension rates are indexed to the higher of the increase in the Consumer Price Index and the Pensioner and Beneficiary Living Cost Index. Pensions are indexed twice a year, on 20 March and 20 September. This reflects changes in pensioners' costs of living and wage increases. Some of the goods and services regarded in this process include food, health care, postage, fuel and utilities, all of which are frequently used by the older population. Moreover, if these indexations are still not sufficient the pension rate may be increased again. Pension rates are compared to a wages benchmark, and increased if necessary. The wages benchmark ensures the couple combined rate of pension is at least 41.76% of Male Total Average Weekly Earnings. All of these factors indicate why the Australian pension system is one of the most formidable across the globe.

3.3. Future of the Australian pension system

Whilst the outstanding positives of Australia's retirement scheme have been discussed, it is not a system without drawbacks. The system is still largely complex, with many Australians having a low financial literacy. There are many misconceptions when it comes to the interaction between various systems including the tax system, aged pension and private investment funds. Another drawback is the threat that longevity risk poses, and the fact that there is no option to guarantee a life-long income. For this reason, many Australians die before they are able to utilise the full benefits of the pension system.

However, the Australian retirement plan is still relatively young, and these obstacles will be overcome as the system matures. Looking to the future, more people will be able to fund their retirement entirely from their own income and superannuation combined, without the need to rely on the government. Figure 5 highlights the financial returns of various types of superannuation funds.

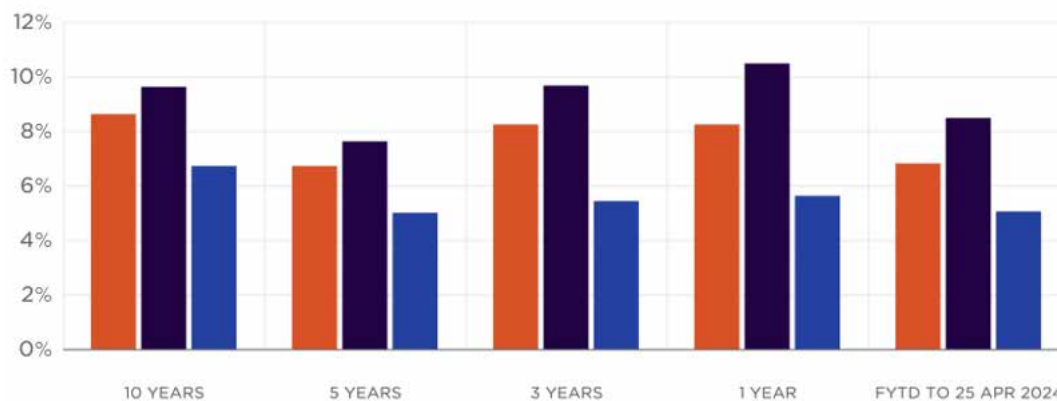


Figure 5 Returns on superannuation funds

Source SuperAustralia (2024)

As can be seen in the graph, there are a variety of options for Australians to choose from, all with solid and consistent returns. The orange bar shows a balanced fund, the purple bar shows a high growth fund, which carries higher risk and is therefore more popular among younger investors, and a conservative balanced fund represented by the blue bar. To complement these returns, the government has introduced tax concessions on these earnings, allowing Australians to more efficiently fund their own retirement. Considering this, it is reasonable to say that the Australian government will fulfil its goal to deliver adequate standards of living in retirement in an equitable, sustainable and cohesive way, long into the future.

4. Summarized comparison

It is very hard to compare countries that are so different like Australia and Croatia, however it is still interesting to summarize and observe the numbers in the context of different pension systems. For the purpose of clear view table 8 has been created.

Table 8 Differences in key criterion between Australia and Croatia (2023)

Criterion	Australia	Croatia
<i>Demographical trends</i>		
Average age (years)	37	44.2
Birth rate (per women)	1.7	1.62
Migrations (difference from table 1)	518 000	11 685
Life expectancy	84.6	79.02
<i>Sources of financing pension income</i>		
Mutual fund	+	+
Private funds	+	+
Average retirement age	65.5	64
<i>Household financial assets (%)</i>		
Pension funds	53.5	29
Currency and deposits	23.8	61
Shares and other equity	19.1	2
Financial literate population (%)	64	44
<i>Factors taken in consideration in calculation of retirement income</i>		
Working years	+	+
Obligatory investments in mutual fund	+	+
Obligatory investments in private funds	+	+
Total worth of personal financial assets	+	-
Total worth of other personal assets	+	-
Need for further reforms	+	+

Australia is much younger country in terms of demographical data but with same tendency of aging as Croatia. Life expectancy in Croatia is lower than in Australia but shows similar trends in terms of increasing. Retirement age is similar in both countries. In terms of structure of household financial assets, there exists a very important difference. In Australia, financial assets, such as saving deposits, investments in equity, shares and bonds, form an important part of overall wealth of households, and are an important source of revenue, either through the sales of these assets, or as a source of property income (such as interest and dividends). This difference needs to be treated taking in consideration a substantial difference in level of financial literacy of citizens of these two countries. Financially literate people are more likely to invest in capital market but also to understand what retirement income in terms of change in quality of life and lifestyle attitudes really means.

In summary, Croatia's pension system is a mix of state and mandatory private savings components, with an additional voluntary savings option, while Australia's system is heavily based on mandatory employer contributions to private superannuation funds, supplemented by a means-tested state Age Pension. This system seems to be more sustainable.

Although, from the perspective of Croatia, the results achieved by model of pension system in Australia are good, in both countries further reforms are to be expected. New challenges should be approached potentially by using new models but also observing and learning true experience of those who perform better.

5. Conclusion

There are major differences in financial conduct between Australian and Croatian citizens. By analyzing and comparing pension systems as well as important variables in Australia and Croatia we have learned that the issue of low financial literacy greatly influences the financial

activity of a population. Increase of levels of financial literacy within populations should lead to more financial activities that could bring greater income to individuals in their period of retirement.

Croatia is in a far worse situation in terms of demographical data, but Australia shows corresponding trends, and they pose a serious risk for the long-term sustainability of retirement income based on intergenerational solidarity. The future of retirement income must be less dependent on this component and more focused on investment income. Australia has more tax deductions on investments which creates an encouraging atmosphere for investments.

The reforms of pension system in both countries are going to happen in upcoming decades in order to secure sustainability of this important system.

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IMPACT OF GOVERNMENT DEBT ON ECONOMIC GROWTH IN THE EUROPEAN UNION COUNTRIES

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Abstract. The aim of this paper is to investigate the impact of EU-27 debt on economic growth. The study is based on data from 2013 to 2022. Panel data are used to investigate the relationship between debt and economic growth in the EU using the gretl software package. A fixed effects model is used. The study shows that EU sovereign debt does not have a significant impact on economic growth. It also shows that a growth in the debt share of GDP above 60% is not a significant factor. The calculations show that only interest payments and government spending have an impact on the EU economies. An increase in the level of interest payments has a negative impact on economic growth, while an increase in government spending has a positive impact on the EU economies.

Key words: *Public Debt, Economic Growth, Maastricht Criteria.*

1. Introduction

In a challenging global economy, public debt is both a pillar of fiscal strategy and the subject of intense debate. As countries face the challenges of economic growth, infrastructure development and social welfare, the management of public debt is becoming a key element of their economic policy toolbox.

Public borrowing is inevitable. It is the main source of financing budget deficits, and is particularly important in times of crisis, such as pandemics, wars or economic crises. In particular, countries with high levels of debt are increasingly vulnerable, with higher debt servicing costs and fewer options for investment. High debt levels can further reduce countries' resilience in the future. As Briceño and Perote (2020) note, excessive debt is considered to be one of the main constraints on economic policy and countries' competitiveness. While EU countries have seen a slight decline in debt in recent years (from 87.4% of GDP in 2021 to 83.5% of GDP in 2022), as many as 13 countries have debts above the Maastricht Treaty threshold of 60% of GDP. This calls for research on how sovereign borrowing affects economic developments.

The impact of public debt on economic growth of nations is a controversial issue both at theoretical and empirical level (Abate, 2023). Although a number of studies have examined the impact of public debt on economic growth, their results are mixed and controversial. The main source of debate is the public debt limit. Most studies show that lower public debt, or debt below a certain threshold, has a positive impact on economic growth (Vogel, 2015; Reinhart, Rogoff, 2010; Baum et al., 2013; Woo, Kumar, 2015; Taylor et al., 2012; Irons, Bivens, 2010; Pescatori et al., 2014; Rankin, Roffia, 2003; Mencinger et al., 2015; Bexheti et al., 2020). Studies over the last decade suggest that high and rising public debt burdens are slowing growth in the long run, but there is no clear consensus on the tipping point. The relationship between debt and economic growth is complex and depends on a wide range of factors.

The challenging Covid-19 pandemic, when Europe and the rest of the world were gripped by austerity, had a negative impact on the sustainability of public finances. Declining revenues and increased spending in EU countries have led to rising budget deficits. As deficits have risen, the need for borrowing has increased. Currently, as a result of the effects of COVID-19 and the large-scale fiscal support measures, some EU countries' debts relative to GDP are at or even above historical highs. While there is a large body of research on the effects of public debt on economic growth, there is a lack of research covering the period of the global pandemic. While studies in the last decade suggest that high and rising public debt burdens slow down economic growth in the long run, there is no consensus on the threshold beyond which the debt-to-GDP ratio becomes a significant drag on growth.

The problem addressed in this paper is formulated around the question: what is the impact of public debt on economic growth in the European Union?

The aim of the paper is to investigate the impact of the debt of European Union countries on their economic growth.

The study is based on data for EU countries for the period 2013-2022. The calculations of the impact of debt on economic growth are carried out using gretl software. The study is based on data from the Eurostat database and the European Central Bank.

2. Literature review

The link between rising public debt and economic growth has attracted a lot of attention in recent years, spurred by the increase in government indebtedness in advanced economies following the global pandemic. The academic literature has focused on the borrowing limit, at which the ability of countries to repay their debts is significantly reduced. While the Maastricht Treaty provides for a debt-to-GDP threshold that undermines the stability of public finances, scholars debate the tipping point beyond which the impact of debt becomes detrimental to national economies. Caner et al. (2010) argue that a public debt-to-GDP ratio of 77% is the threshold above which each additional percentage point of debt costs 0.017 percentage points of annual real economic growth. According to Checherita-Westphal and Rother (2012), the tipping point above which the government debt-to-GDP ratio has a negative impact on long-term growth is around 90-100%. The ranges of the debt break-even point suggest that the negative impact of high debt on growth can start as early as around 70-80%. According to Baum, Checherita-Westphal and Rother (2013), the short-term impact of debt on GDP growth is positive and statistically significant. However, at high debt-to-GDP ratios (above 95%), additional debt has a negative impact on national economies. A study by Reinhart and Rogoff (2010) showed that the relationship between government debt and real GDP growth is weak when the debt-to-GDP ratio is below 90%. Above this level, median growth rates fall by one percentage point, while average growth falls by much more. The study finds that the public debt threshold is similar in developed and emerging market economies. According to Hilscher, Raviv and Reis (2022), borrowing can weaken a country's ability to formulate appropriate counter-cyclical policies in response to economic crises, which can have implications for the stability of the overall economy and society. On the other hand, studies by Wu (2014) and Zhang, Luo, Zhao, Kang, Wang, Zhou and Lyu (2020) show that if the government issues additional sovereign bonds and implements a fiscal deficit policy, it can effectively boost domestic demand and stimulate the development of regional economies.

When analysing the research on the impact of debt on the economy, different results can be observed. Some studies show that government debt boosts economic growth in both the short and long term. Others, on the other hand, point to a negative impact of borrowing on the economy.

Despite the different results, it can be noted that the most controversial issue is the debt threshold beyond which debt will have a significant impact on economic growth. The results of Chudik, Mohaddes, Pesaran and Raissi (2018) in a long-run sample of 40 developing countries showed that long-term public debt is associated with lower levels of economic activity. According to the authors, rising public debt slows GDP growth in the long term. This is supported by a study by Arčabić et al. (2018), which showed that a debt-to-GDP ratio above 90% has a negative impact on long-term economic growth. Marieta (2014), Abate (2023) argue that public debt above 60% GDP, economic growth slows down up to this threshold, debt and economic growth are proportional. Mencinger, Aristovnik and Verbic (2015) found that the public debt threshold ranges from 90% to 94% in developed countries, which means that above this level, debt will have a negative impact on economic growth. According to these authors, the threshold for public debt in developing countries ranges from 44% to 45%, i.e. up to this threshold, public debt has a positive impact on economic growth, while above this threshold it has a negative impact. These findings show that the sovereign debt thresholds of developed and developing countries differ. On the other hand, DeLong, Summers, Feldstein and Ramey (2012) argue that countercyclical fiscal policy is important to reduce macroeconomic instability, especially when monetary policy is tight. In other words, short-term volatility potentially lowers future output as firms reduce current investment, which undermines both technological development and economic capacity. As a result, deficit-financed fiscal policy becomes self-sustaining as long as interest rates remain low, with positive long-term effects on economic growth and a levelling of consumption across generations. According to Tran (2021), public borrowing is driven by external and domestic debt, which can have a positive impact on a country's economic growth in the short run and a negative impact in the long run if not properly managed. A study by Bhimjee and Leão (2020) showed that countries with low levels of public debt have higher economic growth rates, while lower economic growth rates are associated with higher levels of public debt.

The analysis of the scientific literature shows that the focus in assessing the impact of debt on economic growth is on the detrimental effects of a country's „debt overhang“, i.e. when the accumulation of debt is so high that it threatens the country's ability to repay previous loans, which in turn scares away potential lenders and investors. Economists also tend to agree that, in the short term, an increase in public debt due to fiscal expansion stimulates aggregate demand, which should help the economy to grow. Meanwhile, there is no consensus on the long-term impact of public debt growth on the economy. Some studies suggest a negative long-run relationship between the two, while others question whether there is a long-run relationship between debt and economic growth at low or medium levels of public debt. This leads to the need to investigate the long-term implications of rising public debt for national economies.

In the light of the literature analysis and the objective, hypotheses are formulated:

H1: Public debt has a positive impact on economic growth in European Union countries.

H2: Public debt has a negative impact on economic growth in EU countries when the Maastricht criterion (60% of GDP) is exceeded.

The first hypothesis is based on the fact that this can be explained theoretically by applying the traditional Elmendorf and Gregory Mankiw (1998) approach to debt. They argue that an increase in public debt helps to stimulate aggregate demand and output through job creation and productive investment. This is supported by studies by Gómez-Puig and Sosvilla-Rivero (2016) and Burhanudin et al. (2017), who argue that public debt can contribute to higher economic growth. The analysis of research papers shows that economic growth decreases when a country increases its debt level. In this case, many projects may have to be postponed as the additional debt will only slow down economic growth. According to Elmendorf and Gregory Mankiw

(1998), the positive effects of debt only exist in the short term. If debt continues to grow, the effect can become negative. This leads to the need to assess the impact on the economy of debt above 60% of GDP. The second hypothesis is based on these statements.

3. Methodology and Results

Course of the study

The study is based on data for EU countries for the period 2013-2022. The calculations of the impact of debt on economic growth are carried out using gretl software. The study is based on data from the Eurostat database and the European Central Bank. The first stage involves collecting, organising and processing data from EU countries and calculating relative indicators. The econometric analysis is carried out using gretl software, which is one of the most suitable software for panel data analysis. The use of panel data allows to control for variables that cannot be observed or measured, in other words, to take into account their heterogeneity. According to Cottrell and Lucchetti (2012), in studies where there is no single variable that varies only between individuals, in this case countries, but does not vary at all over time, it is necessary to use a fixed-effects (FE) model. However, to test this assumption, a basic OLS model will be built and then tested to select the most appropriate model for the study. Once the final model has been constructed, it will be checked whether the model meets the characteristics of a quality model. That is, whether the model is free from autocorrelation between variables and whether the error variance is homoskedastic. Hypotheses are accepted or rejected on the basis of the significance of the independent variables for the dependent variable.

Overview of the subject of the study

In the wake of the global pandemic in 2019, many EU governments have taken the decision to increase borrowing to support their economies during this difficult period. To avoid excessive increases in public debt, the EU has two main tools in place: the Stability and Growth Pact and the fiscal criteria of the Maastricht Treaty. The formalised Maastricht criteria aim to limit public deficits and public debt: the budget deficit-to-GDP ratio cannot exceed 3%; the gross public debt-to-GDP ratio cannot exceed 60%. Fiscal discipline rules were suspended in 2020 to facilitate the recovery of EU economies from the economic consequences of the pandemic and Russia's war against Ukraine. The suspension of the rules lasted until the end of 2023. Figure 1 shows the average values of the EU countries' debt-to-GDP ratios (as a percentage of GDP) between 2013 and 2022.



Figure 1 The EU countries' debt-to-GDP ratios (%)

While the average value of the debt-to-GDP ratio of EU countries has been above the Maastricht threshold for the period 2013-2020, the debt-to-GDP ratio of EU countries has been declining year on year between 2014 and 2020 (from 86.9% in 2014 to 77.7% in 2019), rising to 90% in 2020. This increase is due to a more than 11% increase in EU sovereign debt and an almost 4% decrease in GDP due to the global pandemic. While a decrease in the debt-to-GDP ratio of EU countries can be observed after the pandemic, as many as 13 countries have average debt ratios above 60%. Figure 2 shows the average value of each EU country's debt as a share of GDP (%) from 2013 to 2022.

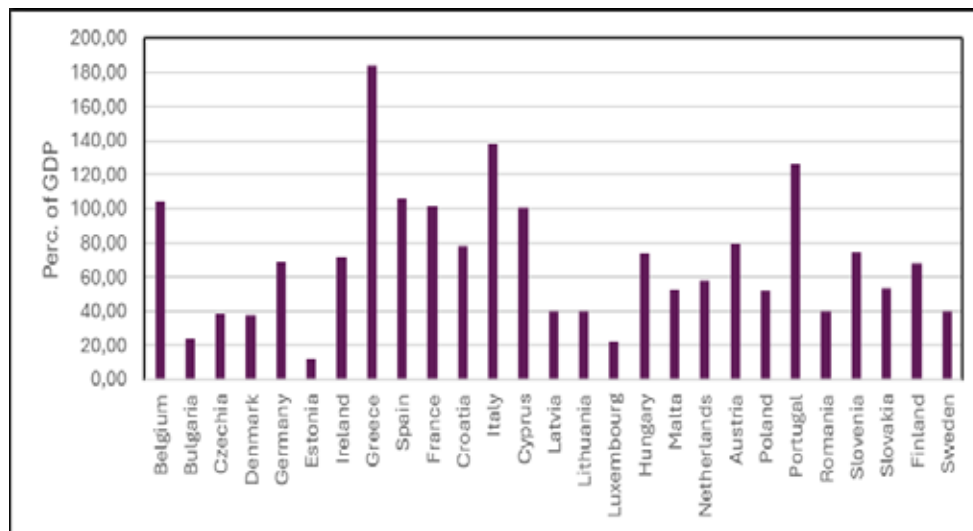


Figure 2 The average value of each EU country's debt-to-GDP ratios (%)

Greece was the most indebted EU country during the period under review, with an average debt of more than 186%. The next most indebted EU country, Italy, had an average debt of 138.46% of GDP between 2013 and 2022. The least indebted country, Estonia, had an average debt of only 13.16% of GDP.

Although the rules on sovereign debt are now back to 60% GDP, and national budget deficits must not exceed 3%, at the end of 2023, the Council of EU Finance Ministers decided to review and reform these rules. The reform of the rules will aim to achieve a gradual debt reduction in high-debt EU countries, while ensuring that low-debt countries maintain fiscal sustainability. The revised fiscal rules will create additional incentives for growth-enhancing reforms and investment. This should strengthen the EU's economic potential and resilience to future shocks. The shift towards country-specific fiscal target-setting will foster the strengthening of national ownership and lead to more consistent and effective compliance with fiscal rules.

Study method

A regression model equation is constructed to assess the impact of debt on economic growth:

$$\ln(GDP_{it}) = \alpha + \beta_1 \ln(DEBT_{it}) + \beta_2 \ln(EXTdebt_{it}) + \beta_3 (DEBTPcapita_{it}) + \beta_4 (Maastricht_{it}) + \beta_5 \Delta \ln(Interest_{it}) + \beta_6 \Delta \ln(GOVexp_{it}) + \mu_i + \theta_t + \varepsilon_{it} \quad (1)$$

Here:

θ_t - time-varying random component;

μ_i - individual specific and time-invariant effects;

$\varepsilon_{i,t}$ - error;

t – period;

i – indicates the cross-sectional tracking number (EU Member States).

This study uses independent variables: Consolidated general government debt (DEBT); Foreign debt (EXTdebt); Debt per capita (DEBTPcapita); Public debt-to-GDP ratio (Maastricht). Control variables used in the study: Interest on debt (Interest); Government expenditure (GOVexp).

General government consolidated debt (DEBT) is a measure of a country's overall level of indebtedness. Public debt, sometimes also called government debt, refers to the total outstanding debt (bonds and other securities) of a country's central government. According to Sichula (2012), high levels of debt in countries are associated with significant negative effects on economic growth. The most common indicator of external debt is the *gross external debt (EXTdebt)*, which reflects the government's debt to foreign creditors. External debt is broken down by instrument, original maturity and institutional sector. According to Clements, Bhattacharya and Nguyen (2003), an excess of external debt can negatively affect economic growth. *Debt per capita (DEBTPcapita)* is a measure of the value of government debt expressed as an amount per citizen in a government jurisdiction. The level of net debt per capita can be an important factor to consider when assessing a government's ability to continue to cover its debt servicing costs from its current level of tax revenues. *The public debt-to-GDP ratio (Maastricht)* is introduced as a dummy variable in this study. If public debt exceeds 60%. The GDP threshold is denoted by 1, if not 0. The impact on the national economy of *interest (Interest)* on the servicing of the public debt is based on the fact that interest payments, by constraining the government's ability to balance the budget or to finance the activities of other sectors, force the government to reduce spending for other purposes or to finance a larger annual budget deficit. This holds back economic growth. *General government expenditure (GOVexp)* is the purchase of goods and services, comprising public consumption and public investment, and transfer payments, consisting of income transfers (pensions, social benefits) and capital transfers. The relationship between government expenditure and economic growth is a recurrent issue in the debate on economic development. Wagner's (1958) law states that government expenditure is elastic to income and that the income ratio of government expenditure tends to increase in line with economic development.

Study results

Table 1 shows the initial OLS model, whose results confirm that the selected factors have a significant impact on the growth of the economies. All selected factors are statistically significant at the 99% level. In order to confirm or reject the hypothesis regarding the model's usability, diagnostics are performed.

Table 1 Initial OLS model

Depended variable: 1 Y GDP				
	Coefficient	Std. error	t-ratio	p-value
Constant	0,207879	0,328499	0,6328	0,5276
1_X_DEBT	1,45822	0,0920049	15,85	<0,0001
1_X_EXTdebt	-0,217492	0,0804066	-2,705	0,0074
1_X_Interest	-0,438472	0,0369644	-11,86	<0,0001
1_X_GOVexp	0,066251	0,0146011	4,537	<0,0001
X_DEBTPcapita	0,128344	0,045465	2,823	0,0052
X_Maastricht	-0,555459	0,0466268	-11,91	<0,0001

The next step is model specification, which aims to identify model choices and the most appropriate model for panel data analysis. This step will involve estimation comparing an OLS least squares model, a random effects model, a fixed effects model and their possible alternatives. The first test examines the choice between the OLS and the fixed effects model. The hypothesis of the first test is that if $p\text{-value} > 0.05$, the OLS model is appropriate. The $p\text{-value}$ of the test is $5.64464\text{e-}126$. This means that the OLS model is not appropriate and is a more appropriate fixed effects model. The Breusch - Pagan test checks which model is more appropriate, the random effects model or the OLS model. The hypothesis of the test states that if $p\text{-value} > 0.05$ the OLS model is appropriate. The $p\text{-value}$ of the test is $1.57726\text{e-}112$. This indicates that the random effects model is more appropriate. The Hausman test is performed to determine which model to choose, the fixed effects model or the random effects model. The test hypothesis states that if $p\text{-value} > 0.05$, the random effects model is consistent. The $p\text{-value}$ of the test was $2.93473\text{e-}041$. This indicates that the random effects model is not consistent and a fixed effects model should be chosen for the study. After the estimation of the fixed effects model, in order to ensure that the model is appropriate and robust for the data analysis, the model is tested for possible model errors, i.e. autocorrelation and heteroskedasticity. The Wooldridge test is used to determine autocorrelation. With a $p\text{-value}$ of $1.39762\text{e-}13$, the hypothesis of no autocorrelation is rejected. This means that there is an autocorrelation problem. Next, the Distribution free Wald test for heteroskedasticity is performed. A $p\text{-value} > 0.05$ for this test indicates that heteroskedasticity is not detected and that the variation in error between the data is not equal. The tests performed indicate that the standard errors are not reliable and therefore the significance of the factors may not be reliably determined. In this respect, the model is corrected using standard errors that allow for the presence of autocorrelation. Since heteroskedasticity was not detected (only autocorrelation was detected), the model must use Arellano standard errors. Table 2 shows the results of the calculations carried out.

Table 2 Fixed Effects (FE) model

Dependent variable: l_Y_GDP				
Reliable (HAC) standard errors				
	Coefficient	Std. error	t-ratio	p-value
Constant	5,42175	0,668627	8,109	<0,0001***
l_X_DEBT	0,00248388	0,130586	0,01902	0,985
l_X_EXTdebt	0,084944	0,0689991	1,231	0,2302
l_X_Interest	-0,0653875	0,0368912	-1,772	0,089*
l_X_GOVexp	0,535599	0,0883864	6,06	<0,0001***
X_DEBTPcapita	0,0451009	0,165864	0,2719	0,788
X_Maastricht	-0,0881801	0,0524533	-1,681	0,1057

The estimates using the Fixed Effects Model show that the impact of l_X_Interest is significant and has an impact on the economies of EU countries. A 1% increase in interest paid reduces economic growth by -0.0653875%. The second factor that also affects economic growth is l_X_GOVexp (government expenditure). The results show that an increase in government expenditure leads to a potential growth of 0.535599%. For the EU as a whole, neither the impact of government gross debt nor the impact of external debt is significant. The study also shows that there is no significant impact on economic growth beyond the Maastricht criterion. In the light of the results obtained, the hypotheses: **H1**: Public debt has a positive impact on economic growth in the EU countries; **H2**: Public debt has a negative impact on economic growth in the EU countries when the Maastricht criterion is exceeded (60% of GDP) are rejected.

It is worth underlining that the results of the study depend mainly on the time period, on specific events in the economic space and on other debt-related considerations, so that studies carried out by different authors in different periods, in different economic cycles, may differ.

4. Conclusions

Research has shown that sovereign borrowing is an important and often unavoidable economic phenomenon that can have both negative and positive effects on national economies. Empirical studies show mixed results on the impact of debt on national economies. There is also considerable debate on the threshold of debt as a share of GDP, beyond which debt would have a negative impact on the growth of national economies.

Given the steady rise in sovereign debt, and the particularly rapid increase during the Covid-19 pandemic, this study aimed to identify the impact of EU sovereign debt on economic growth. The study is based on data for the EU-27 for the period 2013-2022. The results show that EU sovereign debt has no significant impact on economic growth. It also found that a growth in the debt share of GDP above 60% is not a significant factor. Only interest payments and government expenditure have an impact on EU economies. An increase in the level of interest payments has a negative impact on economic growth, while an increase in government expenditure has a positive impact on EU economies.

The results of the study encourage further research into the links between economic growth and debt. In further research, it would be appropriate to study the impact of debt in EU countries with a higher and lower level of economic development, especially those with a debt-to-GDP ratio exceeding 60 percent. Also, one of the directions of further research could be related to the as the results of the study encourage further research into the links between economic growth and debt. In further research, it would be appropriate to study the impact of debt in EU countries with a higher and lower level of economic development, especially those with a debt-to-GDP ratio exceeding 60 percent. Also, one of the directions of further research could be related to the assessment of the impact of factors on the state debt. assessment of the impact of factors on the state debt.

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THE INFLUENCE OF SELECTED FINANCIAL INDICATORS ON THE MOVEMENT OF SHARE VALUES

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Abstract. The company's operations are aimed at maximizing value for its owners. In the case of joint-stock companies, the key is the value of their shares, whose oscillations on the capital market depend on the dynamics of supply and demand. However, what is behind these fluctuations is often the result of investors' expectations, which are formed on the basis of fundamental and speculative assessments of the company itself. Fundamental assessments are based on financial indicators and can be expressed in value, while speculation cannot. Therefore, the main goal of this research is to investigate the influence of selected financial variables of the company on the annual change in the price of shares listed on the Zagreb Stock Exchange. The variables covered in the research, and whose impact on stock change is investigated, include return on equity (ROE), net financial debt (NFD)/EBITDA ratio, percentage change in annual revenue, enterprise value (EV)/EBITDA ratio, yield from dividend, operating margin ratio, debt-to-equity ratio and current liquidity ratio. The research was conducted on a sample of companies that are included in the official stock index of the Zagreb Stock Exchange, CROBEX, with data from 2010 to 2019, with an emphasis on the period before the Covid-19 pandemic. The analysis was performed using panel analysis, which allows a better understanding of the dynamics and connections between variables across different companies and years. The results of this research can provide a deeper insight into the factors that shape the price of shares on the Zagreb Stock Exchange (ZSE) and useful guidelines for investors, managers and regulatory bodies in making decisions.

Key words: *Share, Zagreb Stock Exchange, Financial indicators, Share value*

1. Introduction

In the world of finance, the value of a company's shares is a key indicator of its performance and potential. The fluctuations in share prices on the stock market are driven by the forces of supply and demand, which are influenced by investors' expectations based on both solid financial data and speculative calculations. Despite the wealth of research on the relationship between financial variables and share prices, there remains a gap in understanding how these dynamics manifest in the context of the Zagreb Stock Exchange (ZSE). This paper aims to explore how specific financial factors of companies impact the yearly changes in share prices on the ZSE. Authors emphasis on important metrics such as return on equity, debt levels, revenue growth, and other key indicators to understand their influence on stock prices. Analysis is focused on companies listed on the ZSE and included in CROBEX index, using data from 2010

to 2019, with a particular accent on the period before the Covid-19 pandemic. To unravel the complexities of these relationships, authors employ dynamic panel analysis, a method that allows us to examine how different variables interact across various companies and time periods. By utilizing this approach, authors aim to uncover the underlying drivers of share price movements and provide practical insights for investors, managers, and regulators. This research seeks to offer valuable insights into the factors shaping share prices on the ZSE, offering actionable guidance for stakeholders navigating the stock market landscape. By shedding light on the determinants of share price dynamics, this paper aims to contribute to the field of financial analysis and investment decision-making.

2. Literature review

Stock price reaction to financial metrics is a crucial area of study in finance and investment research. Numerous studies have explored the relationship between various financial indicators and stock prices, shedding light on the factors that influence market valuations. The existing body of literature provides valuable insights into the factors that drive share price reactions in various market environments. Studies conducted in different regions and industries have highlighted the significance of financial indicators such as profitability, liquidity, leverage, and operational efficiency in influencing share price movements. Research in markets like Greece, emerging countries, Poland, and Lithuania has demonstrated the diverse impact of financial variables on share prices, underscoring the need for market-specific analyses (e.g. Dimitropoulos and Asteriou (2009), Ligocka (2019), Roldugin and Roldugin (2018), Takamatsu (2019)). Moreover, methodological approaches such as regression analysis, neural networks, and factor analysis have been instrumental in uncovering the complex interplay between financial metrics and share price fluctuations. These analytical tools have enabled researchers to identify key indicators that have a substantial effect on share prices, providing valuable insights for investors and market participants.

According to Pavić Kramarić, Miletić and Pavić (2017) Profitability is a key metric that investors often consider when evaluating the financial health and performance of a company. Higher profitability typically indicates that a company is effectively utilizing its resources to generate returns for its shareholders. As such, strong profitability can positively influence investor perception and confidence in the company, potentially leading to an increase in share value.

Research by Eka et al. (2016) and Aktas (2008) highlighted the positive correlation between profitability ratios, such as net profit margin and operating profit margin, and stock prices. These studies emphasized the importance of considering profitability metrics when analyzing stock price movements. Studies by Aydemir et al. (2012) and Kaya and Ozturk (2015) examined the impact of efficiency ratios on stock prices. They found that metrics like return on assets and return on equity had a significant influence on stock returns, indicating that operational efficiency plays a key role in determining market valuations. Kohansal et al. (2013) focused on sector-specific analyses of stock price reactions. They observed varying responses of stock prices to financial metrics across different sectors, highlighting the importance of sectoral dynamics in influencing market valuations. Studies by various authors have explored causal relationships between financial metrics and stock prices.

The paper by Ligocka (2019) examines the relationship between stock prices of food, energy, metallurgical, and chemical companies listed on the Polish Stock Exchange (GPW) and selected financial ratios over the period 2006-2015. The study utilizes the Johansen test to investigate long-term equilibrium and the Vector Error Correction Model (VECM) for short-term dynamics analysis. The findings highlight significant links between stock prices and financial ratios, with

positive associations noted between stock prices, return on assets (ROA), and return on equity (ROE). The research underscores the impact of rentability, liquidity, and financial leverage on stock prices of companies listed on the GPW. Overall, the study provides valuable insights into the factors influencing stock prices in the examined industries.

Dividends can also have influence on share price movement. Miletić (2011) confirmed that dividend change represents an information relevant for market investors. Based on the shortage of information about company's present and/or future business, investors use management's dividend decisions as information upon which they question company's market value. If announced dividend is above expected, investors perceive this signal as positive information used by management to signal present and/or future company business. In case of positive information (dividend increase), company's stock price on dividend announcement day will increase above expected. If dividend announcement is below expected, investors perceive this as negative information used by management to signal present and/or future company business. In case of negative information, company's stock price on dividend announcement day will decrease below expected.

The research of Pesik and Taušl Prochazkova (2022) highlights the importance of understanding how financial indicators influence share prices, providing valuable insights for potential investors in making informed investment decisions. By focusing on the 100 largest companies on the NYSE and NASDAQ, the study contributes to filling a research gap in analysing the effect of financial indicators on stock prices in these prominent stock exchanges. The findings underscore the significance of fundamental analysis in evaluating the relationship between financial metrics and share prices, emphasizing the need for investors to consider specific indicators when making investment decisions

Research by Fajriati and Zarkasyi (2022) explored the influence of liquidity, profitability, and leverage on stock prices in the food and beverage sector. Their findings indicated that these financial factors play a significant role in determining stock price movements, with liquidity positively affecting stock prices, while leverage may have a negative impact.

There are also studies that researched the influence of market conditions on stock price reactions. Factors such as market volatility, investor sentiment, and macroeconomic indicators were found to impact stock prices significantly. Understanding market conditions is essential for predicting stock price reactions to external events and economic changes.

Stock price reactions are influenced by a complex interplay of financial metrics, market conditions, external events, and industry-specific factors. By examining these various influences, researchers can gain a comprehensive understanding of stock price dynamics and provide valuable insights for investors and stakeholders in navigating the complexities of the financial markets

3. Variable and sample description

The data was taken for 10 years period, from 2010 and 2019 (period before Covid-19 pandemic), from the Thomson Reuters database for 19 large companies which are included in CROBEX, official share index of the ZSE. From the Thomson Reuters database authors collected financial information of companies for NFD/EBITDA ratio, changes in revenue, price/earnings; Enterprise value/EBITDA ratio, dividend yield, operating margin ratio and return on equity ratio. Information of yearly share price was taken from annual trading reports from ZSE.

For the purpose of econometric data analysis, dynamic panel data analysis was employed in the research. The dynamic panel data was estimated using Arellano-Bond (1991) estimator.

Arellano and Bond dynamic panel estimator with independent variables is shown by the following equation:

$$y_{it} = \mu + \gamma y_{i,t-1} + x'_{it} \beta + \alpha_i + \varepsilon_{it}, i = 1, \dots, N, t = 1, \dots, T \quad (1)$$

where y_{it} is the dependent variable presented by yearly share price change (SHARE YIELD), $y_{i,t-1}$ is the lagged dependent variable, is matrix of type $1 \times K$ independent variables. α_i is an unobserved individual effect and ε_{it} is an unobserved white noise disturbance. γ and β are regression coefficients.

X_{it} are k independent variables for each year from 2010. to 2019. as follows: Return on equity (ROE), Financial ratio Net financial debt to Earnings before interests, taxes, depreciation and amortization (NFD/EBITDA), Yearly revenue percent change (ΔREV), Financial ratio Enterprise Value to Earnings before interests, taxes, depreciation and amortization (EV/EBITDA), Dividend yield in percent (DY), Operating margin (OM), Debt to equity ratio (D/E) and Current ratio (CR).

4. Empirical data and results

Descriptive statistics for all variables employed in research is provided in Table 1. Descriptive statistic is computed based on maximum of 167 observation for all variables. For some variables there were no data, so dynamic panel data was done on unbalanced panel data.

Table 1 Descriptive statistic

Variable	Observation	Mean	Standard deviation	Min	Max
SHARE YIELD	167	0,0423	0,4609	-0,8360	3,7041
ROE	159	-0,1926	2,8168	-31,0480	8,6810
NFD/EBITDA	147	6,5125	23,7262	0,0000	266,3100
RC	166	0,0374	0,2281	-0,7530	1,0000
EV/EBITDA	145	12,6623	27,1103	2,1000	298,8100
DY	167	0,0700	0,4436	0,0000	5,2400
OM	167	0,0071	0,2237	-1,6530	0,4970
D/E	160	2,2285	5,2458	0,0000	40,4000
CR	164	1,3795	0,9715	0,0100	5,5500

Using several independent variables in research can lead to misleading and unrealistic valuation of contributions of individual independent variables when trying to explain the dependent variable. This problem can occur when high collinearity exists between two or more independent variables. Multicollinearity can cause unrealistically high standard error estimates of regression coefficients and in the end can cause false conclusion about the significance of independent variables in the model being evaluated. The assumptions that should be followed in research assert that the independent variables are inter-independent. The matrix of Pearson correlation coefficients was computed. An absolute value of the Pearson coefficient higher than 0,7 indicates a strong correlation between independent variables.

Table 2 shows that multicollinearity problem occurs between NFD/EBITDA variable and EV/EBITDA variable, which was expected because both variables have the same denominator. Therefore, variable EV/EBITDA was omitted from further analysis and variable NFD/EBITDA was left in research.

Table 2 Correlation matrix

	SHARE YIELD	ROE	NFD/ EBITDA	RC	EV/ EBITDA	DY	OM	D/E	CR
SHARE YIELD	1,0000								
ROE	0,0896	1,0000							
NFD/ EBITDA	-0,0762	-0,1333	1,0000						
ΔREV	0,1518*	0,1148	-0,1760*	1,0000					
EV/ EBITDA	-0,0434	-0,1246	0,9834*	-0,1724*	1,0000				
DY	0,0048	0,0234	-0,0071	0,3016*	0,0212	1,0000			
OM	0,1813*	0,1894*	-0,3781*	0,2559*	-0,3895*	0,0465	1,0000		
D/E	0,0893	-0,0412	0,0751	-0,1096	0,0351	-0,0386	-0,1678*	1,0000	
CR	-0,0242	0,0439	-0,1943*	0,0764	-0,1680*	-0,0410	0,3063*	-0,2986	1,0000

*p<10%

After examine the multicollinearity problem and omitting variable EV/EBITDA from analysis Arellano and Bond dynamic panel estimator was used in research. Table 3 shows the result of dynamic panel data analysis. In same table results of Sargan test and Arellano-Bond test for autocorrelation are shown. Based on the p value of Sargan's test, which is 0,4151, it can be concluded that the instruments are not correlated with the residuals and that there is no endogeneity problem in the model. Based on the p value of the m2 test (Arellano-Bond test for autocorrelation of the second order), which is 0,2945, the null hypothesis of no correlation is not rejected. Therefore, it can be concluded that there is no autocorrelation problem in the model.

Table 3 Parameter estimates of dynamic panel

Variables	SHARE YIELD
SHARE YIELD L1	0,2061583*** (0,0675511)
ROE	-0,0226974 (0,0446478)
NFD/EBITDA	-0,0028586*** (0,0001994)
ΔREV	0,0352346 (0,1131054)
DY	-0,0446735 (0,0715745)
OM	0,4728802*** (0,0395365)
D/E	-0,0270659** (0,0126598)
CR	-0,0708319 (0,0422446)
cons	0,2134369 (0,0906375)
Number of instruments	15
Number of groups	19
Sargan test	p value = 0,4151
Arellano-Bond test for autocorrelation - order 2	p value = 0,2945

*, **, *** Statistically significant at the; 10%, 5%, 1% level, respectively. Standard errors are between parentheses.

The operating margin (OM) demonstrates a positive and statistically significant impact on SHARE YIELD. This finding suggests that companies with higher operating margins tend to yield higher returns for shareholders. A strong operating margin indicates efficiency in generating profits from core business operations, which is often viewed positively by investors. The lagging variable (SHARE YIELD L1) from the previous year also demonstrates a positive and statistically significant influence on SHARE YIELD. This result indicates that past SHARE YIELD performance significantly influences current SHARE YIELD. In other words, companies that have historically performed well in terms of shareholder returns tend to continue to do so in the following periods. This reinforces the notion of momentum in stock returns, where past performance influences future performance.

Conversely, the debt-to-equity ratio (D/E), current ratio (CR) and variable NFD/EBITDA exhibit negative and statistically significant influences on SHARE YIELD. These results indicate that higher levels of debt relative to equity (D/E), higher current ratios (CR), and higher ratios of Net Financial Debt (NFD) to Earnings Before Interest, Taxes, Depreciation, and Amortization (EBITDA) are associated with lower share yield. Higher D/E ratios may be perceived as indicating greater financial risk or lower profitability, leading to lower shareholder returns. Higher CR may suggest lower leverage but could also indicate underutilized assets, both of which might lead to lower returns. Investors might prefer companies with more efficient asset utilization. Companies with higher NFD/EBITDA ratios might be seen as financially leveraged or carrying more debt relative to their earnings, which can be perceived negatively by investors, potentially leading to lower shareholder returns.

5. Conclusion

This study provides significant insights into the determinants of share prices on the ZSE, highlighting the complex interplay between various financial metrics and shareholder returns. By employing dynamic panel analysis, authors have identified several key financial indicators that appear to significantly influence the annual performance of shares listed on the CROBEX index from 2010 to 2019.

Our analysis reveals that a strong operating margin consistently correlates with higher share yields, underscoring the importance of efficiency in core business operations as a metric for assessing company performance and investor attractiveness. The positive correlation between past share yields and current performance suggests a momentum effect, where historical profitability tends to predict future financial success, providing a reliable indicator for both investors and analysts.

Conversely, the study indicates that higher levels of debt, both in terms of the debt-to-equity ratio and net financial debt relative to EBITDA, adversely affect shareholder returns. These findings highlight investor sensitivity to financial risk and the preference for companies with sustainable debt levels. Additionally, while a higher current ratio is typically viewed as a measure of financial stability, our findings suggest that excessive liquidity might be perceived as inefficient asset utilization, thereby dampening investor enthusiasm.

These findings are very useful for investors, company managers, and regulators. Investors can use this information to make smarter decisions about where to put their money. Managers can use these insights to tweak their strategies to better attract and benefit shareholders. Regulators might find this information helpful for understanding the financial health of the market and shaping policies.

In short, by figuring out what financial factors affect share prices on the ZSE, this research helps everyone involved make better decisions. It's important to keep looking into these relationships as the market changes to ensure the stability and growth of the financial market.

Looking ahead, further research could expand on these findings in several ways. First, it would be beneficial to explore how external economic factors such as interest rates, inflation, and economic growth impact share prices alongside the financial metrics studied here. Also, examining how non-financial factors, like company reputation or the impact of technological innovation, affect share prices could provide a more comprehensive view of what drives market movements. Additionally, extending the study period to include more recent years would help understand the post-COVID-19 economic landscape's effect on the ZSE. Such studies could enrich our understanding of the dynamics at play and further aid stakeholders in making well-informed decisions.

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THE IMPORTANCE OF REVENUES FROM SHARE IN PERSONAL INCOME TAX IN LOCAL COMMUNES' BUDGETS – A CASE STUDY OF SELECTED CITIES IN CROATIA AND POLAND

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Abstract. The correct functioning local community is determined by their budgets. Increased revenue needs of local governments are also met using the personal income tax (PIT) at the local level. The article focuses on the explanations of the present role of PIT in selected Croatian and Polish cities. Firstly, it shows and compares general information about PIT in these two countries such as taxation base, rate, and key rules. Secondly, it presents the importance of revenues from PIT paid by natural persons in local budgets by per capita analysis in main regional cities in Croatia and Poland. Finally, it compares the situation in capital cities (Zagreb/Warsaw) as due to their character they differ from the other regional cities. The results will indicate the similarities and differences in administrative considerations and if there is a strong diversity of cities concerning the value of revenues from the tax and the share of the PIT in total revenues. Finally, the research will show some trends in local taxation in selected countries. The scope of the analysis: a period of 2011-2022 and selected 20 regional cities in Croatia and 18 regional capital cities Poland.

Key words: *personal income tax, local budgets, regional cities, Croatia, Poland*

1. Introduction

The availability of funds is crucial for the proper functioning of the local community, both in terms of providing basic services and supporting economic and social development. Resources are needed to finance public services such as healthcare, education, road infrastructure and waste collection. Lack of sufficient funds can lead to a shortage or reduction of these services, which negatively affects the quality of life of residents. Funding basic public services can help reduce social inequalities by ensuring that all residents have equal access to needed services. The funds are also crucial for the development of the local community. Investing in infrastructure projects and supporting business ventures can support economic growth, job creation and prosperity. Without adequate funding, the community may find it difficult to carry out such development initiatives. Funds are also essential for the management of crises and emergencies, such as natural disasters or pandemics, or economic crises which was already the case of Covid-19. Communities must have sufficient financial reserves to be able to respond quickly to such situations, providing humanitarian aid, financial support to those affected by the crisis and the reconstruction of infrastructure.

The scope of the study concerns the own sources of financing of the local budget of the commune in the form of a share in the personal income tax (PIT). The study of the share of PIT in the commune's own revenue is important for several reasons. Firstly, income tax can constitute a significant part of a municipality's revenue and have a significant impact on its budget. Understanding this contribution will allow local authorities to plan their activities and allocate resources in an efficient manner. Secondly, an analysis of trends in the share of income tax in the municipality's revenue can provide important clues about the financial stability of the municipality and changes in the economic situation of the local community. Thirdly, a comparison of the share of income tax between selected municipalities and countries will allow to assess the competitiveness of the municipality and identify areas where tax policy can be improved, or economic development can be promoted.

Along with the increasing scope of own tasks implemented by the municipalities, which was the effect of advancing decentralization all over the Europe (Nørgaard, Braestrup, 2003) the legislator granted to municipalities larger part of PIT taxes collected on their territory by the budget. However, the lack of diversification of tax revenue sources and (limited) taxation powers is typical for many countries according to Storonyanska et al. (2017), and is justified by saving administrative costs (Bordignon, Grembi, Piazza, 2017). But limited power taxation in turn creates risk relating financial capacity of municipalities in the face of changes and shocks in the structure of the economy and, accordingly, sources of tax revenue (Olejniczak, Maci, 2021). Although local governments are essential providers of public services and infrastructure across Europe, they ultimately depend on funding from or powered by higher levels of government (Geissler, Hammerschmid, Raffer, 2021) also in the form of surcharge of income tax. Including share in income tax as own income seems controversial (Wojtowicz, 2013). The research is also justified by that aspect.

This analysis is aimed at examining the significance of shares in PIT constituting the revenues in selected Croatian and Polish urban municipalities in the years 2011-2020. The article focuses on the explanations of the present role of PIT in selected Croatian and Polish cities.

2. Research methodology

The research covered urban municipalities which are 20 regional cities in Croatia and 18 voivodeship capital cities in Poland in period 2011-2020. Their selection is justified by their influence on regional development and thou similar possibilities of tax base creation in the long term. Unlike the others urban municipalities and urban-rural municipalities, these municipalities are characterized by many residents who are the taxpayers of PIT taxpayers.

The first step of analysis refers to presentation of the systems of shares in PIT as one of the sources for funding the municipalities in Croatia and Poland. It includes a brief analysis of the evolution of scale and form of funding the municipal budgets share in PIT throughout the studied period. It also shows and compares general information about PIT in these two countries such as taxation base, rate, and key rules. This part of the analysis is based on the legal sources and the selected literature research.

Secondly, the article presents the importance of revenues from PIT paid by natural persons in local budgets. Analysis by per capita for main regional cities in Croatia and Poland is conducted. Its direct purpose is to answer the question concerning the existence of differences in the level and share of PIT in revenues of the urban municipalities in selected municipalities in Poland and Croatia, with special attention to the situation in capital cities (Zagreb/Warsaw) as due to their character they differ from the other regional cities. This part of analysis includes PIT shares selected municipalities income data collection and analysis. Data is collected from

the Ministry of finance state treasury in case of Croatia (accessed 2024.04.15), and Central Statistical Office database (GUS, accessed 2024.04.10) in case of Poland. The study considers the analysis of changes over time in the share of income tax in the revenues of municipalities in the years 2011-2022. Trend analysis will allow understanding whether the share of income tax is increasing, decreasing, or remaining stable, which can provide important clues to the financial stability of a municipality. A comparison of the share of income tax in the revenues of municipalities of selected cities and countries will allow to understand whether the municipality achieves a similar level of income from this source compared to others.

3. Literature Review

Under the Law on Financing Local and Regional Self-Government Units in Croatia revenues of local, regional (regional) self-government units are (Špoljarić, Javorović, 2017):

- municipal, city, or county taxes, surcharges, fees, contributions and fees,
- revenue from things in ownership and property rights,
- income from companies and other legal entities owned by it, that is, in which share or shares are owned,
- income from concession fees given by its representative body,
- fines and forfeited property benefits for offenses that it prescribes in accordance with by law,
- share in common taxes with the Republic of Croatia,
- aid funds and donations from the Republic of Croatia provided for in the state budget,
- other income regulated by law.
- Non-tax revenues, according to Bajo et al. (2020) are an important source of income for local government units. Tax free revenues are:
 - revenues from administrative and administrative fees,
 - income from communal fees and contributions,
 - income according to special regulations.

Under the Law on Financing of Local and Regional Self-Government Units a municipality's in Croatia own revenue is revenue generated by the local government that does not come from transfers from the central government or other external sources. Own revenues in Croatia can be divided into (local) taxes, charges, shares in central government taxes, personal income tax (PIT) and real estate transfer tax. Local self-government unit taxes in Croatia are: consumption tax, tax on vacation homes, tax on the use of public areas and surtax on income tax (abolished from January 2024). Surtax on PIT for municipalities before 2024 was:

- city under 30,000 inhabitants up to 12%,
- city over 30,000 inhabitants up to 15%,
- city of Zagreb up to 30%.

Table 1 provides the summary of PIT legislation in Croatia.

Table 1 Legislation PIT in Croatia

Year	Percentage shares of municipalities in PIT	PIT rate (%)	Personal deduction	Progressive PIT tax scale ¹
2011	55 %	12-25-40	1800 HRK (238,90 EUR)	0-3600 12% 3600-10800 25% >10800 40%
2012	56,5 %	12-25-40	2200 HRK (291,99 EUR)	0-2200 12% 2200-8800 25% >8800 40%
2013	56,5 %	12-25-40	2200 HRK (291,99 EUR)	
2014	56,5 %	12-25-40	2200 HRK (291,99 EUR)	
2015	60 %	12-25-40	2600 HRK (345,08 EUR)	0-2200 12% 2200-13200 25% >13200 40%
2016	60 %	12-25-40	2600 HRK (345,08 EUR)	
2017	60 %	24-36	3800 HRK (504,35 EUR)	0-17500 24% >17500 36%
2018	60 %	24-36	3800 HRK (504,35 EUR)	
2019	60 %	24-36	3800 HRK (504,35 EUR)	0-30000 24% >30000 36%
2020	60 %	24-36	4000 HRK (530,89 EUR)	
2021	74 %	20-30	4000 HRK (530,89 EUR)	0-30000 20% >30000 30%
2022	74 %	20-30	4000 HRK (530,89 EUR)	

Source: creation of the author according to Law on personal income tax and Law on Financing of Local and Regional Self-Government Units.

Percentage shares of Zagreb in 2011 70,5 % in PIT from 2012-2014 was 72,5 % in PIT, from 2015-2018 was 76,5 % in PIT, from 2018-2020 was 77 % in PIT and from 2021-2022 94% in PIT (Law on Financing of Local and Regional Self-Government Units).

Local government at the commune level in Poland was reactivated in the early nineties of XX century. Since 1999 the system of local government units consists of municipalities, counties, and voivodeships. This three-tier division does not create a hierarchical system and does not imply the superiority of a voivodeship over a county and municipality, or a county over a municipality. Each local government unit operates independently and is separate from the state budget, meaning municipalities, counties, and voivodeships are responsible for managing their own finances. The division of public revenues between the state - understood as the government sector - and the local government sector is one of the main components shaping the decentralised system of public finances (Gałęcka, 2011). Providing local governments with adequate revenues enables them functioning and allows them to fulfil tasks, for which they were established. Therefore, it is necessary to divide the income by law, especially in the case of the division of taxes between the state and local government.

The primary role of local government units is to satisfy the collective needs of residents through the execution of public tasks. To carry out these duties, local government units must have appropriate financial resources in relation to the assigned responsibilities.

Under the Act of 2003 on revenues of local government units, a municipality's own revenue is revenue generated by the local government that does not come from transfers from the central government or other external sources. Own revenues can be divided into (local) taxes, charges, shares in central government taxes, personal income tax (PIT) and corporate income tax (CIT), revenues from municipal property, and other revenues. Taxes consist of two subgroups. First group includes real estate tax, agriculture tax, forest tax, and means of transportation (vehicle) tax, where the local self-government councils have taxing powers (negative). The second group includes flat rate income tax, inheritance and donation tax, and tax on civil law entities, where local governments have no taxing power. Next group includes stamp duty, market (sell) charge,

1 Thresholds for taxation are in Croatian Kunas.

local charge, administrative charge, dog charge, or charge from premises for selling alcoholic beverages (rates are usually set by local self-government councils (Olejniczak, 2017). The Polish legislator granted to municipalities part of PIT and CIT taxes collected on their territory by the budget (share in central taxes). Shares in personal income tax as one of the sources of own revenue for the municipality is however characterized by the lack of taxing powers of municipalities. This tax still is not a general tax as a significant number of people are statutorily exempted from its regulation (e.g. people conducting agricultural activity).

Shares in central taxes are a form of financial transfer to the budget of local government units. The amounts of financial resources from shares in central taxes are received by these local government units in the area where the taxpayer resides (PIT). The shares due to individual local government units in the revenues from PIT and CIT differ. The municipality, which carries out a wide range of public tasks, has the largest share in PIT, while the voivodeship has the lowest share in PIT but the highest share in CIT. The low share of PIT in voivodeships is compensated by the highest share in CIT. The county has the lowest share in CIT.

The problem that local government units (especially large cities) have to deal with is a method of calculating income for individual units. Communes do not receive income from PIT from people who:

- live in a given unit, but this fact is not reported to the local municipality,
- live outside the unit's boundaries (most often these are neighbouring communes - the so-called bedroom cities) and use many public goods, while commuting to work every day offered by this entity (Furman, 2017).

Taxpayers can pay income tax in advance to the tax office, and then they are transferred to the local governments after appropriate calculation. During the tax year the number of payments can vary and depends primarily on advance payments made by taxpayers. There are legal provisions that allow taxpayers to choose various forms of paying income tax advances such as all advance payments paid monthly, quarterly or in a simplified form. Due to such regulations, local governments often receive payments to the budget with delay.

Polish regulations allow the transfer of part of the revenues obtained by the central budget to the budgets of local government units. Under the Act of 2003 the share in PIT revenues from taxpayers residing in the municipality is 39.34%. It is reduced by the number of percentage points corresponding to the product of 3.81 percentage points and the indicator calculated for the entire country. The indicator is determined by dividing the number of residents admitted to social welfare homes before January 1, 2004, as of June 30 of the base year, by the number of residents admitted before January 1, 2004, as of December 31, 2003.

General PIT rules provide for the rates based on the tax scale (available for income obtained from employment and business activities). Individuals running business activities (as sole traders or as partners in partnerships) can, instead of being subject to the tax scale, opt for a flat 19% income tax rate, lump-sum tax, or the so-called "tax-card". It should be noted, that due to the "Polish Deal" tax-card was liquidated as of 1 January 2022 as a method of tax settlement, and only taxpayers who settled in the form of a tax card in 2021 are still able to use it. However, if they resign from this option, they will not be able to return to the tax card in the following years. Income from tax cards contributes to the commune budget. Revenues from income tax paid in the form of a lump sum on recorded income and flat-rate income tax on clergy's income constitute the income only of the state budget, therefore won't be analysed in this study. The new regulations which came into force from 1 January 2022 had a significant impact not only on business activity taxation, but also on local governments budgets.

The table 2 presents percentage shares of municipalities in PIT 2002 - 2022 years and tax rates in Poland.

Table 2 Legislation PIT in Poland

Year	Percentage shares of municipalities in PIT	PIT rate (%)	PIT (flat rate, %)	Progressive PIT tax scale ²
2011	37.12%	18-32	19	18% - 556,02 PLN as a tax reducing amount- up to 85 528 PLN revenue *32% above 85 528 revenues
2012	37.26%	18-33	19	
2013	37.42%	18-34	19	
2014	37.53%	18-35	19	
2015	37.67%	18-36	19	
2016	39.34%	18-37	19	
2017	37.89%	18-38	19	
2018	37.98%	18-39	19	17,75% - tax reducing amount -up to 85 528 PLN 32% above 85 528 revenues
2019	38.08%	17.75-32	19	
2020	39.34%	17-32	19	17% - tax reducing amount -up to 85 528 PLN 32% above 85 528 revenues
2021	38.23%	17-33	19	
2022	38.34%	12-32	19	12% - tax reducing amount - up to 120 000 PLN 32% above 120 000 PLN revenue

Source: creation of the author according to Law on personal income tax and Law on Financing of Local and Regional Self-Government Units.

When discussing tax rates, it's important to note that as of August 1, 2019, taxpayers up to the age of 26 are eligible to utilize the so-called youth discounts. The annual income limit entitling to this tax relief is PLN 85,528 PLN.

4. Data, Analysis and Results

Data includes total revenue, PIT revenue, and numbers of inhabitants for selected cities. The data comes from official statistics proper for each country as explained in the methodology. Values from Croatian Kunas were recalculated to EUR using conversion rate by the National Bank of Croatia. Values from Polish zloty were recalculated to EUR using an average EUR-PL exchange rate published by the National Bank of Poland.

Firstly, total revenue per capita is presented in terms of trends and dynamics (Table 3, Table 4, Table 5).

² Thresholds for taxation are in Polish Zloty.

Table 3 Revenue per capita (2011-2022), selected cities in Croatia and Poland (EUR)

City	2011-2022	Aver.	City	2011-2022	Aver.
Split		615	Wrocław		1 571
Rijeka		800	Bydgoszcz		1 256
Osijek		570	Toruń		1 344
Zadar		700	Lublin		1 388
Velika Gorica		591	Gorzów Wlk.		1 259
Pula		707	Zielona Góra		1 362
Slavonski Brod		440	Łódź		1 352
Karlovac		560	Kraków		1 486
Varaždin		734	Warszawa		2 060
Šibenik		581	Opole		1 605
Dubrovnik		1 228	Rzeszów		1 469
Sisak		588	Białystok		1 414
Bjelovar		454	Gdańsk		1 572
Koprivnica		600	Katowice		1 482
Čakovec		558	Kielce		1 476
Vukovar		730	Olsztyn		1 529
Požega		463	Poznań		1 521
Virovitica		589	Szczecin		1 322
Krapina		408			
Gospić		685			
Zagreb		1 224			

Source: creation of the author.

It is evident that the total income of cities in Poland per inhabitant is significantly higher than the income per inhabitant in Croatia. The trend in both countries is generally positive with some fluctuations related to economic conditions and tax policy changes (Table 4, Table 5).

Table 4 Revenue per capita (2011-2022), selected cities in Croatia (EUR), dynamics

City	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	
Split	-4%	8%	-1%	-4%	7%	9%	9%	13%	-17%	21%	15%	
Rijeka	8%	-1%	1%	4%	1%	2%	12%	7%	-2%	14%	12%	
Osijek	2%	-1%	3%	-9%	5%	4%	12%	14%	5%	24%	43%	
Zadar	13%	-2%	10%	-1%	9%	-5%	5%	10%	8%	21%	7%	
Velika Gorica	9%	2%	-4%	16%	-7%	4%	6%	10%	2%	22%	23%	
Pula	-1%	10%	-3%	1%	12%	13%	-10%	2%	-2%	15%	18%	
Slavonski Brod	-8%	5%	3%	5%	9%	5%	26%	12%	23%	28%	-19%	
Karlovac	5%	16%	-1%	-6%	22%	-10%	0%	26%	-5%	5%	16%	
Varaždin	1%	18%	-3%	-3%	7%	-1%	8%	10%	-5%	59%	-1%	
Šibenik	25%	-12%	12%	-12%	2%	9%	10%	13%	-2%	29%	11%	
Dubrovnik	14%	7%	9%	2%	4%	4%	23%	17%	-48%	33%	26%	
Sisak	-5%	-5%	3%	1%	4%	6%	7%	12%	-3%	31%	-1%	
Bjelovar	-1%	7%	-3%	1%	9%	-1%	15%	15%	6%	18%	12%	
Koprivnica	1%	-2%	1%	8%	-6%	-2%	18%	15%	-3%	14%	30%	
Čakovec	2%	3%	6%	0%	8%	4%	5%	11%	2%	38%	-12%	
Vukovar	13%	10%	10%	-18%	62%	5%	15%	1%	-13%	26%	12%	
Požega	6%	33%	-20%	-7%	0%	6%	44%	17%	-12%	16%	19%	
Virovitica	-3%	0%	7%	-9%	3%	3%	111%	15%	-23%	-4%	16%	
Krapina	7%	3%	-1%	7%	14%	-7%	15%	7%	4%	19%	18%	
Gospić	17%	6%	11%	-15%	-4%	3%	12%	12%	-7%	6%	25%	
Zagreb	3%	15%	-7%	-6%	4%	1%	13%	4%	-4%	31%	7%	

Source: creation of the author.

Table 5 Revenue per capita (2011-2022), selected cities in Poland (EUR), dynamics

City	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	
Wrocław	1%	0%	-2%	2%	7%	5%	8%	9%	-4%	17%	-3%	
Bydgoszcz	0%	5%	11%	6%	6%	10%	11%	12%	-1%	6%	1%	
Toruń	18%	5%	0%	13%	-16%	10%	10%	7%	8%	5%	-4%	
Lublin	9%	17%	4%	-7%	4%	15%	10%	4%	-1%	13%	-5%	
Gorzów Wlk.	1%	9%	5%	5%	15%	6%	16%	7%	11%	2%	2%	
Zielona Góra	3%	2%	8%	-1%	10%	22%	7%	15%	-8%	11%	-1%	
Łódź	9%	19%	-4%	14%	-2%	3%	5%	10%	6%	7%	0%	
Kraków	2%	8%	9%	2%	8%	9%	6%	10%	-2%	13%	-2%	
Warszawa	4%	2%	12%	3%	-2%	7%	9%	5%	-5%	13%	-2%	
Opole	4%	5%	4%	4%	9%	12%	15%	15%	9%	-8%	-1%	
Rzeszów	20%	6%	2%	4%	-1%	11%	13%	7%	8%	1%	-7%	
Białystok	13%	-6%	26%	-21%	10%	16%	15%	4%	1%	3%	-4%	
Gdańsk	39%	-6%	-1%	-1%	-2%	7%	12%	9%	1%	7%	-1%	
Katowice	1%	13%	4%	4%	2%	7%	8%	11%	8%	5%	-1%	
Kielce	-6%	5%	4%	4%	-2%	13%	4%	17%	2%	1%	0%	
Olsztyn	4%	7%	9%	26%	-17%	12%	6%	9%	1%	10%	-4%	
Poznań	10%	-3%	7%	18%	-6%	11%	6%	12%	-1%	12%	1%	
Szczecin	18%	7%	6%	15%	1%	-2%	6%	15%	13%	4%	-1%	

Source: creation of the author.

According to data from 2017, the average monthly disposable income per person in households in Croatia was 47% higher than in Poland - although these data do not relate solely to revenues in cities. Already in 2022, the median equivalent disposable income per inhabitant in Poland was 23% higher than in Croatia. Comparing GDP per capita in 2023 according to purchasing power parity, Poland achieved a result 6% higher than Croatia (GUS 2018, Eurostat, Worldbank). That may be an argument for justifying the observation that Poland coped better than Croatia with the situation after subprime crisis in 2008. Revenue per capita and its dynamics presents better for Polish cities till 2019 when its decrease in Polish cities due to Covid-2019 was stronger then in Croatian cities.

Secondly, total PIT revenue per capita is presented in terms of trends and dynamics (Table 6, Table 7, Table 8).

Table 6 PIT revenue per capita (2011-2022), selected cities in Croatia³ and Poland (EUR)

City	2011-2022	Aver.
Split		316
Rijeka		383
Osijek		301
Zadar		265
Velika Gorica		338
Pula		317
Slavonski Brod		213
Karlovac		292
Varaždin		375
Šibenik		237
Dubrovnik		378
Sisak		245
Bjelovar		227
Koprivnica		273
Čakovec		280
Vukovar		185
Požega		221
Virovitica		211
Krapina		238
Gospić		271
Zagreb		821

City	2011-2022	Aver.
Wrocław		414
Bydgoszcz		291
Toruń		298
Lublin		304
Gorzów Wlk.		253
Zielona Góra		349
Łódź		330
Kraków		413
Warszawa		652
Opole		355
Rzeszów		306
Białystok		282
Gdańsk		377
Katowice		394
Kielce		308
Olsztyn		321
Poznań		423
Szczecin		301

Source: creation of the author.

The trend of PIT revenues in both countries in selected cities is positive but contrary to total revenues, it is evident that the income from PIT in the analyzed cities in Poland is not that much higher compared to the analyzed cities in Croatia. There are some fluctuations related to economic conditions and tax policy changes as in the case of total revenues (Table 7, Table 8).

Table 7 PIT revenue per capita (2011-2022), selected cities in Croatia, dynamics

City	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	
Split	5%	3%	0%	-8%	7%	-2%	20%	9%	-8%	13%	25%	
Rijeka	11%	5%	4%	-5%	4%	-9%	16%	11%	-5%	9%	20%	
Osijek	8%	4%	-1%	-9%	12%	-5%	16%	11%	1%	12%	21%	
Zadar	23%	6%	2%	-11%	10%	-6%	17%	9%	-8%	14%	25%	
Velika Gorica	10%	2%	4%	-11%	9%	-8%	16%	12%	-5%	7%	24%	
Pula	13%	9%	3%	-2%	5%	-6%	17%	2%	-14%	15%	33%	
Slavonski Brod	9%	9%	4%	-9%	10%	-10%	74%	14%	1%	-28%	23%	
Karlovac	10%	5%	3%	-6%	17%	-8%	5%	12%	-1%	10%	18%	
Varaždin	9%	4%	3%	-6%	4%	1%	10%	10%	-4%	19%	15%	
Šibenik	2%	3%	2%	-12%	4%	-3%	18%	17%	-10%	10%	25%	
Dubrovnik	8%	6%	2%	-8%	12%	-2%	14%	7%	-31%	12%	42%	
Sisak	2%	-2%	1%	-9%	3%	-8%	17%	9%	-2%	9%	23%	
Bjelovar	8%	2%	-2%	-9%	7%	-4%	31%	9%	-7%	-5%	20%	
Koprivnica	11%	-3%	0%	-9%	8%	-2%	12%	4%	-1%	13%	26%	
Čakovec	11%	4%	2%	-9%	20%	2%	8%	8%	-5%	10%	22%	
Vukovar	1%	7%	1%	-32%	-16%	-51%	510%	10%	-1%	-76%	36%	
Požega	11%	4%	-1%	-10%	11%	-8%	72%	15%	-1%	-24%	34%	
Virovitica	11%	4%	-4%	-12%	6%	-7%	76%	16%	4%	-27%	29%	
Krapina	10%	1%	4%	-6%	17%	-11%	22%	13%	-3%	21%	28%	
Gospić	11%	3%	-6%	-41%	5%	-6%	75%	4%	-7%	-19%	19%	
Zagreb	8%	21%	-8%	-10%	6%	-5%	15%	4%	-3%	8%	19%	

Source: creation of the author.

3 PIT revenue in Croatia include also Surtax on PIT

Table 8 PIT revenue per capita (2011-2022), selected cities in Poland, dynamics

City	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	
Wrocław	2%	5%	8%	8%	4%	13%	15%	10%	-9%	12%	-3%	
Bydgoszcz	2%	2%	7%	8%	3%	11%	10%	10%	-4%	10%	-3%	
Toruń	3%	7%	5%	8%	2%	10%	11%	8%	-5%	9%	-3%	
Lublin	3%	2%	8%	9%	2%	8%	10%	9%	-5%	12%	-4%	
Gorzów Wlkp.	4%	4%	6%	8%	4%	11%	13%	8%	-4%	13%	-2%	
Zielona Góra	6%	0%	5%	17%	4%	11%	15%	8%	-15%	10%	3%	
Łódź	4%	3%	8%	8%	3%	10%	13%	9%	-5%	11%	-2%	
Kraków	-1%	4%	8%	8%	5%	15%	16%	9%	-7%	11%	-3%	
Warszawa	0%	4%	8%	7%	3%	11%	13%	8%	-9%	10%	-2%	
Opole	2%	4%	7%	6%	4%	7%	11%	8%	-5%	9%	-3%	
Rzeszów	6%	5%	7%	7%	2%	10%	11%	8%	-5%	13%	-3%	
Białystok	6%	0%	10%	6%	2%	11%	13%	8%	-5%	11%	-2%	
Gdańsk	0%	5%	8%	9%	3%	12%	13%	8%	-9%	15%	-5%	
Katowice	2%	3%	8%	8%	1%	9%	12%	7%	-5%	11%	-4%	
Kielce	2%	4%	8%	4%	1%	13%	9%	8%	-2%	12%	-5%	
Olsztyn	5%	2%	5%	7%	3%	9%	11%	7%	-6%	11%	-3%	
Poznań	1%	5%	6%	7%	4%	11%	13%	9%	-8%	8%	-2%	
Szczecin	-2%	4%	5%	10%	2%	11%	13%	8%	-5%	11%	-3%	

Source: creation of the author.

The decline in income from PIT in Croatia in 2015 and 2017 can be explained by reforms in personal income tax taxation (Vukovar suffered the most); while there is an increase noticed in all the cities in 2018, 2019, 2022. There is an evident decline in all Polish cities in 2020 which results from Covid-2019 and decline in 2022 explained by the reform called “Polish Deal”. It was as a major tax reform package implemented by the Polish government. It significantly changed the taxation of personal income, particularly for employees. As it has faced criticism due to unintended consequences for many stakeholders and required multiple amendments to address its shortcomings, some of the problematic mechanisms have been abolished.











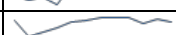
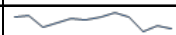




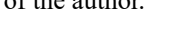
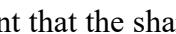
Thirdly, the share of the PIT in total revenues is calculated (Table 9, Table 10).

Table 9 Share of PIT revenue in revenues (%) (2011-2022), selected cities of Croatia

City	2011-2022	Aver.	Min.	Max.
Split		51%	46%	55%
Rijeka		48%	44%	53%
Osijek		54%	41%	61%
Zadar		38%	32%	44%
Velika Gorica		58%	50%	68%
Pula		45%	37%	49%
Slavonski Brod		51%	28%	61%
Karlovac		52%	49%	56%
Varaždin		52%	40%	59%
Šibenik		41%	34%	49%
Dubrovnik		31%	25%	37%
Sisak		42%	33%	50%
Bjelovar		51%	38%	60%
Koprivnica		46%	41%	52%
Čakovec		51%	39%	54%
Vukovar		28%	7%	44%
Požega		48%	38%	59%
Virovitica		37%	30%	45%
Krapina		58%	54%	62%
Gospić		40%	29%	54%
Zagreb		68%	56%	73%

Source: creation of the author.

Table 10 Share of PIT revenue in revenues (%) (2011-2022), selected cities of Poland

City	2011-2022	Aver.	Min.	Max.
Wrocław		26%	22%	30%
Bydgoszcz		23%	22%	25%
Toruń		22%	19%	25%
Lublin		22%	19%	23%
Gorzów Wlk.		20%	18%	22%
Zielona Góra		26%	24%	29%
Łódź		24%	21%	27%
Kraków		28%	26%	30%
Warszawa		31%	29%	35%
Opole		23%	18%	25%
Rzeszów		21%	19%	22%
Białystok		20%	17%	23%
Gdańsk		24%	18%	27%
Katowice		27%	24%	29%
Kielce		21%	19%	22%
Olsztyn		21%	18%	22%
Poznań		28%	26%	30%
Szczecin		23%	20%	28%

Source: creation of the author.

It is evident that the share of PIT revenue in revenues is higher in Croatia. This conclusion is expected considering the value of revenues and PIT revenues per capita in cities in Croatia and Poland. As on general, total revenues per capita are higher in Poland (in analysed period for analysed cities by approx. even 50% on average), at the same time PIT revenues are higher in Poland “only” by 15%.

Apart from that, capital cities require special attention. It is evident, that PIT share in Zagrzeb is significantly larger since it has the status of a city and a county. On average, PIT share in total revenue for Zagreb is 68%, while the average for remaining Croatian cities is 46%. However, all the analyzed cities in Poland, including Warsaw as capital city, have a status of a city and county, too. The average PIT share in total revenues for Warsaw is 31%, while for the remaining cities it is 23%. The difference then expressed in pp. is lower in case of Polish cities.

5. Discussion and Conclusions

The income level of residents directly impacts the level of revenues obtained by local government units. Therefore, the prosperity of residents influences the financial situation of local government units. Any changes regarding both the wealth of the population and the number of residents, primarily involving actions by the authorities of local government units aimed at preventing outflows and attracting population as well as private investors, affect the budgetary revenues of local governments. A difficult situation in the revenue state of local government units is observed during economic downturns. During such times, state budget revenues from taxes decrease. This has consequences for the budgets of local government units, as it results in a decrease in funds received by these entities from shares in central taxes. Such a situation may threaten the implementation of public tasks in local government units.

Revenues from personal income tax (PIT) are an important source of financing for local government units, as they are used to cover current needs and development investments of the municipality, such as the construction of road, educational or cultural infrastructure. Improving the quality of infrastructure and accessibility of public services contribute to increasing the attractiveness of the municipality for residents and businesses.

The analysis of the importance of personal income tax revenues in the budgets of selected cities in Croatia and Poland reveals several key findings:

- There are notable differences in the level and dynamics of total revenues and PIT revenues per capita between Croatian and Polish cities. Polish cities generate evidently higher revenues per resident compared to Croatian cities.
- The share of PIT in total revenues has been relatively stable over the 2011-2022 period in both countries, with some fluctuations related to economic conditions and tax policy changes.
- PIT constitutes a significant source of own revenues for local governments in both countries, with its share in total revenues ranging from around 47% for Croatian cities to 24% for Polish cities. Therefore, that Croatian cities are more dependent on that source of revenues.
- Capital cities (Zagreb and Warsaw) stand out with the highest PIT revenues per capita, reflecting their economic importance and concentration of high-income taxpayers.
- Decline in revenues from PIT in Croatia in 2017 and 2015 can be explained by reforms in personal income tax taxation, while the Polish Deal tax reform package introduced in 2022 by the Polish government significantly changed personal income taxation, with mixed effects on local budgets.

The findings highlight the fiscal significance of PIT for local governments in Croatia and Poland - personal income tax is an important source of own revenues for urban municipalities in Croatia and Poland. But the reliance on this revenue source exposes municipalities to risks related to economic cycles and tax policy changes at the national level. To limit the risks associated with over-reliance on this revenue source and to enhance the financial resilience of local governments, diversification of revenue sources and greater fiscal autonomy should be considered.

Simultaneously, it should be noted that a lower share of PIT revenues in the budgets of local governments in Poland puts such local governments in a situation of less exposed to economic trends compared to Croatia. The results of the research suggest that Polish local governments are less exposed to economic trends due to diversification of revenue streams, stability of revenue streams, and fiscal decentralization. With a lower reliance on PIT revenues, Polish local governments have a more diversified revenue base, which reduces their exposure to changes in personal income levels. Croatian local governments, on the other hand, derive a larger portion of their revenues from PIT, making them more vulnerable to economic downturns that affect personal incomes. The lower share of PIT revenues in Poland implies a higher share of other revenue sources, such as property taxes, fees, and transfers from the central government. These alternative revenue sources tend to be more stable and less sensitive to economic cycles, providing a buffer against fluctuations in personal income levels. The lower reliance on PIT revenues in Poland seems to result from a more decentralized fiscal system, where local governments have access to a broader range of revenue sources. This decentralization can help insulate local governments from economic shocks by allowing them to adjust their revenue mix and rely more on stable sources during downturns. However, it's important to note that a lower share of PIT revenues does not necessarily imply better financial stability for local governments in Poland compared to Croatia. Other factors, such as the overall level of revenues, expenditure responsibilities, and fiscal management practices, also play a crucial role in determining the financial resilience of local governments.

The research limitations refer to specific period (2011-2022) and the focus on selected cities. It may not therefore reflect the most recent developments in personal income tax and does not

provide a comprehensive picture of all municipalities in Croatia and Poland. The data used in the analysis comes from official statistics for each country, which may have inconsistencies or differences in methodology, making direct comparisons more challenging. Finally, the research does not consider the impact of economic factors, such as GDP growth, unemployment rates, or inflation, on the dynamics of PIT and does not analyze the effects of specific tax policy changes, although it might be a subject of further research. Also, comparative studies across a broader range of cities and countries could provide valuable insights into best practices in local government financing.

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THE EFFECT OF MEASURES IN COMBATING TAX FRAUD

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Abstract. Suppressing the chain of fraud implies firstly the identification of risky taxpayers: those who do not fulfill their legal obligations (submitting a VAT return) and, with the established legal framework, a quick measure implementation, that is, a reaction in the shortest possible period. Starting January 1, 2019, amendments to the Law on Value Added Tax (Official Gazette 106/18) in Croatia introduced a new obligation for taxpayers registered in the VAT system. Taxpayers must submit their VAT return electronically and a specific record of invoices received (URA form). A special software solution is utilized to create a network of taxpayers, identifying at-risk taxpayers based on whose accounts other taxpayers have claimed the right to withhold input tax, rather than solely those who submit VAT declarations. The amount of value-added tax declared by taxpayers in their VAT returns based on the accounts of taxpayers who do not submit VAT returns represents damage to the state budget. At the end of the deadline for submitting tax returns and after invitations have been sent to “non-applicants”, the customer (who has expressed the right to deduct input tax) is sent a Notice under Article 127 of the VAT Act, the so-called “warning letter”. A taxpayer who supplies goods and services in the country with the right to deduct input tax will be responsible if, for objective reasons, it follows that the taxpayer knew or should have known that due to fraudulent activities, part or all of the VAT amount related to the supply made to him/her or any previous or subsequent delivery of the same goods or services, remain unpaid. If it is determined that the taxpayer is responsible, their right to dispute the tax withholding will be affected. Not only that the previously mentioned measure of the warning letter delivery break the fraudulent chain, but it also enables recovery of the resulting damage. In this paper, we will demonstrate how to determine the resulting damage and monitor its movement during each step of the procedure.

Keywords: tax frauds, risky taxpayers, warning letter, VAT.

1. Introduction

One of the crucial instruments of fiscal policy is the value-added tax (VAT), which, along with the profit tax and the income tax, is the most generous form of tax in the Republic of Croatia, where 68.6% of tax revenue is accounted for by VAT (Explanation of the general part of the state budget and financial plans of extra-budgetary users for 2023 and projections for 2024 and 2025, 2022).

Because of the above, the state strives for systematic control and monitoring of the calculation, recording, and payment of this income from the state budget.

VAT is neutral for entrepreneurs as taxpayers because they have the right to deduct the VAT they pay to their suppliers from their tax liability, for example, the amount of tax they charge on their output invoices.

A taxpayer registered in the register of VAT payers must determine the VAT liability for the taxation period and declare it in the VAT return (VAT form) in which all the data necessary for calculating VAT, the total value of taxable transactions, and the amount of VAT are stated as well as the amount of input tax at VAT rates, and exempt transactions and those that are not subject to taxation (Art. 85 of the Value Added Tax Act, 2013 – 2024).

However, some taxpayers were founded and operated exclusively with the intention of fraudulent behavior, and, in addition to creating unfair competition, they also caused damage to the state budget. Most often, it concerns taxpayers who have the characteristics of disappearing traders: they do not submit tax returns, they are unavailable, established liabilities are uncollectible, and the rest.

Following the previously mentioned situations, the Tax Administration takes various measures and actions to detect taxpayers who fail to fulfill their legal obligations as soon as possible. These measures include issuing subpoenas, collecting relevant information for taxation purposes, conducting tax investigations, and carrying out supervision.

2. Combating tax frauds

Concerning safeguarding state finances, all member countries are implementing measures to detect and prevent tax fraud as early as possible. That is because fraud is typically only uncovered after it has been committed, resulting in damaging the state budget. All measures can be categorized as either company's pre-registration or post-registration in the VAT system (Raspudić, 2004, p. 67). In the previously mentioned manner, the Guide for Good Practice in Combating VAT-related Fraud within the Community (2013) elaborates on the measures for combating tax fraud for combating VAT-related fraud, which we present below.

2.1 Pre-registration combating measures

Given that the measures aim to prevent the company registration of a future disappearing trader, which would be ideal, specific measures and procedures are proposed that the tax authorities of the member states should perform before registering the company and enabling it to operate and access the VAT system (Mrčela & Zovko Marić, 2021). Denial is not achievable where electronic registration is implemented as it depends on individual member states' legal regulations. Therefore, for efficient protection, it is necessary to collect as much information as possible, for example, through a questionnaire, which is submitted to the company during registration, that is before registration itself (Fiscalis Risk Analysis Project Group, 2016). If the company does not provide all the relevant data or the same requires verification, it is possible to postpone the company's registration or refuse it. The same applies when registering for VAT purposes and assigning a VAT ID number. In any case, it is advisable to conduct the check at the business premises. In addition to collecting beneficial information and creating a risk analysis, the purpose of this questionnaire is also the possible effect of deterring organizers or participants who do not want to reveal their identity so they can also give up registration (Projektna grupa Fiscalis FPG082, 2013, p. 92.)

2.2 Post-registration combating measures

After registering a company in the fight against fraud with a disappearing trader, it is significant to find the fraudulent company at the earliest possible stage to take particular measures such as deleting it from the VAT system, detecting a company that does not fulfill its obligations (filing reports and settling obligations) as and taking other actions to protect the state budget. Member states utilize special assessments of collected data and risks (Projektna grupa Fiscalis FPG082, 2013, pp. 91–92).

This includes thorough analyses of VAT returns for detecting large values, small profits, identification of business associates, and others. The VAT ID number is significant for doing business in the European market, so the supplier/acquirer must be able to check the validity of that number. For this purpose, the member states have introduced a special register of taxpayers who intend to do business within the Community, for which registration criteria are more demanding (checks in the VIES system). If the verified number is not in the register or the same has been canceled (discontinued), the company that does business with such a company cannot be exempt from VAT obligations, which is why they risk being a participant in tax fraud. The purpose of such a register is to prevent a business relationship with a fraudulent company and the creation of a chain of fraud (Mrčela & Zovko Marić, 2021).

Submitting tax returns within shorter periods can help prevent tax fraud by providing more opportunities to detect disappearing traders earlier. If a taxpayer submits their tax return irregularly, it can signal to tax authorities to take specific actions or conduct additional checks (Mrčela & Zovko Marić, 2021, p.8).

Risk analysis is a useful tool in preventing, detecting, and combating tax fraud. It involves two main processes: risk assessment and risk management (Projektna grupa Fiscalis FPG082, 2013, p. 99). A list of companies can be generated and categorized based on specific criteria by using a database. The categorization helps to prioritize checks, checking high-risk companies first. Establishing trustworthy methods is essential for identifying high-risk taxpayers and examining submitted VAT returns. This includes reviewing non-submitted VAT returns, VAT returns with zero amounts, and discrepancies in VIES.

It is possible to inform the company of the risk of VAT-related fraud and suggest measures to prevent involvement in fraud before or after registration. The letter warns companies that measures could be taken against them if they are involved in fraud and act negligently (Projektna grupa Fiscalis FPG082, 2013, p. 99).

In cases where a chain of fraud is detected, it is possible to remove the disappearing trader and the first buffer company from the register. However, this is not always feasible with larger buffer companies or brokers. If we want to prove their involvement in the fraud, we must demonstrate that they were aware of or participated in it. In such instances, they will receive a letter informing them to be participants in the fraud. The letter will indicate the companies from whom they purchased the goods and warn them about potential measures to be taken for future transactions if they are found to be in a similar situation. If we determine that they knew or should have known about the intention to avoid VAT payment, they will be held accountable from the date they received the notification.

3. In-depth analysis of stakeholders of the sales chain and identification of risky taxpayers

It is crucial to detect fraudulent companies and break the chain of fraud in the battle against VAT fraud. To achieve this, the Tax Administration has created a specialized application solution

that visually displays transactions and deeply analyzes all parties involved in the sales chain (Marinelić & Palašek, 2023, p. 10). This helps identify taxpayers who fail to submit tax returns or settle their obligations and enables participants in the chain to use input tax and reduce the tax base.

The application enables the above because it enables data from the URA Form (book of incoming invoices)¹, VAT-S form, ZP form, PPO form, and application-created book of outgoing invoices to be collected within it. The application creates a network of taxpayers connected through transactions, and as long as the URA form exists, the network can expand. The chain is broken at the moment a taxpayer who has not submitted the URA form is connected. Considering that the application is also connected with the other data mentioned above, the network can be formed by inserting this data to create a complete picture of business connections. In addition to the above, it is possible to determine from the application that taxpayers have not submitted tax returns just after the deadline for submitting tax returns has passed. In this way, it is possible to react much earlier in suppressing the fraudulent chain if the company that did not submit the report is a disappearing trader.

Swift measures were taken based on the factors mentioned earlier to guarantee prompt and responsive action. At the end of the deadline for submitting a VAT return, all taxpayers who have not submitted a tax return will receive an automatic invitation through the application, inviting them to submit a tax return within an additional period. After the expiry of that period (3 days from the delivery of the summons), taxpayers who still have not submitted a report are to be sent a second summons informing them that their customer will be warned of the risk of doing business with the same. After all the deadlines, tax inspectors perform on-site verification of taxpayers who still do not submit reports and assign status (Marinelić & Palašek, 2023, pp. 27–28).

Individuals who purchase goods or services but fail to submit tax returns will be notified as per Article 127 of the VAT Act (Value Added Tax Act, 2013 – 2024). They will receive a “warning letter” if they have claimed input tax based on input accounts of taxpayers who have not submitted tax returns despite being notified twice by the tax administration. If they discover through field checks that these taxpayers are disappearing traders, they will receive a notification accordingly. This causes direct damage to the state budget. Not only that the customer is informed that the supplier does not fulfill legal obligations, but it also warns of his responsibility. From the date of receipt of the notification, the tax administration may consider that the taxpayer (customer) knew or must have known that he was participating in fraudulent transactions with such transactions.

4. Damage calculation

A part of taxpayers was established and operates solely to participate in tax frauds, do not submit tax returns, do not settle obligations, are unavailable, and cause damage to the state budget. As part of the already mentioned application, a special application part was created for the calculation of damages made by taxpayers who do not file tax returns and taxpayers who claim the right to deduct input tax from the accounts of taxpayers who do not file tax returns. Damage calculation and trend monitoring can be monitored through the application according to defined criteria. It is monitored on certain pre-defined days and follows the business process of automatically sending calls, going out to the field, and sending notifications, according to Art. 127 of the VAT Act:

¹ From January 1, 2019 amendments to the VAT Act (Official Gazette 106/18) introduced the obligation that taxpayers entered in the register of VAT payers must electronically submit records of invoices received along with the application.

1. The day when the invitation to submit the form went out
2. Deadline when the 1st invitation should have been acted upon
3. The deadline for acting on the 2nd invitation
4. The day when the warning letters go
5. Additional calculation if more than 5 months have passed since the deadline for submission of forms (Marinelić & Palašek, 2023, p. 60).

In addition to specific dates, the calculation of damages is also determined according to the following criteria based on the pattern of behavior of taxpayers who do not submit tax returns (Marinelić & Palašek, 2023, p. 61):

- did not submit the VAT form by the given parameter on the day
- The VAT form has been submitted, but items II.1.- II.3. handed in with zero
- the amount on the VAT form is lower than that on the URA
- the amount on the VAT form is greater than or equal to that on the URA.

Considering the degree of riskiness of certain criteria and the greater incidence of the criteria in the case of fraudulent behavior, the emphasis will be on the calculation of damages according to the criteria “the taxpayer did not submit the VAT form by the given parameter on the date” and “the VAT form was submitted, but items II.1.- II.3. submitted with zero”.

- *did not submit the VAT form by the given parameter on the day*

When calculating damages according to this criterion, all taxpayers who, on the date of calculation of damages, did not submit a VAT form for the specified accounting period, and in the same period other taxpayers (customers) used the right to deduct input tax on the input accounts of non-applicants.

Table no. 1 below shows the number of taxpayers by month for 2023 who did not submit a VAT form, as well as the calculation of damage to the state budget expressed in millions of euros due to the stated right to deduct input tax for the tax that was not reported or paid to the state budget. The calculation was made on the third working day after the legal deadline for submitting the VAT form.

Table 1 Presentation of the number of taxpayers according to the criterion “Did not submit the VAT form by the given parameter ON THE DAY”

PERIOD	ON THE DAY	NUMBER OF TAXPAYERS	DAMAGE CALCULATION -mil. €
1/2023	23.02.2023	3611	19,42
2/2023	23.03.2023	2.941	20,46
3/2023	25.04.2023	3.111	28,36
4/2023	24.05.2023	2.437	19,48
5/2023	26.06.2023	3.314	40,57
6/2023	25.07.2023	2.861	22,82
7/2023	24.08.2023	2.910	23,07
8/2023	25.09.2023	2.422	21,39
9/2023	25.10.2023	2.299	23,99
10/2023	23.11.2023	2.920	27,15
11/2023	27.12.2023.	2.596	26,80
12/2023	25.01.2024	3.728	33,25

Source: ISPU on April 10, 2024

Table no. 2 shows the calculation of damages on the date of expiry of all deadlines for submission of the VAT form: after the first and second call and after the field inspection.

Table 2 Display of the number of taxpayers according to the criterion “Did not submit the VAT form by the given parameter ON THE DAY”

PERIOD	ON THE DAY	NUMBER OF TAXPAYERS	DAMAGE CALCULATION -mil. €
1/2023	31.03.2023	360	0,77
2/2023	02.05.2023	296	0,75
3/2023	31.05.2023	371	1,17
4/2023	30.06.2023	309	0,95
5/2023	31.07.2023	258	1,03
6/2023	31.08.2023	369	1,03
7/2023	02.10.2023	357	1,33
8/2023	31.10.2023	252	0,89
9/2023	30.11.2023	235	0,72
10/2023	02.01.2023	288	0,84
11/2023	31.01.2024	263	0,42
12/2023	29.02.2024	291	0,60

Source: ISPU on April 10, 2024

There is an evident decrease in the number of taxpayers who did not submit a report after the measures of calls and inspections in the field, and thus, a significant decrease in the amount of damage committed. This is a direct effect of this business process and the measures taken. However, looking at the monthly level, the total amount of monthly damages is increasing. The goal is to minimize such taxpayers who harm the state budget, so to prevent them, it is necessary to take other measures to prevent tax fraud: canceling and/or suspending the VAT ID number, printing it from the register of VAT payers, issuing measures to ensure collection, starting tax inspections or tax investigations.

All individuals or businesses who have not filed their tax returns are not automatically considered disappearing traders. The status of the disappearing trader is only assigned after a field check to determine the availability of the taxpayer. If the taxpayers still do not submit a tax return and cannot be found at the address of their registered office, they are then assigned one of the following statuses: “disappearing trader”, “the suspicious one” or “needs to be checked”.

Figure 1 Display of the number of non-submitting taxpayers according to the criterion “Did not submit the VAT form by the given parameter ON THE DAY”. Source: ISPU on April 10, 2024

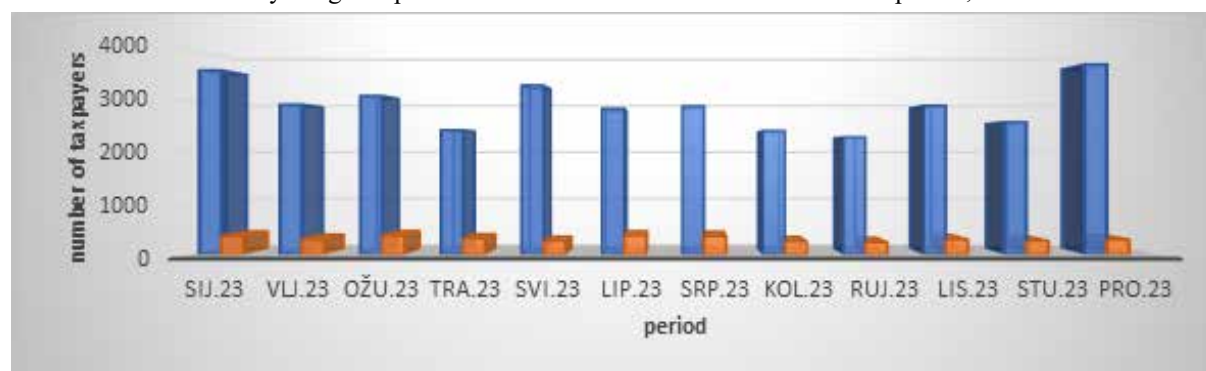
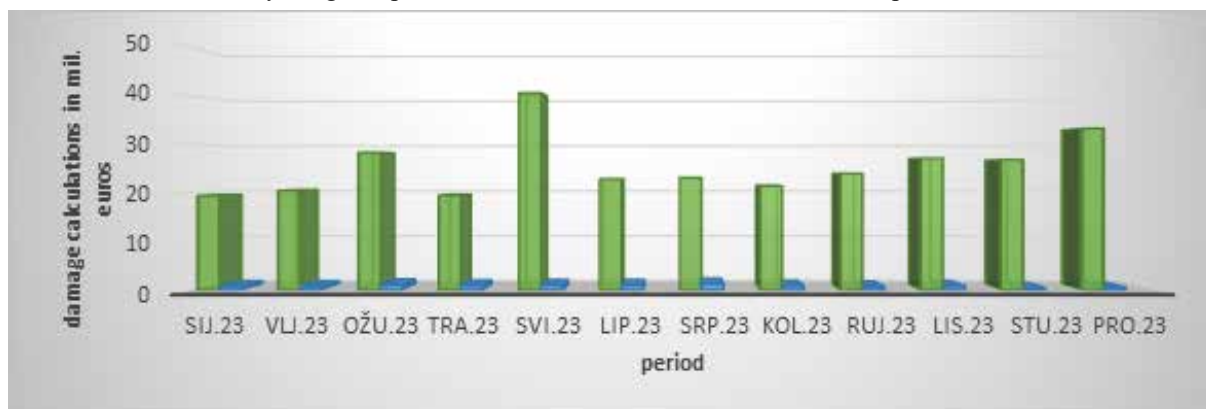


Figure 2 Display of the number of non-submitting taxpayers according to the criterion “Did not submit the VAT form by the given parameter ON THE DAY”. Source: ISPU on April 10, 2024



– *The VAT form has been submitted, but items II.1.- II.3. submitted with zero²*

When calculating damages for the criterion “The VAT form has been submitted, but items II.1.-II.3. submitted with zero” are taken into account all taxpayers who, on the day of the calculation of the damage, submitted a VAT return and on items II.1. to II.3. they reported zero, but in the same accounting period, another taxpayer declared the right to deduct input tax on the accounts of those taxpayers.

Table 3 shows the number of taxpayers who submitted their tax returns on the third working day after the deadline but with a zero amount on the specified items. The damage was calculated based on the data of the UR form of taxpayers who declared the right to advance tax on the accounts of those taxpayers because they were issued an invoice with the stated amount of calculated VAT.

Table 3 Display of the number of taxpayers and calculation of damages according to the criterion “VAT form submitted but items II.1. to II.3. submitted with zero” on a certain date

PERIOD	ON THE DAY	NUMBER OF TAXPAYERS	DAMAGE CALCULATIONS -mil. €
1/2023	23.02.2023	3034	5,22
2/2023	23.03.2023	2597	4,50
3/2023	25.04.2023	3022	5,64
4/2023	24.05.2023	2724	5,02
5/2023	26.06.2023	2688	6,12
6/2023	25.07.2023	3148	10,52
7/2023	24.08.2023	3044	8,80
8/2023	25.09.2023	2751	6,87
9/2023	25.10.2023	2997	6,74
10/2023	23.11.2023	3187	6,19
11/2023	27.12.2023	3419	7,19
12/2023	25.01.2024	3629	9,50

Source: ISPU on April 10, 2024

Table 4 shows the same data, but on the day after the deadline for the first and second calls.

² Under point II. the VAT form contains data on the total of taxable transactions (tax bases) and VAT amounts, Article 175 of the Ordinance on Value Added Tax, Official Gazette, number: 79/13, 85/13-correction, 160/13, 35/ 14, 157/14, 130/15, 1/17, 41/17, 128/17, 1/19, 1/20, 1/21, 73/21, 41/22, 133/22, 43/23, 1/24, 39/24).

Table 4 Display of the number of taxpayers and calculation of damages according to the criterion “VAT form submitted but items II.1. to II.3. submitted with zero” on a certain date

PERIOD	ON THE DAY	NUMBER OF TAXPAYERS	DAMAGE CALCULATIONS -mil. €
1/2023	31.03.2023	2730	3,65
2/2023	02.05.2023	2412	3,57
3/2023	31.05.2023	2620	4,43
4/2023	30.06.2023	2494	4,10
5/2023	31.07.2023	2307	4,95
6/2023	31.08.2023	2718	7,90
7/2023	02.10.2023	2621	5,99
8/2023	31.10.2023	2629	2,96
9/2023	30.11.2023	2697	5,12
10/2023	02.01.2024	2777	4,50
11/2023	31.01.2024	3099	4,74
12/2023	29.02.2024	3270	6,60

Source: ISPU on April 10, 2024

It is evident that taxpayers who submit a VAT form and report zero in the place of VAT liability, and customers who have declared their right to input tax, also cause great damage. After the implemented measures, the number of taxpayers does not drop as significantly as in the case of non-filers of tax returns. After implementing the measures, some taxpayers corrected their submitted forms, while some non-filers “hid” even after receiving invitations. This is also visible in Figures 3 and 4.

Figure 3 Display of the number of taxpayers and calculation of damages according to the criterion “VAT form submitted but items II.1. to II.3. submitted with zero” on a certain date. Source: ISPU on April 10, 2024

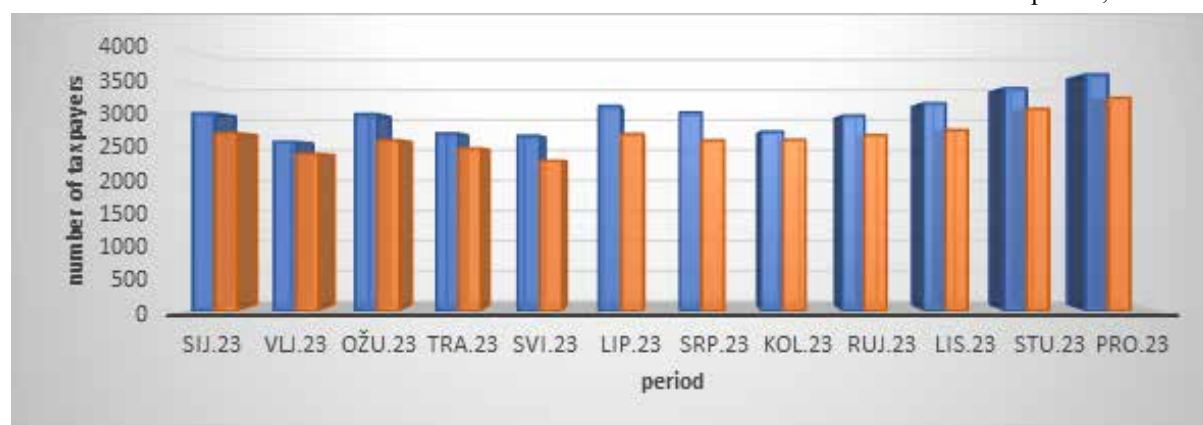
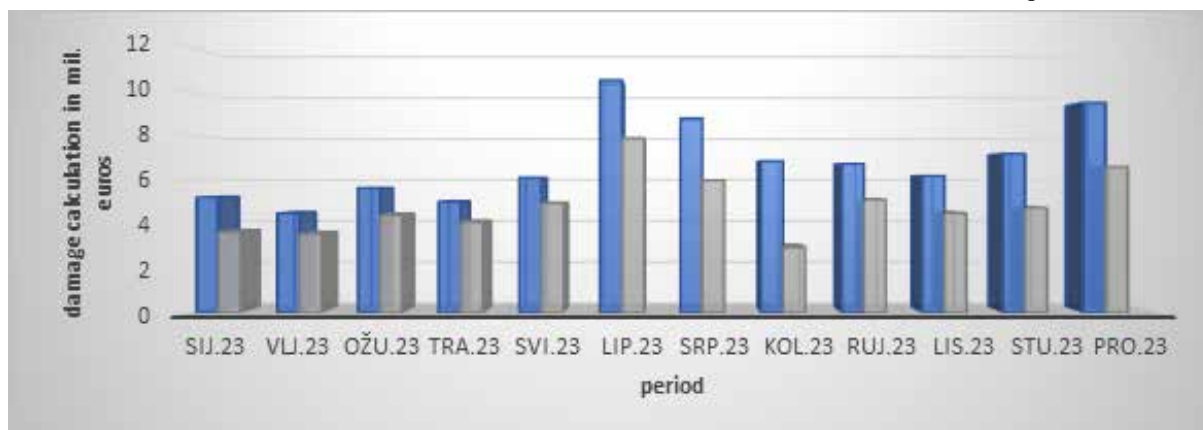


Figure 4 Display of the number of taxpayers and calculation of damages according to the criterion “VAT form submitted but items II.1. to II.3. submitted with zero” on a certain date. Source: ISPU on April 10, 2024



What has been stated as the goal for non-filers is equally valid for these taxpayers: the goal is to have as few such taxpayers as possible who cause damage to the state budget. To prevent tax fraud, it is essential to take additional measures. These may include canceling or suspending the VAT ID number, printing the list of registered VAT payers, implementing collection security measures, and conducting tax inspections or investigations.

6. Conclusion

Serious problems of all member states, including Croatia, are frauds, especially those related to the payment of VAT, which is why there is a need for tools that will enable the early detection of tax frauds and the companies that commit them. Tools based on quality IT solutions, and automation of business processes lead to more concrete results in combating tax fraud. However, companies and persons who commit tax fraud are constantly inventing new ways and methods to commit fraud and remain undetected, therefore, even tax authorities cannot stop at existing solutions but must improve and develop new ones, following market phenomena.

Along with utilizing advanced technologies, international cooperation, and information exchange, educating taxpayers about their obligations and the consequences of non-fulfillment and tax fraud is crucial.

The efforts to combat tax fraud are ongoing. With the development and utilization of new tools and solutions, it is now possible to detect tax fraud perpetrators earlier. This represents a significant improvement in terms of more efficient supervision and prevention of tax fraud.

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DOES PRICE EARNINGS RATIO REALLY MATTER?

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Abstract. Investors who are interested in investing in stocks have to take into account a large number of information in order find the stock that will bring largest return. Generally, each stock has profile available online. In these profiles information about past performance and financial ratios are reported. Among reported data there is always information about price earnings ratio, and this ratio is usually on the top of the list. In this paper we investigate if price earnings ratio is significantly connected with stock performance.

Key words: stock return, price earnings ratio, Zagreb Stock Exchange

1. Introduction

Price earnings ratio is one of the most common ratios reported on online platforms that deal with investment in stocks. This ratio also can be found in each annual report announced by the company by the end of April. By now it is clearly documented and reported through many studies that price of stocks and trading activity, especially in March and April, react to fundamental data and annual earnings releases. Prudent investor will not rely only on fundamental data and possibly not only on technical data, investment decision should be based on combination of these two. Price earnings ratio and its behaviour in previous periods gives some indication what could happen with stock price/return in future period. Price earnings ratio is calculated as stock price over reported earnings divided by the number of shares that have dividend rights. Simply, it says how much investor will pay for each euro of earnings that belongs to single share. High price earnings ratio says that investor pays high price for company that has low earnings per share. Investors unusually avoid investing in stocks with high price earnings ratios as they perceive these stocks as overvalued. Investors usually focus their interest on companies that have lower price earnings ratios. Authors that tested price earnings investment strategies in most cases report that portfolios composed of stocks with lower price earnings ratios yield larger returns. Stocks with small and negative price earnings ratios are usually on margins of interest and should be considered with great caution and knowledge.

In this paper we observe price earnings ratios for firms from Zagreb Stock Exchange (ZSE) and their relation with price, return, turnover and four financial ratios. The purpose of this paper is to determine whether price earnings ratio provides information about future stock performance. As Basu (1977) stated, results indicate that P/E ratio information was not fully reflected in security prices in rapid manner, there seem to be lags in adjustment process. Determination of that lag is also one of the research questions that will be addressed in this paper. In second section previous researches are presented, in section three data and methodology are given and in the section four research results are discussed. In last section, fifth part of the paper, conclusions are drawn and recommendations for further research are given.

2. Previous researches

Relation between stock prices and price earnings ratio was well investigated for developed markets while similar studies for small markets where there is no large number of quality stocks to be traded with are rather rare. Attention to relation between price earnings ratio and stock returns was heavily drawn by Basu. Basu (1977) investigated investment performance of common stocks in relation to their price-earnings ratios during period April 1957 – March 1971. Author concluded that low P/E portfolios seem to have on average, earned higher absolute and risk adjusted rates of return than the high P/E securities. Tilley (2015) extended analysis performed by Basu (1977) and tested the relationship of stock performance in relation to its PE ratio and concluded that investing using the PE ratio as a leading indicator produces excess unexplained returns for low and mid-priced stock.

Kelly et al. (2008) examined whether the investment performance of low P/E stocks is greater than the investment performance of other classes of P/E stock for Australian industrial firms. It was found that on average, the low P/E portfolios earned higher absolute and risk-adjusted rates of return than their higher P/E counterparts. It was found that stocks with negative earnings also performed quite well. Sun (2012) observed information Content of P/E Ratio and found that beginning PE ratios have no predictive power when looking at subsequent short-term one-year excess returns. Over short periods, excess returns appear to be unrelated to PE ratios. Over longer holding periods (three years or five years), there is a tendency for low PE groups to obtain higher excess returns. Sun (2012) also found a relative proof that the lower price-to-book ratio, the higher mean return premiums in long run. Persson and Ståhlberg (2007) examined PE and EV/EBITDA Investment Strategies on Swedish Stock market and showed that the P/E strategy was successful in outperforming the market represented by the AFGX (Affärsvärldens Generalindex, a broad index that measures the market average on the Stockholm Stock Exchange). Gunnlaugsson (2005) observed Icelandic Stock Market and found that the returns of stocks with a low P/E ratio are much higher than returns of other stocks, and that these returns are statistically significantly higher when differences in systematic risk are accounted for. The finding that stocks with low P/E and M/B ratios provide high returns on the Icelandic stock market is consistent with findings on other stock markets. Sezgin (2010) investigated relationship among P/E Ratio, stock return and dividend yields for Istanbul Stock Exchange. Results of cointegration test and error-correction models (ECM) showed that there is relationship among variables long-run and short-run. Stock return effects negatively on P/E Ratio in long-run and dividend yield ratio effects positively on P/E Ratio in long-run. Furthermore, it is understood that there are unidirectional Granger-causalities from dividend yield to P/E Ratio. Weigand and Irons (2007) analyzed periods characterized by high P/E ratios. High-P/E periods are preceded by accelerating equity returns and declines in both nominal interest rates and stock market volatility. High-P/E periods triggered by temporary earnings declines are followed by low positive stock returns, but returns are negative for at least a decade when earnings grow rapidly and the market P/E climbs above 20. Following both types of high-P/E events, however, real stock returns are appreciably lower than average for the subsequent decade. Maditiniset al. (2007) explored the value relevance of traditional accounting performance measures (EPS, ROI, ROE) in explaining stock return variations in the Greek stock market. Earnings per share outperform ROI and ROE. This is also expected since investors are more focused on the already known and used EPS and not in more complicated measure such as ROI and ROE. The obvious advantage of EPS compared to the other performance measures was clear. Aga and Kocaman (2006) investigated P/E ratios and stock price behaviour for Istanbul Stock Exchange and found that for each of the stock, price earnings ratio appears to be a significant explanatory variable for the stock returns. Aydoğan and Gürsoy (2000) investigated P/E and price-to-book

ratio as predictors of stock returns in emerging equity markets. Results indicate that both P/E and book-to-market ratios have low explanatory power in shorter return horizons and better predictive power of future return over longer time periods. Alajbeg et al. (2016) concluded that in Croatia the level of P/E has no bearing whatsoever on realized returns. Authors noticed that when excluding negative P/E stocks from the equally weighted CROBEX portfolio, returns drastically improved. Vidović (2022) estimated panel regression for stock prices and stock returns for liquid stocks from Croatian Stock Market. Three financial ratios: Debt to Equity Ratio (DER), Current Ratio (CR) and Turnover ratio (TATO), where not statistically significant in explaining stock returns, only two ratios were significant; Return on Assets (ROA) and Price Earnings Ratio (PER). The estimated sign for the ROA is positive indicating that increase in company's profit relative to assets results in higher stock return. The estimated sign for the PER is negative indicating that companies with higher stock price relative to its earnings have lower stock return.

3. Data and methodology

Data for this study were gathered from Zagreb Stock Exchange (ZSE) website. Research sample is composed of 10 most liquid stocks that are constituents of CROBEX 10 stock index. Past trading data for period starting from the beginning of the 2014 to the end of 2022 were drawn for each observed stock. For each stock yearly stock returns, standard deviations of stock returns, average prices and yearly turnover were calculated. Based on annual reports of observed stocks announced on the ZSE website, ratios for each stock were calculated; price earnings ratio (PE), return on assets (ROA), total assets turnover (TATO), current ratio (CR), debt to equity (DE). Observed stocks are: ADPL (AD PLASTIK), ADRS2 (ADRIS GRUPA), ARNT (ARENA HOSPITALITY GROUP), ATGR (ATLANTIC GRUPA), ATPL (ATLANTSKA PLOVIDBA), ERNT (ERICSSON NIKOLA TESLA), HT (HT), KOEI (KONCAR), PODR (PODRAVKA) and RIVP (VALAMAR RIVIERA).

Ratios based on fundamental data are calculated according to following expressions:

PE – price earnings ratio. Average yearly stock price over net income divided by number of ordinary shares that have dividend rights.

ROA – return on assets. Net profit divided by total assets.

RETURN – yearly return. Average of continuously compounded returns of single stock in one-year period.

STDEV – standard deviation of stock return in one-year period.

$$STDEV_i = \sqrt{\sum_{t=1}^N (R_t - \bar{R}_i)^2 / (N - 1)} \quad (1)$$

where R_t - is daily stock return of stock i in on year period $t \in [1, \dots, N]$ and \bar{R}_i is expected stock return of stock i .

TATO - total assets turnover. Operating revenues divided by total assets.

ANTURN – annual turnover. Total traded value of single stock in one-year period.

AVPRICE – average stock price in one-year period. Sum of continuously compounded stock returns in one year divided by number of trading days in that year.

CR – current ratio. Current assets divided by current liabilities.

DE – debt to equity. Total debt divided by equity.

Sample is organized as panel data set of ten stocks observed in nine-year period were all observed variables have one yearly observation. Before performing causality tests, correlation coefficients were estimated for observed variables and optimal lag was selected according to Schwarz lag selection criteria. Finally, Granger causality tests were performed in order to define whether observed variables cause PE, or PE causes some of these observed variables. In the case when PE causes one variable and that variable causes PE we can say that causality is bidirectional. In the case when observed variable does not cause PE and PE does not cause the same observed variable it can be said that there is no causality. Observations for those years where PE ratios are negative were excluded from the analysis. This approach is common when observing PE ratios, this is according to Alajbeg et al. (2016), Sezgin (2010) and Damodaran (2002).

4. Results

In following tables, results of correlation coefficients and results of Granger causality test are presented.

Table 1 Correlation coefficients between observed variables

	PE	ROA	RETURN	STDEV	TATO	ANTURN	AVPRICE	CR
PE	1,00							
ROA	-0,92*	1,00						
RETURN	-0,80*	0,62*	1,00					
STDEV	0,89*	-0,80*	-0,60*	1,00				
TATO	-0,17	0,40*	-0,39*	-0,38*	1,00			
ANTURN	0,63*	-0,29*	-0,73*	0,60*	0,41*			
AVPRICE	-0,19	0,40*	-0,27*	-0,35*	0,72*	0,38*	1,00	
CR	0,32*	-0,23**	-0,36*	0,14	0,06	0,36*	0,65*	1,00
DE	-0,27*	0,10	0,16	-0,18	-0,03	-0,52*	-0,54*	-0,84*

** significant under probability of 10%

*significant under probability of 5%.

Source: author's calculations.

Results from Table 1 indicate that price earnings ratio is significantly connected with majority of observed variables. Largest correlation coefficient is between PE and ROA (-0,92). This founding is expected since in calculation of both variables net profit is included. ROA is higher when net profit is higher while PE is smaller when net profit is higher, therefore negative correlation between PE and ROA is expected and finally proved as significant. PE and stock return are negatively and strongly correlated (-0,80), indicating that high values of price earnings ratio are connected with smaller returns. Price earnings ratio is not correlated with TATO and AVPRICE while these two AVPRICE and TATO are strongly positively correlated (0,72). Here question appears, if ROA is strongly and negatively correlated with PE and ROA is strongly and positively correlated with TATO and AVPRICE, why price earnings ratio is not significantly correlated with TATO and AVPRICE? It seems that AVPRICE reacts positively to operating income (TATO) and current ratio (CR) and negatively to debt to equity ratio (DE). Stock return is strongly negatively correlated to PE and, expectedly, strongly positively correlated with ROA, return is also strongly and negatively correlated with annual turnover (ANTURN) and strongly and negatively correlated to standard deviation of stock return (STDEV). Total annual trading activity (ANTURN) is significantly correlated with all observed variables where correlation coefficient between PE and ANTURN is largest (0,63) indicating that stocks with higher PE

ratio have larger annual turnover (ANTURN). This founding is extremely important since relation between turnover and PE ratio is not previously observed and clearly documented for Croatian Stock Market. All other correlation coefficients calculated for financial ratios report significant correlations according to theoretical expectations based on theoretical connection between them, for example CR and DE are negatively correlated (-0,84).

Table 3 Results of Lag Order Selection Criteria

VAR Lag Order Selection Criteria						
Included observations: 54						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	-758,91	NA	299,15	28,40	28,70	28,52
1	-577,80	301,84	4,01	24,07	26,72*	25,09*
2	-502,24	103,54	0,30	23,64	28,65	25,57
3	-413,73	95,07*	1,89*	22,73*	30,10	25,57

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

Source: author's calculations.

Before performing Granger causality test, lag selection criteria test was performed on overall sample. According to Schwarz criterion optimal lag is 1.

Table 3 Results of Granger causality tests

Pairwise Granger Causality Tests			
Lags: 1			
Null Hypothesis:	Obs	F-Statistic	Prob.
AVPRICE does not Granger Cause ANTURN	80	90,65	0,0000
ANTURN does not Granger Cause AVPRICE		0,17	0,8970
CR does not Granger Cause ANTURN	80	1,43	0,2351
ANTURN does not Granger Cause CR		5,08	0,0271
DE does not Granger Cause ANTURN	80	10,94	0,0014
ANTURN does not Granger Cause DE		8,24	0,0053
PE does not Granger Cause ANTURN	60	204,41	0,0000
ANTURN does not Granger Cause PE		46,07	0,0000
RETURN does not Granger Cause ANTURN	80	17,93	0,0001
ANTURN does not Granger Cause RETURN		0,08	0,7811
ROA does not Granger Cause ANTURN	80	268,98	0,0000
ANTURN does not Granger Cause ROA		0,68	0,4125
STDEV does not Granger Cause ANTURN	80	13,40	0,0005
ANTURN does not Granger Cause STDEV		1,25	0,2666
TATO does not Granger Cause ANTURN	80	120,26	0,0000
ANTURN does not Granger Cause TATO		1,93	0,1686
CR does not Granger Cause AVPRICE	80	7,18	0,0090
AVPRICE does not Granger Cause CR		0,72	0,3982

DE does not Granger Cause AVPRICE	80	11,06	0,0014
AVPRICE does not Granger Cause DE		1,65	0,2029
PE does not Granger Cause AVPRICE	60	3,92	0,0526
AVPRICE does not Granger Cause PE		8,65	0,0047
RETURN does not Granger Cause AVPRICE	80	16,04	0,0001
AVPRICE does not Granger Cause RETURN		56,42	0,0000
ROA does not Granger Cause AVPRICE	80	19,97	0,0000
AVPRICE does not Granger Cause ROA		14,72	0,0003
STDEV does not Granger Cause AVPRICE	80	10,93	0,0014
AVPRICE does not Granger Cause STDEV		7,43	0,0079
TATO does not Granger Cause AVPRICE	80	17,36	0,0001
AVPRICE does not Granger Cause TATO		1,14	0,2888
DE does not Granger Cause CR	80	181,30	0,0000
CR does not Granger Cause DE		10,69	0,0016
PE does not Granger Cause CR	60	13,03	0,0006
CR does not Granger Cause PE		0,00	0,9947
RETURN does not Granger Cause CR	80	3,00	0,0873
CR does not Granger Cause RETURN		151,71	0,0000
ROA does not Granger Cause CR	80	11,48	0,0011
CR does not Granger Cause ROA		40,43	0,0000
STDEV does not Granger Cause CR	80	40,35	0,0000
CR does not Granger Cause STDEV		16,93	0,0001
TATO does not Granger Cause CR	80	17,88	0,0001
CR does not Granger Cause TATO		8,28	0,0052
PE does not Granger Cause DE	60	12,60	0,2664
DE does not Granger Cause PE		3,78	0,0569
RETURN does not Granger Cause DE	80	7,52	0,0076
DE does not Granger Cause RETURN		49,63	0,0000
ROA does not Granger Cause DE	80	21,04	0,0000
DE does not Granger Cause ROA		17,79	0,0001
STDEV does not Granger Cause DE	80	7,12	0,0093
DE does not Granger Cause STDEV		8,90	0,0038
TATO does not Granger Cause DE	80	9,24	0,0032
DE does not Granger Cause TATO		1,86	0,1770
RETURN does not Granger Cause PE	60	13,38	0,0006
PE does not Granger Cause RETURN		30,28	0,0000
ROA does not Granger Cause PE	60	126,08	0,0000
PE does not Granger Cause ROA		55,95	0,0000
STDEV does not Granger Cause PE	60	1,75	0,1913
PE does not Granger Cause STDEV		10,99	0,0016
TATO does not Granger Cause PE	60	29,43	0,0000
PE does not Granger Cause TATO		13,16	0,0006
ROA does not Granger Cause RETURN	80	9,74	0,0025
RETURN does not Granger Cause ROA		3,84	0,0535
STDEV does not Granger Cause RETURN	80	3,17	0,0787
RETURN does not Granger Cause STDEV		4,41	0,0391

TATO does not Granger Cause RETURN	80	5,35	0,0234
RETURN does not Granger Cause TATO		2,20	0,1417
STDEV does not Granger Cause ROA	80	1,57	0,2146
ROA does not Granger Cause STDEV		0,02	0,8830
TATO does not Granger Cause ROA	80	0,05	0,8214
ROA does not Granger Cause TATO		5,68	0,0196
TATO does not Granger Cause STDEV	80	4,37	0,0399
STDEV does not Granger Cause TATO		2,08	0,1536

Source: author's calculations.

Results from Table 3 for variable PE (price earnings ratio) indicate that there is bidirectional causality between PE and ANTURN. AVPRICE Granger causes PE. It is important to notice that under one lag PE does not Granger cause AVPRICE. PE ratio Granger causes CR and STDEV. There is no causality found between DE and PE. There is bidirectional causality between PE and RETURN, PE and TATO and PE and ROA.

Average price Granger causes ANTURN and PE. TATO, CR and DE Granger cause AVPRICE. There is bidirectional causality between AVPRICE and RETURN, AVPRICE and ROA and AVPRICE and STDEV.

Return Granger causes ANTURN and STDEV. CR, ROA and TATO Granger cause RETURN. There is bilateral causality between RETURN and PE and RETURN and DE.

AVPRICE, RETURN, ROA, STDEV and TATO Granger cause ANTURN. There is bidirectional causality between ANTURN and PE and ANTURN and DE.

Previously through examination of correlation coefficients it was documented that ROA and PE have largest correlation coefficient while correlation between average price and PE is not significant. When observing only ROA it can be seen that ROA Granger causes ANTURN, TATO, AVPRICE, CR, DE, RETURN and PE. When observing causalities between ROA, PE and information from trading data (stock price, return, standard deviation and turnover), results of Granger causality test indicate that ROA causes AVPRICE, ANTURN and RETURN while PE causes STDEV, ANTURN and RETURN.

TATO Granger causes PE but it does not Granger cause ROA. In fact, ROA Granger causes TATO.

Results regarding annual turnover (ANTURN) are very interesting, annual trading value predicts only PE and DE and CR, while all observed variables Granger cause ANTURN within one lag; DE, PE, RETURN, AVPRICE, ROA, TATO, STDEV, except CR.

5. Conclusions

In this paper relations between fundamental ratios and stock return, stock price and annual turnover were observed for 10 stocks from ZSE. Firstly, correlation coefficients for observed variables were estimated and in the second part of the analysis Granger causality was tested for one lag.

Sample correlation coefficients gave indication about further possible relations that should be closer considered. For instance, correlation coefficient between ROA and PE is very large (-0,92), while correlation between PE and AVPRICE is not significant. Results indicate that ROA causes a great number of variables including PE, ANTURN, TATO, AVPRICE, CR, DE and RETURN. Average price Granger causes ANTURN, ROA and PE.

Price earnings ratio is not correlated to TATO and AVPRICE while these two AVPRICE and TATO are strongly positively correlated (0,72).

Annual turnover predicts only PE within one lag and it is in the same time highly correlated with PE (0,63). ANTURN is highly correlated to RETURN (-0,73) and it Granger causes RETURN within one lag.

Altogether it can be concluded that investor by observing PE does not have excess advantage compared to the situation when only ROA was observed. Compared to ROA, PE does not cause average stock price in the next year, it causes only annual turnover, standard deviation of stock return and return, while ROA Granger causes annual turnover, return and average price within one lag, but fails to Granger cause standard deviation of stock return within one lag. This is consistent with Aga and Kocaman (2006) and Sezgin (2010) who found that stock price earnings ratio appears to be a significant explanatory variable for the stock returns. These results are consistent with Maditinos et al. (2007) who confirmed advantage of EPS over ROI and ROE; and Vidović (2022) who concluded that PER and ROA were only significant variables in explaining stock return in panel regression. Another advantage of ROA is that it Granger causes TATO, this is especially important because correlation between TATO and PE is not significant. Annual turnover (ANTURN) annual turnover seems to be very sensitive to observed fundamental ratios and trading information within one lag. Debt to equity ratio, price earnings ratio, stock return, average stock price, return on assets, total assets turnover and standard deviation of stock return Granger cause annual turnover.

Major drawback of this paper is that due to sample size it was not possible to estimate causalities for lags larger than 1. These causalities for lags larger than 1 were documented in Aydoğan and Gürsoy (2000) and Sun (2012). Further researches should investigate causality between PE Ratio and stock returns for lags above 1.

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COOPERATIVISM AS A TOOL FOR RURAL TOURISM DEVELOPMENT. THE CASE OF THE AUTONOMOUS COMMUNITY OF VALENCIA

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Abstract. Rural tourism can be understood as a practice that promotes the economy and quality of life through the provision of accommodation and leisure activities, with the mediating presence of the inhabitants of rural areas, and which discloses visitors a living reality in all its natural and cultural wealth. This activity can be understood, as a way of activating social processes of activation of the economy, which in turn should improve the training of local people; in the context of the profound reconversion of concepts, structures and active activities that affect rural communities.

Related to the Social Economy Organizations in Spain and many European countries, it can be said that the relevance of this type of organizations lies not only in their size but also, in some qualitative factors like their capacity to innovate and adapt, their ability to meet the needs the rest of the economy and their contribution of building values; all of these factors contribute to support the economic cycles with an enviable stability.

In connection with the establishment of relations between rural tourism and cooperatives, we note the ability of the social economy organizations, including cooperatives, to correct social and economic imbalance and contribute to the achievement of multiple objectives of general interest. Furthermore, cooperatives in rural areas promote endogenous development, since they make possible to maintain wealth in their area of influence, through democratic processes with a fair redistribution of the wealth generated.

The tourist activity created and promoted by cooperatives involves economic diversification, and help to preserve, maintain, and improve cultural, natural, and social resources. Finally, from a social point of view this fact implies to develop and promote alliances and partnerships.

Considering the relationship between rural tourism and social economy organizations, including cooperatives, the main purpose of this paper is: i) analyze the role of rural tourism as a developing factor for different regions in Spain, ii) explain the main features of the social economy organizations as drivers of economic growth, iii) explore the role of cooperativism as a tool for development of rural tourism, iv) analyze the current situation of cooperativism in relation with the rural tourism in the Valencian Community and, v) propose improvements that should be made in order to foster economic development of rural communities.

Key words: *Cooperativism; Rural Tourism Development; Cooperation & Alliances; Regional Development; Valencian Community*

1. INTRODUCTION

The economic crisis that Spain suffered during the COVID-19 pandemic has been the trigger for many changes in society, in politics and in the Spanish economy. as in the rest of Europe and the rest of the world, the outbreak of the covid-19 pandemic and the subsequent containment aimed at halting the spread of the disease brought with it a series of negative consequences

for the economy: a sharp fall in GDP, gross fixed capital formation and consumption, a sharp increase in public spending and public debt and a sharp rise in unemployment. However, after the pandemic ended, the Spanish economy has embraced an extraordinary recovery; GDP growth has been one of the highest in the European Union and there was a innovation take off that has been accompanied by job creation (Secretaría de Estado de Presupuestos y Gastos, 2022).

The evolution of the Spanish economy has been marked during past years by the impact of the COVID-19 pandemic, the recovery of activity in the course of 2021, which is still in place since then, and Russia's war against Ukraine. Even in a particularly complex European and international context, in which the shock of the pandemic and the bottlenecks in global supply chains have been compounded by Russia's aggression against Ukraine and geopolitical tensions, the Spanish economy has maintained a pace of strong growth in the current year, highlighting the resilience of the foreign sector, whose weight in GDP has increased and now is at record highs.

The evolution of the Spanish economy over the last four years confirms a change of pattern in the new economic cycle. Compared with previous crises, the measures adopted since the beginning of the pandemic (financed by the Next Generation funds of the European Union) to protect the productive fabric, employment and household incomes this time provided a solid basis for the recovery of activity, employment and investment, initiating an expansionary cycle marked by fairer and more sustainable growth (Secretaría de Estado de Presupuestos y Gastos, 2022).

The key differentiating factors of the Spanish economic cycle are the performance of the labour market, the strong momentum of investment, the improvement in public finances and the excellent evolution of the external sector, including a strong recovery in tourism activity. Tourism (domestic and international) has recovered strongly, surpassing the record level of year 2019 and has almost reached the level recorded in the record year of 2019, allowing the financing capacity of the Spanish economy to be maintained despite the difficult international context.

Spain closed 2023 with record tourism figures, according to the *Instituto Nacional de Estadística* (National Statistics Institute - INE). A total of 85.1 million international travelers, 18,7% more than in 2022 and 1,9% more than in 2019, before the pandemic, visited the country between January and December. Additionally, to the growth in the number of tourists, spending per tourist grew even more exponentially during 2023; specifically, non-resident tourists in Spain spent 108,662 million euros in 2023 (Instituto Nacional de Estadística, 2024). Regarding the Valencian Community, tourism is undoubtedly a key pillar of the economy, with a contribution to GDP of 15.8% and a growth in employment of 4.4% in 2022, and with a forecast of 6.5% growth in sectoral GDP by 2023 (IMPACTUR, 2021).

The cooperative enterprise model emerged as a great alternative, with its working philosophy of solidarity, mutual aid and the supremacy of man. It was in 1844, when 27 men and 1 woman founded the first cooperative in the town of Rochdale, England.

The new Declaration of Cooperative Identity adopted by the Second General Assembly of the ICA (International Co-operative Alliance) , that was took place in the month of September 1995 in the city of Manchester, on the occasion of the celebration of the Centenary of the Alliance includes a new definition of cooperative and a review of the formulation of cooperative principles and values . The new formulation maintains the essence of a system of principles and values that proved to be efficient in more than 150 years of history and contributed to transform the cooperatives in one of the greatest social and economic forces worldwide, while incorporating new elements for better interpretation of the present historical moment.

Since its birth, the cooperative movement has continued to grow worldwide and today, members of cooperatives worldwide stand above 800 million.

In 1994, the United Nations Organisation estimates that the daily food intake of more than 3,000 million people (half of the world population) was secured or facilitated by cooperative enterprises.

In order to highlight cooperatives as companies that create jobs, we will enumerate some facts:

- Cooperatives employ more than 100 million people worldwide, representing 20%.
- Only in Europe, cooperative banks employ more than 700,000 people
- In Canada, cooperatives employ over 160,000 people.
- In Colombia, a health cooperative stands second national in the ranking of employment generation.
- In Slovakia, cooperatives employ more than 75,000 people.
- In France, 21,000 cooperatives employ over 700,000 people and in Kenya cooperatives employ over 250,000 people.

In Spain, the importance of Social Economy companies lies not only in size but also, in its qualitative factors. Its capacity to innovate and adapt, its ability to meet the needs the rest of the economy and its contribution of values; all of these factors contribute to support the economic cycles with an enviable stability (Monzón, 2010).

The generation of employment by the social economy in Spain and all European Union members, and especially the cooperatives, is one of the solutions which proposed by the European Commission and highlighted by its current president, Jose Manuel Durao Barroso who said: "Promote and support self-employment, social enterprises and companies of new creation. Job applicants who are motivated to create and run businesses may face significant obstacles, including lack of professional or business skills and mentoring opportunities and difficulties in obtaining financing. To facilitate self-employment and creating new jobs, are particularly important to promote the entrepreneur spirit and a wider availability of support services to the creation of enterprises and microfinance as well as conversion systems of unemployment benefits in grants for the creation of companies. Assistance should be directed to groups with higher potential (such as unemployed workers with professional skills, women or youth) and based on close cooperation between employment services, services and business support providers financing. The agents of the social economy and social enterprises are important engines of job creation and inclusive social innovation and require specific support, which can occur through public procurement and access to financing" .

The main purposing of this work is to carry out a thorough analysis of certain kinds of cooperatives like worker cooperatives, as key factors contributing to the development of tourism in Spain and particularly through fieldwork, and on the other hand to analyze their role in the Community of Valencia.

2. COOPERATIVISM AS A TOOL FOR DEVELOPMENT OF RURAL TOURISM

Rural tourism can be understood as a practice in the rural tourism that promotes the economy and quality of life through the provision of accommodation and leisure activities, with the mediating presence of the inhabitants of rural areas, and which discloses visitors a living reality in all its natural and cultural wealth (Gil, 1992).

Thus, rural tourism can be understood, as a way of activating social processes of activation of the economy, which in turn should improve the training of local people; in the context of the

profound reconversion of concepts, structures and active activities that affect rural communities. Rural tourism is a broad term, which includes many activities, stakeholders and interests; all are closely related to the new demands of tourist and recreational services that are developed in rural areas.

The Institute of Tourist Studies (Spain) defined this type of tourism as “Any type of tourism used in rural areas, with the following limitations: it is a tourism diffuse (scattered and not concentrated supply), that it respects the natural and cultural heritage, involving the active participation of local people in order to maintain the traditions of the medium, moving away from tourism monoculture .”

From that definition we may draw the following features that can help us to understand better what rural tourism is. (Fuentes, 2009): first, rural tourism is a type of tourism that takes place in rural areas. Second, tourism is innovative as it is a non-traditional activity that provides wealth and development opportunities to rural areas with wealth and development opportunities. Moreover, tourism is dispersed, with no major concentrations or infrastructure, which should be integrated into their environment without damaging it. As the third feature, we note that tourism enables communication between tourists and local people, so this plays an important role. In addition, rural tourism is a way of promotion and safeguarding of cultural values and traditions that are part of everyday life of the rural population, such as gastronomy, festivals, crafts, etc... This is a factor of interest for visitors.

Finally, it is worthwhile to remark that if the rural tourism facilitates communication and understanding between different peoples, the different cultures that make up the demand for this type of tourism should be analyzed, in order to know their motivations, their characteristics, their languages, etc., so that the supply satisfies the expectations of tourists and consequently, a demand continuity is encouraged.

In Spain, the current Constitution of 1978, in article 148, 1, 18th, allows regions to take responsibility for promotion and planning of tourism in their area. As a result of the regulation of rural tourism in our Constitution, there are a multitude of regulations affecting this sector; this involves many problems for the promotion, marketing and quality of this type of tourism.

Today, it cannot be said that different regulations of rural tourism in Spain actually offer a definition of what constitutes the concept of rural tourism. Their concern focuses on accommodation located in rural areas, which means establishing its definition and typologies, regulating its infrastructure and services, as well as establish performance requirements. The intervention of the competent administration results in the need to obtain an administrative authorization for the opening and operation of all institutions devoted to housing in rural areas (Gil-Albarelos 2007).

Rural tourism regulation in Valencia can be found nowadays in Law 15/2018, of June 7, on Tourism, Leisure and Hospitality of the Valencian Community; Executive Order 184/2014, of October 31, of tourist and accommodation rural in the interior of the Valencian Community and Executive Order 10/2021, of January 22, of tourist accommodation in the Valencian Community. The objectives of these regulations are, among others, to adapt the existing regulations to the current reality; define the short- and medium-term tourism planning; address complex issues such as the municipality tourism, governance and management skills, the role of brands, starting from the reality that the entire territory of the community forms a tourist destination; enlarge. The object of these laws goes beyond the traditional conception of tourist activity by making a inclusive text that also considers the social needs associated with tourism such as leisure and introduce the concept of hospitality as a necessary condition that establishes the relationship framework of visitors with the local population; give prominence to issues such as sustainability

or accessibility; introduce references to the code of ethics of the tourism and include the gender perspective through the development of equality plans in the companies and ending the wage gap.

In connection with the establishment of relations between rural tourism and cooperatives, we note the ability of the social economy (cooperatives are social economy companies) to correct social and economic imbalance and contribute to the achievement of multiple objectives of general interest. Among these objectives, the following are closely linked to some rural development (Chavez; Monzón, 2000):

1. Endogenous economic development, especially in the local area, and autonomy of the territories.
2. The social economy has revealed its ability to correct the deficit in the field of social welfare services; for instance in services to disadvantaged people.
3. The social economy has shown a great capacity to increase the level of social cohesion in the territory, to revitalize the social participation and democratic culture, so as to correct the imbalance in the capacity of negotiation and pressure from different interest groups in the process development and implementation of public policies, especially those articulated in the regional and local levels.
4. The social economy has the capacity to distribute and redistribute income and wealth more equitably than traditional capitalist enterprises do.
5. The social economy is capable of correcting various types of imbalance in the labour market. Indeed, it has helped to create new jobs; keep jobs in sectors in crisis, to increase the level of job security, to emerge occupations from the informal to the formal economy (handicrafts) and to extract new professions (jobs social care).

Cooperatives in rural areas promote endogenous development, since they make possible to maintain wealth in their area of influence, through democratic processes with a fair redistribution of the wealth generated. In addition, we must be aware that these entities are companies, by definition, socially responsible; from all the cooperatives existing in our country, agricultural cooperatives and worker cooperatives are companies which, at present, are contributing most to develop and promote rural tourism.

The tourist activity created and promoted by agriculture cooperatives involves economic diversification, and with it the realization of new activities in order to invent new strategies in marketing and advertising. The above implies that members of these cooperatives have to create an image, which gives rise to the consolidation of the long-term tourist activity. It can also help to preserve, maintain and improve territorial resources: cultural, natural and social ones. Finally, from a social point of view this fact implies to involve partners on a new activity.

One should wonder, how can agriculture cooperatives operate as facilitators in the diversification of rural areas. The answer is given in the following issues: agriculture cooperatives have to take advantage of their knowledge and expertise members. Additionally they should have strong initiative and showing willingness to change. Furthermore, the cooperative should be able to develop new learning tasks and new ways new ways of communicating its initiatives to society. We should not forget, finally the capacity for analysis and diagnostic capabilities (Cortés, 2009).

Current regulations concerning cooperatives allow the development of new activities in rural areas. For instance, Executive Order 2/2015, of May 15, which it approves the consolidated text of the Cooperative Law of the Valencian Community, in its article 87 clearly defines one of the objectives of agriculture cooperatives, “Provide partners with raw materials, means of production, products and other goods they need”. The consideration of this objective coincides with the development of the processes to create sections within agriculture cooperatives engaged in rural development and rural tourism.

Agriculture cooperatives can play a key role in the development of tourist activities in rural areas. Cooperatives are legal ways that brings together the joint efforts between farmers; in the context of economic globalization cooperatives are very important because its flexibilization, economic diversification and production, can generate competitive advantage and strategic positioning. The development of tourism in rural areas by improving agricultural resources can benefit not only members of the cooperative, but also farmers and local people (Cortés, 2008).

Regarding the worker cooperatives, there are companies whose members have the condition of workers and owners. This means that the relationship of these people with the co-workers acquires a new dimension, different from the other cooperatives. That is, not only members' economic progress is conditioned by the progress of the cooperative, but also members spend most of their time directly linked to the business that has developed and made dependent on the future of their own acting. In this situation member suffers a kind of "corporate schizophrenia" because they are both employers and employees.

What are we, employers? Does it depend on our future work on the viability of the cooperative or the cooperative's viability depends on how we do our work? How does this duality, as natural to us, in a society and a market in which labour relations are designed only enrolled in the traditional? (Alba, 2006). Their contribution to rural tourism development, especially in Valencia, will be referred in to the following section of this paper.

To conclude this section, we will discuss, even briefly the present role of public policies in rural cooperatives. In Spain, Social Economy regulations establish a starting point for policies to promote cooperatives and social economy in Spain and in Europe in two key areas: first, the recognition of this sector as a social partner in the process of elaboration of public policies; and secondly, the conception of a whole battery of policies to promote social economy. Concerning the latter, this legislations provides four groups of policies (Chaves, 2011):

- Institutional measures aimed at eliminating legal obstacles to the development of social economy. In particular, this measures implies the simplification of administrative procedures for the creation of social economy entities; the revision of current regulations to remove restrictions on the entities of the social economy so that they can act in any type economy activity and the revision of labour regulations in order to implement subsidies for the cooperatives.
- Measures aimed at disseminating, training, researching and innovating in this field, such as, promoting the principles and values of the social economy; introducing references to the social economy in course curricula at different educational levels; and facilitating access to the processes of technological innovation and organizational entrepreneurs in social enterprise.
- Measures aimed at establishing a public agency for the promotion of social economy. As a part of the Ministry of Labour, there is an organ of social participation and dialogue on social economy; the Council for the Promotion of Social Economy, which are represented state governments, regional and municipal unions, organizations whose are representing social economy.
- Institutional measures of explicit inclusion of the social economy in various sectorial policies, in particular, active labour market policies, especially for those sectors most affected by unemployment (women, youth and long- term unemployment) in rural development policies; social services for people who are in a situation of dependency and social integration, as well as the integration of the social economy companies in the strategies for improving productivity and competitiveness.

In rural areas and as an aid to cooperatives, it is very important to implement each and every one of the measures described, although it is especially important for cooperative the supervision in implementing the measures on institutional measures. However, due to the situation of severe economic crisis in our country, we are aware that the effective implementation of these policies is in fact impossible.

3. THE CURRENT SITUATION OF COOPERATIVISM IN RELATION WITH THE RURAL TOURISM OF THE AUTONOMUS COMMUNITY OF VALENCIA

In order to analyze the current situation, we made a series of in depth interviews to representatives of rural cooperatives with tourism initiatives; seeking the highest-rank representatives wherever as possible. We interviewed representatives of agriculture cooperatives in rural tourism initiatives.

Also, we interviewed experts in cooperatives and rural tourism in the Comunitat of Valencia: Dr Javier Solsona is a specialist in rural tourism in Valencia and technician in tourism in the Research Department of Valencia Tourism Agency ; John Joseph Damiá, is the director of the Foundation INTERCOOP, a non-profit cooperative group.

The objectives of the interviews were to learn the situation of the sector, its problems and expectations. In particular:

- The importance of public sector cooperatives in rural tourism development
- The impact of public support in the development of rural tourism initiatives by the cooperative.
- If tourism is a main or supplementary activity for cooperatives and their members.
- The services provided by the cooperative in relation to rural tourism.
- If criteria of sustainability have been considered in rural tourism initiatives.
- The role of women in these initiatives.
- Problems detected and future proposals.

In all the cases studied, the public sector participation has been a key factor in the development of rural tourism through municipalities, associations of municipalities or provincial councils themselves. This fact has made it easier for agriculture cooperatives to begin with rural tourism projects.

This is caused by considering tourism as a way to diversify and complement activity income, agricultural or otherwise, of the inhabitants of the area and therefore, comply with a twofold purpose: to stop the depopulation of rural areas and increase the income of their inhabitants.

The first initiatives were generate offer and involved the rehabilitation of homes and farms to be dedicated primarily to renting a full house for days, without any other additional service. We note that the existence of such aid, in many cases not related to a master plan for development of the area, has caused an excess of supply.

The travel services offered by the members of cooperatives interviewed were focused on accommodation, offering some activities such as visits to wine cellars, hiking, etc. In all cases, the cooperative provides marketing (reservations center, web...) and some specific training in tourism. Both women and men perform these activities, which help to solve the female depopulation; this fact is great concern to the women in rural areas.

Also, all interviewees considered that public support has had a strong impact on tourism development which have allowed the generation of basic tourism infrastructure with the rehabilitation or construction of tourist accommodation, cultural heritage and natural resources:

signaling of roads, rehabilitation of buildings, etc. Public support has decreased to almost disappear and makes it difficult for some of these initiatives to grow nowadays.

The rural tourism projects initiated by the cooperatives, with or without public aid, are based on criteria of environmental sustainability, asset recovery and the physical environment. They also help with preservation of local traditions and customs.

All the interviewed highlight the importance of governance in tourism and the difficulties in generating public-private spaces for better coordination of different stakeholders: tourism is composed mostly of small businesses, and therefore the experts consider cooperative as a way to grow together. The creation of opportunities for public-private cooperation is an opportunity for growth and consolidation of rural tourism.

Quite a few cooperatives consider tourism as their main source of income; sometimes incomes, which are obtained by cooperative, are a supplementary activity, more or less important depending on the case. Agriculture cooperatives emphasize the importance of tourism as a way of advertising to sell their products; egg, wine linked to wine tourism.

Regarding the problems of the cooperatives analyzed, Solsona and Damiá highlighted the following: the sharp reduction in demand due to the crisis; excess supply and low occupancy; strong seasonality; lack of adaptation to changes; and public aid reduction. All the experts interviewed considered the lack of training in terms of product structure and marketing which make it difficult to overcome the above problems.

Future perspectives at the moment are not very optimistic, although the introduction of more professional management models, stimulating quality facilities and expansion of additional supply are seen as key factors for success.

4. PROPOSALS AND CONCLUSIONS

Resulting from our research work in the situation of cooperatives in the tourism sector of our country, especially in Valencia, we present the following conclusions as well as proposals for the future.

Referring to the regulatory framework, it is necessary to regulate homogeneously rural tourism in each region of Spain. It is also clear needed to coordinate the different regional policies to establish a quality tourism offer. The establishment of a single rural tourism concept applicable to all regional laws should be added.

The role of public administration has been very significant in promoting cooperative movement but it is necessary to strengthen the dialogue between representatives of the cooperative world and the political authorities in order to receive higher subsidies. Public intervention in support of cooperatives was based basically on the need for the correction of market and institutional failures. In the same line, it would be very convenient the participation of cooperatives in advisory councils: the Economic and Social Council (State organ) and the organ with the same name of the Community of Valencia (Chavez, 2012).

It is also important to enable local people to participate in making decisions; associations of rural tourism should be promoted because they can make possible that the inhabitants of rural areas have voice and vote in the tourism activity; an activity from which they obtain their main source of income.

In addition, formation of the partners of a cooperative should also increase so that its members and employees can acquire more professional skills. To do this, the role of training to members of the cooperative as a strategic value should be reconsider. Training is the basis for work and has to be innovative in the tourism sector.

Finally, we propose to promote local community participation, especially cooperatives, in the process of planning and management of rural tourism; designing communication activities designed to explain the importance of rural tourism to the resident population and their implication in rural development.

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ALLOCATION OF FUNDS FOR THE DIGITALIZATION OF ROMANIAN UNIVERSITIES THROUGH THE EUROPEAN COMMISSION'S RECOVERY AND RESILIENCE FACILITY

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Abstract: The Recovery and Resilience Facility (RRF) administered by the European Commission is the important part of a temporary financial instrument - NextGenerationEU. Through this mechanism, the European Commission raises funds by borrowing from capital markets, i.e., issuing bonds on behalf of the European Union. Out of the €750 billion for NextGenerationEU, €672.5 billion have been allocated to the Recovery and Resilience Facility to finance the Recovery and Resilience Plans developed by the member states of the European Union. Thus, Romania has also developed its own Recovery and Resilience Plan establishing its priority areas of investment, approved by the Council of the European Union in October 2021. This paper refers to the allocation of funds through the National Recovery and Resilience Plan for Component C15: Education, Investment 16: Digitalization of universities, and their preparation for the digital professions of the future. For the digitalization of state and private universities in Romania and their preparation for the digital professions of the future, a competitive call for projects was launched in 2022, with a financial allocation of 234 million euros excluding VAT (VAT is covered by the national state budget). With a limit of 3.9 million euros per university, each university in Romania had the opportunity to participate in the competition for the acquisition of digital infrastructure and the development of advanced digital skills for members of the academic community.

Keywords: *funds, digitalization, National Recovery and Resilience Plan, digital infrastructure, digital skills*

1. Introduction

Starting from February 19, 2021, the Recovery and Resilience Facility (RRF), managed by the European Commission, became operational. It provides funding for reforms and investments in the EU member states to strengthen sustainability, resilience, and adaptation to the green and digital transition, and to propose tangible solutions to identified challenges. The RRF is also crucial for the implementation of the REPowerEU Plan, launched in May 2022, which aims to reduce dependence on fossil fuels from Russia and accelerate the transition to clean energy sources. This mechanism contributes to mitigating the economic and social impact of the COVID-19 pandemic and aims to strengthen the sustainability and resilience of European economies and societies, while better preparing them for the challenges and opportunities associated with the transition to the green and digital economy. The RRF will facilitate the

achievement of the EU's objective to achieve climate neutrality by 2050 and promote progress in the digital transition, while simultaneously generating new jobs and stimulating economic growth.

Funding through the RRF is available for measures that adhere to the principle of “do no significant harm” (DNSH), meaning they do not significantly harm the environment and do not involve recurrent expenses in the following policy areas: transition to a green economy; adaptation to digital transformation; promotion of smart, sustainable, and inclusive growth; strengthening social and territorial cohesion; improvement of healthcare systems and enhancement of economic, social, and institutional resilience; implementation of policies for the next generation, such as education and skills development.

The RRF represents a direct form of financial support, linked to achieving results measured by reporting against the objectives and indicators established in the national recovery and resilience plans of EU member states. For this reason, reforms financed through this mechanism require careful monitoring. The RRF focuses on performance. In other words, the European Commission disburses the allocated funds to each country only when it successfully achieves the objectives and targets agreed upon for completing the reforms and investments outlined in its national recovery and resilience plan.

The implementation process of the RRF involves the following steps: after governments achieve the established objectives and targets, they request payment (up to twice a year). The European Commission evaluates these payment requests to verify if the objectives and targets have been met. If so, the Commission disburses the funds collected from capital markets.

In this context, EU member states have developed national recovery and resilience plans, in which they have set their agenda for reforms and investments in a comprehensive and consistent set of measures, in line with:

National challenges and priorities identified within the European Semester. The European Semester is a component of the economic governance framework of the European Union. During this period, member states adjust their budgetary and economic policies in line with the norms established at the EU level. Although initially primarily an economic exercise, the European Semester has evolved to integrate other relevant policy areas. This process of coordinating socio-economic policies takes place annually, from November to July;

- National reform programs;
- National plans regarding energy and climate;
- Territorial plans for a fair transition;
- Plans for implementing the youth guarantee.

These plans allocate at least 37% of the budget to climate measures and 20% to digital measures.

2. Romania's National Recovery and Resilience Plan

Romania's National Recovery and Resilience Plan (PNRR) has been developed by Romanian authorities in collaboration with experts from various fields. It represents a critical opportunity for modernizing the country in the digital and ecological era. Its aim is to align EU priorities with Romania's specific needs, particularly in the context of recovery following the COVID-19 crisis. The Romania's PNRR encompasses a package of reforms and public investments to be implemented by 2026. The total budget allocated for Romania is €29.2 billion, consisting of €14.24 billion in grants and €14.94 billion in loans within the RRF. Its objective is to contribute to the economic, social, and environmental development of the country through major reforms and key investments in various sectors, including water management, energy, sustainable

transport, digital transformation, healthcare, education, and more. The implementation of the PNRR is crucial for enhancing Romania's sustainable growth and resilience in the face of future challenges.

General objective of the Romania's PNRR, correlated with the general objective of the RRF, is: "the development of Romania through the implementation of essential programs and projects that support resilience, preparedness for crisis situations, adaptability, and growth potential, through major reforms and key investments funded by the Recovery and Resilience Mechanism". [1]

The specific objective of the Romania's PNRR is "to attract the funds made available by the European Union through NextGenerationEU in order to achieve milestones and targets in terms of reforms and investments". [1]

The principles underlying the implementation of the PNRR in Romania are: equitable geographical distribution of funds; decentralization; addressing subsidiary issues within communities; involvement of local authorities.

Romania's PNRR is designed around 15 components that integrate the six pillars provided for in Regulation (EU) 2021/241 of the European Parliament and of the Council, dated February 12, 2021 [2], namely:

- Pillar 1, Green transition with 6 components:
 - ✓ C1. Water management;
 - ✓ C2. Forests and biodiversity protection;
 - ✓ C3. Waste management;
 - ✓ C4. Sustainable transport;
 - ✓ C5. Renovation wave;
 - ✓ C6. Energy.
- Pillar 2, Digital transformation with a single component with the same name (C7)
- Pillar 3, Smart, sustainable and inclusive growth with 2 components:
 - ✓ C8. Tax reform and pension system reform;
 - ✓ C9. Support for the private sector, research, development, and innovation.
- Pillar 4, Social and territorial cohesion with 2 components:
 - ✓ C10. Local Fund;
 - ✓ C11. Tourism and Culture.
- Pillar 5, Health, and economic, social and institutional resilience with 3 components:
 - ✓ C12. Health;
 - ✓ C13. Social reforms;
 - ✓ C14. Good governance.
- Pillar 6, Policies for the new generation with a single crucial component: C15. Education

3. Pillar 6: New Generation Policies, Component C15 - Education from Romania's PNRR

The challenges Romania has faced over the past 30 years regarding the education system are related to the high level of inequality between educational institutions in rural and urban areas, especially in terms of infrastructure and educational offerings. Additionally, Romania's education system still faces issues related to early school dropout rates (15.3% in 2019) and

low access to tertiary education (25.8% in 2019). PISA tests (which measure the mathematical, text comprehension, and scientific competencies of 15-year-olds students) consistently rank Romania at the bottom among European Union countries [1, p. 30] which can lead to serious long-term economic and social problems.

In these conditions, the specialists who developed Romania's PNRR proposed 7 reforms and 18 investments to address the challenges in the Education sector, with a budget of 3,605.97 million euros excluding VAT.

Following the implementation of the investments, the expected results are:

- establishment of 110 nurseries;
- training of 420 curriculum and early education service monitoring trainers;
- training of 19,950 individuals (teaching and non-teaching staff) working in standard and complementary early education services;
- digitalization of 2,500 schools and increasing by over 60% the enrolment in the full route of dual education;
- modernization, renovation, and extension of school laboratories, workshops, IT laboratories, canteens, accommodation spaces, procurement of biological materials, agricultural equipment, and machinery for agricultural work, training of teaching staff in 57 agricultural schools;
- equipping 909 technical profile schools with digital infrastructure and modernizing workshops for student practice;
- training at least 100,000 teaching and educational support staff in digital education;
- providing IT equipment to at least 5,200 educational units;
- providing technological infrastructure to at least 3,600 schools;
- acquisition of at least 1,100 Smart laboratories;
- establishment of 60 innovative technological centres in universities;
- construction of 9,620 places in university campuses and modernization/expansion of 30000 existing places;
- equipping 10,000 science laboratories;
- creation of 3 rural school consortia;
- management skills training for 10,000 inspectors, directors, and school managers.

4. Funding for the Digitalization of Universities in Romania

The COVID-19 pandemic has brought to light the limited level of digitization in education in Romania. Many problems have been identified, especially in rural areas, related to the lack of internet signal, insufficient equipment, inadequate skills in using IT equipment, asynchronous course delivery, and the absence of a unified platform used at the institutional level.

Regarding higher education in Romania, there is a need to change the approach to teaching, actively involve students in this process, intensify the use of IT technology and open-access resources, and invest in state-of-the-art IT equipment to facilitate learning.

Thus, in June 2022, the Ministry of Education launched a competitive call for projects through the PNRR, Component 15 Education, Reform 5 Adapting the legislative framework for the digitalization of education, Investment 16 Digitalization of universities and their preparation for future digital professions. The total budget was 234 million Euros excluding VAT, both for state and private universities, with a limit of 3.9 million Euros per university.

In Romania, higher education is structured into universities, academies of studies, institutes and schools of higher studies.

In the academic year 2022/2023, the national higher education system comprised 489 faculties. State education represented 61% of the total number of higher education institutions and nearly 76% of the total number of faculties. [3]

Currently, there are 46 public civilian higher education institutions, 7 public military higher education institutions, and 34 private higher education institutions, so, a total of 87 higher education institutions are operating.

Within the competitive call for projects, during the period of June 9th to June 17th, 2022, 63 funding applications were submitted (49 applications from state higher education institutions and 14 from private higher education institutions), and 61 of these were approved for funding (49 applications from state higher education institutions and 12 from private higher education institutions). (Table 1)

Table 1 Higher education institutions receiving funding for digitalization

Type of higher education institution	Number of institutions
Public military higher education institutions	5
Public civilian higher education institutions	44
Private higher education institutions	12
Total	61

Source: Data processed and analyzed by the authors from
https://edu.ro/digitalizare_universitati_PNRR

Thus, within Investment 16. Digitalization of universities and preparing them for future digital professions, 61 funding contracts were signed with both public and private higher education institutions, totalling 210 million euros excluding VAT. (Table 2).

Table 2 Allocation of funds by type of higher education institutions

Type of higher education institution	The value of allocated funds
State higher education institutions	184 milion Euro (88%)
Private higher education institutions	26 milion Euro (22%)
Total	210 milion Euro

Source: Data processed and analyzed by the authors
https://edu.ro/digitalizare_universitati_PNRR

By implementing the projects, Romanian universities have the opportunity to invest in digital infrastructure (equipment for laboratories, computing centres, innovation hubs, digital libraries), platforms, software, computer applications, subscriptions for accessing digital libraries, digitization of processes, training programs in digital skills (both for students and teaching and administrative staff), development of entrepreneurial skills for emerging professions in the digital sector, etc.

With immediate impact on higher education in Romania, investments funded from the National Recovery and Resilience Plan contribute to better alignment with labour market demands, as well as to the development of advanced digital skills among students and teaching staff.

5. Conclusions

The digitalization of universities in Romania is an ongoing process, with significant efforts being made to adapt the academic environment to the requirements and opportunities presented

by the digital era. Romanian universities, through projects implemented with non-reimbursable funds, are investing in digital infrastructure, including equipment for laboratories, computing centres, digital libraries, and other technological facilities to support learning and research processes. The implementation of digital platforms and systems is increasingly common in universities for managing academic information, communicating with students and faculty, as well as providing online courses and educational materials. Universities are investing in the development and use of software and educational applications to improve the learning process and provide additional resources to students. Additionally, universities offer training and certification programs in digital skills for students, faculty, and administrative staff to improve digital literacy levels and adapt to technological changes. Romanian universities are partnering with industry and other organizations to develop joint research projects and provide internships and employment opportunities for students in the digital field. In addition to academic aspects, universities are increasingly digitizing administrative processes such as student registration, financial management, and data reporting.

The digitalization of universities in Romania faces some challenges, such as accessibility to technology and resources, data security, and resistance to change, but also offers significant opportunities for improving the quality of education and the student experience. The digitalization of universities in Romania is a complex and dynamic process aimed at adapting to the challenges and opportunities brought by digital transformation and improving the quality of higher education in the country.

The allocation of funds for the digitalization of universities and preparing students for digital professions has a significant impact on the academic environment and the professional future of young people. This financial allocation represents an important step in modernizing the educational system and preparing the new generation of professionals for the digital challenges of the future.

In conclusions, the proposed interventions through this call will address two interrelated aspects of digital education: first, the use of a wide and growing range of digital technologies (such as applications, platforms, software) to enhance and expand education and training, and the need to ensure relevant competencies (knowledge, skills, and attitudes) for an increasingly technology-influenced world.

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CONSUMER SATISFACTION, CASE OF SPLIT AIRPORT

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Abstract. The purpose of this study was to determine the passengers satisfaction rates at the Split Airport. Based on an analysis of 389 passengers who rated the Split Airport via a survey a standard logit model was used to determine the overall satisfaction rates with the Split Airport. Results show that failures associated with airport staff and queueing times as well as poor shop selection are most likely to reduce the probability of a passenger having a good impression of an airport thus making the satisfaction rates lower. This leads us to a conclusion that if any aspect of the airport value chain fails the overall passenger satisfaction rates will drop as well. That is why it is crucial to always improve and follow the global trends when it comes to airport hospitality.

Key words: *airport; survey; passenger satisfaction; consumer behaviour*

1. Introduction

Air traffic is considered one of the most used forms of transportation nowadays and it is expected that by 2035, the number of passengers in aviation will have reached a number greater than 7.2 billion on a global level (IATA, 2016).

Airports provide access to various touristic locations worldwide and as such represent a very delicate segment within the tourism sector. It is regarded as the representation of local tourism promotion. Henceforth, it is crucial to have regular upkeep and annual upgrading in order to obtain the desired image (Mwageni and Uiso, 2024).

In order to accommodate increasing passenger demands as well as satisfaction rates airports are forced to up their competitiveness. According to Gilbert and Wong (2003), delivering quality service in accordance with the customer's expectations and understanding of the service itself is the key to survival and success. Several critical elements on the passenger satisfaction rates have been noted in prior studies and as such have been divided into few categories: flying schedules, information availability, effective security procedures as well as check-in procedures, concise signage and facilities such as restrooms and food and beverages section (Fodness and Murray, 2007).

In this paper passenger satisfaction rates with the Split Airport, Croatia have been assessed in order to explain the subtle factors that lead to traveler's satisfaction/dissatisfaction with the airport in question. The main aim is to enhance every aspect of the passenger's experience which will consequently promote permanent passenger loyalty. It is the job of the airport management

team as well as the service providers to have an extensive knowledge of all of the aspects that affect traveler's satisfaction rates at the Split Airport.

To sum it up, this study is based on researching the complexity of consumer satisfaction rates on the model of the Split Airport, with the main goal being uncovering the underlying determinants, challenges and opportunities that shape each individual passenger's experience at a certain airport.

2. Consumer behaviour

A consumer is defined as a person who buys or consumes certain products or services created by a certain economic system on a certain market (Kotler, 2002). Consumer behavior is a discipline that studies the topic of consumerism and purchasing decisions. Although a relatively young discipline it has been widely studied since the end of the sixties of the last century. The very understanding of the discipline creates a new perspective on what really affects the behavior of an individual in a certain consumer environment. Accordingly, consumer behavior is defined as a specific process of obtaining and consuming products, services and ideas from a consumer unit (Kesić, 2006). Its main components include post-sale processes that combine evaluation of the behavior during the process consumerism as well as the post-sale behavior. There are three basic phases that form an entire behavior cycle, i.e. the purchasing phase, the consumption phase and the disposal phase (Kotler, 2002).

The purchasing phase contains key elements and knowledge necessary in order to understand the consumer in question. Factors influencing the choosing of a certain products or a certain services are of the most importance.

The consumption phase studies in which way a certain product or service is being used as well as the experiences acquired during the process. Experiences obtained by consumers using a certain product or service are used as representative factor that can be helpful during the prediction of future consumer behaviors. The consumption phase attracts an increasing the interest of scientists because it is in this particular phase that today's components of marketing success are generated some of them being for example: consumer satisfaction, the concept of values and benefits, the creation of trust and commitment, the creation of loyal consumers and the realization of long-term relationships. The disposal phase has become an essential part of the sustainability strategy as it looks on the consumer's decision making process regarding the product usage and/or the deposition of the remaining parts of the product (Babić-Hodović et al., 2012).

The basic factors that influence the consumer's behavior are: social, personal and cultural factors as well as psychological processes. Understanding the factors mentioned above provides us with the opportunity to investigate how a certain consumer behaves in a certain environment taking the factors that were discloses prior into consideration. Today's passengers as well as their behavior are greatly influenced by numerous external factors such as: social groups and social trends. Consumer behavior research can for that be viewed through the lens of meeting one's needs and desires but it should be noted that one's needs and desires are consequently influenced by personal preferences, economical possibilities as well as the social position of the individual in question. Aspects such as perceptions, attitudes, beliefs and consumption habits are all part of the broader picture when it comes to consumer behavior. Companies as well as marketers use consumer behavior research to design products, determine prices, create marketing campaigns and improve customer loyalty and contentment. Meeting the demands of consumers nowadays is one of the main issues that business companies are faced with. That is why it is important for the companies to be aware of the upcoming trends that may shift the

consumer behavior patterns. Also it is of vital importance to monitor the emerging changes in order to respond to the needs and expectations of consumers in question. According to Oszut and Stecko (2020.) the behavior of modern consumers is much more complex than the behavior of the traditional consumers.

2.1. Passenger satisfaction rates

A passenger's satisfaction is defined as an assessment of the perceived difference between previous expectations and actual product performance (Tse and Wilton, 1988). In order to achieve competitive advantage a product that has been developed should have a distinct differentiation compared to similar products on the market and a strong relationship with the consumers is strongly advised. According to Oliver passenger satisfaction with a product or a service is defined as a psychological state in which the emotions surrounding a certain expectation are directly correlated with the consumer's previous feelings about the experience itself. Passenger satisfaction rates are one of the main tools in achieving a competitive advantage by continuously improving the quality of the services provided at the airport. The growth, if it is to be sustainable, has to meet both short term as well as long term objectives. In today's day and age consumer expectations are ever changing and as such are highly affected by rapidly growing trends. In order to remain competitive in the market it is essential, nowadays more than ever, to provide superior service (Bakir, 2023).

According to Kesić (2006) passenger satisfaction rates can be expressed through approximated satisfaction levels which can then be grouped into following types:

1. Positive indication (service exceeds expectations)
2. A straightforward affirmation (service meets expectations)
3. Negative confirmation (service is below the expected marks)

It should also be noted that the consumer satisfaction rates are a valuable tool to measure the revenue values and as such can be a reliable indicator of the future success and performance of a certain organization.

2.2. Passenger satisfaction rates -public transportation

Satisfaction in public transportation has been influenced by numerous factors such as social, cultural, economical etc. Dissatisfaction results in passengers opting for individual mode of transportation thus affecting the local economy and environment (Khademi-Vidra, Nemecz and Bakos, 2024). According to Budiono (2009) a good quality service or passenger satisfaction rates can be measured through five independent parameters: tangibles which include staff appearance, infrastructures and equipment; reliability, which is the ability to perform the promised service accurately and continuously; responsiveness, which is the desire to support customers while offering prompt service; assurance, which is the expertise and demeanor of employees and their capacity to generate confidence and trust); and empathy that represents affection or the personalized attention a certain company provides to its customers. Providing customers with a service that is safe, effective, rapid, and comfortable should be the primary goal of public transportation providers. In addition to being crucial for population's mobility, public transportation can also be effective in reducing the vast majority of transportation-related externalities, including traffic jams and accidents.

2.3. Airport service quality

Airport service quality (SQ) rose beyond the simple efficiency indicators and nowadays it includes a more comprehensive approach that takes the full passenger journey in count. SQ shows the organization's ability to meet and exceed certain expectations and it is measured by comparing expected performance with the passenger's perception of how that performance was conducted. SQ is comprised of various factors ranging from reliability to safety, flexibility, convenience, and empathy. Different passenger expectations regarding airport services pose an enormous challenge in quality improvement in the airline industry. Understanding individual needs and expectations can tremendously improve the quality of service (Mikuličić et al., 2024).

The study looks at the various aspects of SQ, such as infrastructure, technology, staff interaction and safety measurements. A thorough evaluation of these aspects is needed in order to form the basis for assessing the impact that they may have on consumers behavior and consequently on the satisfaction rates. According to Bezzer and Gomes (2020) higher level of passenger satisfaction results with a lower possibility of passenger complaints should be a norm when trying to achieve higher satisfaction rates. It has been shown that satisfied passengers tend to return and use the same airports over and over again when compared to those who did not share a similar experience. The satisfaction rates are a direct indicator of the quality of service that is being provided at certain airports (Butler and Keller, 1992). Therefore, the main point in managing the service quality is to provide the best possible product for the consumers in order to obtain a more favorable business outcome. Even though airports are highly specific while during business due to their capacity and infrastructure there is a certain indication that shows that people tend to spend more if they wait longer at the airports (Blichfeldt et al., 2017). Well organized airports can use this human behavior in their advantage in order to increase the revenues of duty free shops and bars.

3. Methodology

A retrospective survey was conducted at the Split Airport, located in the city of Kaštela, Republic of Croatia. 389 participants ranging from 18 to 70 years of age took part in it. From the total number of respondents 163 were male and 226 were female. Only passengers who arrived at the airport at least three hours before the flight's scheduled departure time as well as those who spoke and understood English, were older than eighteen, had valid travel documents and were physically and mentally capable of checking in for a flight on their own without requiring additional assistance from airport personnel were included in this study. If the passengers did not meet the later they were excluded from this study.

3.1. Sample Variables

An anonymous questionnaire was used to gather data on set of variables. This questionnaire was created by trained personnel at the Split Airport in the year 2013. It's main goal was to assess the passenger's satisfaction rates with the services provided at the airport and was for internal use only. In order to collect data for this study, the questionnaire was modified so that it includes all of the newly added amenities. There were fifteen questions in total, fourteen of which were closed-ended and one was open-ended. The survey was developed in such a way that it included a "Did not notice" option in addition to comparable answers scored in a Likert scale as follows: 1 – Poor , 2 – Fair, 3 – Good , 4 - Very good, 5 – Excellent. The survey included questions regarding demographics, general contentment with the service provided at the Split Airport as well as unrestricted comment section.

3.2. Description of the experimental procedure

Permission to conduct this research was given by the ethics committee of the Split Airport after which the printed questionnaire was handed out to passengers. After all the responses had been collected they were coded using the MS Excel application and submitted into the Galiot software.

4. Results

Raw data was obtained from 389 participants was collected for a number of tested parameters. The vast majority of participants were female (N=225, 58,1%) and the rest of participants were male (N=163, 41,9%; Table 1).

Table 1 Gender of participants (*Gender _participants*)

<i>In total</i>	<i>Female</i>	<i>Male</i>
389	226	163
100%	58,1%	41,9%

When grouped into age categories it has been noted that the majority of participants were in the 41-65 age group (N=168; 42.96%) and the least number of participants were in the Under 25 (N=57, 14.57%) and Over 65 (N=66, 16.87%) groups (Table 1). This data comes as no surprise as numerous psychological studies have shown that young people as well as older people feel reluctant to participate in these types of surveys. It can be due to the fact that young people are less cooperative as they hit certain age likely due to puberty but equally so older people feel ill at ease because they usually do not follow the rise of new technologies and are more prone to being suspicious when it comes to these types of surveys. It can also be due to the fact that older people usually navigate the airport's parameters more poorly and in those instances feel a need to proceed to the gate with greater haste thus making them less likely to participate (Table 2).

Table 2 Age of participants (*Age _participants*)

<i>In total</i>	<i>Under 25</i>	<i>26-40</i>	<i>41-65</i>	<i>Over 65</i>
389	57	100	168	66
100%	14,57%	25,57%	42,96%	16,87%

The terminal cleanliness frequency was scored as Excellent by 197 respondents (50.64%) while it was scored as Very good by 117 participants (30.07%). The Poor and Fair frequency was below 2% indicating that the Split Airport has good cleaning protocols and strategies (Table 3).

Table 3 Cumulative frequencies and relative values of the variable (N=389); (*TERMINAL - Cleanliness*)

	<i>Frequency</i>	<i>Cumulative frequency</i>	<i>%</i>	<i>K%</i>
<i>Did not notice</i>	7	7	1,80	1,80
<i>Poor</i>	1	8	0,26	2,06
<i>Fair</i>	7	15	1,80	3,85
<i>Good</i>	60	75	15,42	19,28
<i>Very good</i>	117	192	30,07	49,35
<i>Excellent</i>	197	389	50,64	100,00

Furthermore, it has been observed that the Check-in waiting time was mostly regarded as Excellent (N=181; 46.53%) and Very good (N=100; 25.71%). Out of the total 389 respondents, only 1.03% (N=4) rated the Check-in waiting time as Poor (Table 4).

Table 4 Cumulative frequencies and relative values of the variable (N=389); (*CHECK IN –Waiting time, queuing*)

	<i>Frequency</i>	<i>Cumulative frequency</i>	<i>%</i>	<i>K%</i>
<i>Did not notice</i>	36	36	9,25	9,25
<i>Poor</i>	4	40	1,03	10,28
<i>Fair</i>	11	51	2,83	13,11
<i>Good</i>	57	108	14,65	27,76
<i>Very good</i>	100	208	25,71	53,47
<i>Excellent</i>	181	389	46,53	100,00

The Split Airport emphasizes on the importance of friendly and kind staff knowing that it leads to passengers feeling more at ease and making the whole process of flying which can be challenging for some more pleasant. Those policies also show on the results obtained by the surveys. It has been noted that 39.59% (N=154) passengers found the staff's friendliness Excellent while 25.45% (N=99) found it Very good. Only 2.06% (N=8) passengers found the staff's friendliness as Poor (Table 5).

Table 5 Cumulative frequencies and relative values of the variable (N=389); (*CHECK-IN staff – Courtesy, friendliness*)

	<i>Frequency</i>	<i>Cumulative frequency</i>	<i>%</i>	<i>K%</i>
<i>Did not notice</i>	22	22	5,65	5,65
<i>Poor</i>	8	30	2,06	7,71
<i>Fair</i>	16	46	4,11	11,82
<i>Good</i>	90	136	23,14	34,96
<i>Very good</i>	99	235	25,45	60,41
<i>Excellent</i>	154	389	39,59	100,00

Signage represents a huge part of every airport's transparency and it allows passengers to navigate its parameters more easily thus representing a key factor in the overall satisfaction rate. Table 6 shows that 134 passengers (34.45%) rated signage as Excellent, while 96 respondents (24.68%) rated signage as Very good. Only 1.03% (N=4) rated the signage as Poor which is to be expected as all airport put a great amount of effort into its signalization pathways.

Table 6 Cumulative frequencies and relative values of the variable (N=389); (*Signage*)

	<i>Frequency</i>	<i>Cumulative frequency</i>	<i>%</i>	<i>K%</i>
<i>Did not notice</i>	21	21	5,40	5,40
<i>Poor</i>	4	25	1,03	6,43
<i>Fair</i>	19	44	4,88	11,31
<i>Good</i>	115	159	29,56	40,87
<i>Very good</i>	96	255	24,68	65,55
<i>Excellent</i>	134	389	34,45	100,00

No airport experience would be complete without Duty-free shops, food and beverage shops, cafés and restaurants. Shops represent an opportunity for the airport to make additional income and for the passengers they makes the waiting time ever so slightly more enjoyable thus making them a vital component of the overall customer satisfaction rates. When looking at the results it can be noted that this area is the least favorable in the eyes of the passengers and needs to be improved. 79 respondents evaluate the shops with Poor (N=41; 10.54%) and Fair (N=38; 9.77%). The largest part of respondents, 131 of them or 33.67%, rate the SHOPS Overall satisfaction as Good.

Table 7 Cumulative frequencies and relative values of the variable (N=389); (*SHOPS- Overall Satisfaction*)

	<i>Frequency</i>	<i>Cumulative frequency</i>	<i>%</i>	<i>K%</i>
<i>Did not notice</i>	49	49	12,60	12,60
<i>Poor</i>	41	90	10,54	23,14
<i>Fair</i>	38	128	9,77	32,91
<i>Good</i>	131	259	33,67	66,58
<i>Very good</i>	62	321	15,94	82,52
<i>Excellent</i>	68	389	17,48	100,00

The analysis of Table 8 shows that 129 respondents or 33.16% of them rate Overall satisfaction as Excellent. Also cumulatively 201 respondents rate overall satisfaction as Good (22.88%) and Very Good (28.79%).

Table 8 Cumulative frequencies and relative values of the variable (N=389); (*Overall satisfaction*)

	<i>Frequency</i>	<i>Cumulative frequency</i>	<i>%</i>	<i>K%</i>
<i>Did not notice</i>	37	37	9,51	9,51
<i>Poor</i>	7	44	1,80	11,31
<i>Fair</i>	15	59	3,86	15,17
<i>Good</i>	89	148	22,88	38,05
<i>Very good</i>	112	260	28,79	66,84
<i>Excellent</i>	129	389	33,16	100,00

5. Discussion

This study gives a good insight on the customer satisfaction rates as well as on consumer behavior, mainly focusing on the experiences obtained in the area of airport service and/or the airport facilities. Its main factors include: waiting time, staff, shops, signage, airport cleanliness and overall satisfaction rates. The terminal cleanliness frequency was scored from Good to Excellent by 96.13% of the passengers. The check-in waiting time, which is a major factor for passengers overall satisfaction with the airport services, was scored from Good to Excellent by 86.89%. Additionally, those finding are in line with the staff courtesy rate which scored 88.18% for the same categories. Signage helps passengers to navigate through the airport parameters more freely. Some passengers, due to stress or fear of flying, need additional assistance in form of signs. 88.69% of passengers scored the signage at the Split Airport from Good to Excellent. An evident area that needs improvement is the Shops department as it has been scored from Good to Excellent by only 67.09% of passengers. In order to achieve that additional space within the airport parameters needs to be built. Nonetheless the overall satisfaction was scored from Good to Excellent by 84.83% of passengers. This is in line with previous studies (Fodness and Murray, 2007) which emphasize on the impact of customer service on various parameters such as: waiting time, cleanliness and interaction with the staff. Furthermore, it has been shown that the Split Airport performs remarkably well in the tested areas especially when it comes to waiting time at check-in and the cleanliness of the terminals. The later were rated as acceptable by a large percentage of respondents which proves that the airports values and policies are in line with the global trends in airport hospitality and it is a promising indicator for future improvements.

6. Conclusion

Passenger surveys have been used in the airport setting for several years, but there have been few that were conducted to determine the participant's satisfaction rates by using various parameters. The purpose of this study was to determine if most passengers were satisfied not only with the service provided at the Split Airport but also with the staff. In addition, this study examined what factors motivate participants in choosing a good outcome. These findings will help to inform the airport's management team how the passengers rate their experiences, what factors motivate them to rate an airport experience higher on the satisfaction scale rate and what are the potential flaws that the airport can improve on. The findings demonstrated that the vast majority of passengers rated their experience as highly favorable. Different passengers can have different preferences depending on their needs. Our findings indicate that the majority of passengers rate the overall satisfaction rate as Excellent and Very good. The exception to this statement is regarding the shops. It is known that Split Airport due to its size does not have numerous duty-free shops, different types of restaurants and luxury shops but it compensates that with friendly and helpful staff who help to make the overall experience more enjoyable. A limitation of this study is that it does not address the difference in nationalities or the social status of the passengers that participated in the survey. This alone can be a factor that affects the results of the overall satisfaction rates because some passengers are used to more lavish airport experiences. This limitation is minimized because the participants reflect a true representation of the type of passengers that come to the Split Airport regularly. Another limitation is the potential response bias from administration of the survey at the research sites. Future studies of this nature could use a third party to conduct the survey offsite to limit response bias. In conclusion, the findings from this study suggest that positive attitudes of staff and good work policies can create motivation for passengers to view the Split Airport in a positive light and hence increase willingness to participate in further surveys regardless of their age and gender. Since this kind of studies are not that common for the Dalmatian region it can be utilized for future studies in the field of human resource management.

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ANALYSING E-COMMERCE TRANSFORMATION: A STUDY ON AI-BASED CONSUMER BEHAVIOUR PREDICTION

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Abstract. In an increasingly competitive market, retailers find themselves exposed to advanced technological solutions like never before. Terms such as artificial intelligence, machine learning, and deep learning are trending, particularly in conversations about the future of online retail. This trend gained momentum, especially after “big-player” online retailers like Amazon and eBay successfully adopted AI-based solutions into their business operations. Over time, artificial intelligence evolved from a revolutionary niche to an accessible instrument for building a competitive advantage. In this environment, the future of e-commerce without artificial intelligence is almost unimaginable. Even though some studies focus more on the negative implications, such as the ethical, moral, and legal consequences of artificial intelligence adoption, a general opinion highlights that utilizing AI-based solutions in e-commerce is an inevitable and much-needed step forward from traditional retail. Consequently, this study investigates and highlights a practical application of artificial intelligence methods and fields for analysing consumer behaviour in e-commerce using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). In addition, a systematic literature review is combined with an inductive content analysis, a research method commonly used in qualitative studies, to identify trends, themes, and concepts prevalent in the field. Upon reviewing the preliminary findings, it is evident that artificial neural networks and supervised machine learning algorithms emerge as the predominant approaches for predicting consumer behaviour, whether as standalone models or integrated into hybrid models.

Key words: *artificial intelligence, e-commerce, consumer behaviour, PRISMA, inductive content analysis*

1. Introduction

In recent years, the expansion of artificial intelligence in the commercial market has grown exponentially (Furman & Seamans, 2019), enabling companies to learn faster and more precisely from vast quantities of available online data (Babina et al., 2024). Artificial intelligence is an intriguing concept that, although part of scientific and practitioner discussions for decades, has recently evolved into an integral component of many business models (Dwivedi et al., 2021). Rapid growth has revolutionized various industries, empowering businesses to make data-driven decisions, enhance consumer experience, and optimize operations (Wei, 2023). Within the retail industry, expectations are that artificial intelligence will help online retailers predict what customers want with high accuracy (Davenport et al., 2020), leveraging its ability to collect relevant data, learn from that data, and utilize acquired knowledge to achieve specific goals (Kaplan & Haenlein, 2019). Improving customer experience is an essential goal for retailers and compelling reason for artificial intelligence adoption (Ameen et al., 2021; Ho & Chow,

2023). Specifically, through personalized recommendations, streamlined processes, and tailored interactions, artificial intelligence has the potential to help retailers develop more profound connections with their customers, increasing loyalty and satisfaction (Ameen et al., 2021). Understanding the factors that affect consumer behaviour creates a competitive advantage, and artificial intelligence offers solutions by analysing consumers' purchase history and preferences using the various techniques, tools, or algorithms to support such activities (Ameen et al., 2021; Bawack et al., 2022; Kumar et al., 2019). By employing artificial intelligence algorithms, companies can decrypt data from various sources, thereby uncovering insights into customer preferences (Prakash et al., 2023). In contrast, this study aims to investigate and highlight a practical application of artificial intelligence methods and techniques for analysing consumer behaviour in e-commerce. Accordingly, this study aimed to answer following research questions:

RQ1: What are the practical applications and thematic areas regarding utilizing artificial intelligence to analyse consumer behaviour in e-commerce?

RQ2: What are the data sources and types used to explore practical applications regarding utilizing artificial intelligence to analyse consumer behaviour in e-commerce?

RQ3: What are the reported artificial intelligence methods and fields regarding consumer behaviour analysis in e-commerce?

Consequently, the authors approached this study using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (Page et al., 2021). In addition, a systematic literature review is combined with an inductive content analysis, a research method commonly used in text-based qualitative studies, to identify trends, themes, and concepts prevalent in the field (Vears & Gillam, 2022). The entire procedure, including all steps, is detailed in Section 2 below. The remainder of the study is structured as follows: Section 3 presents the results of the inductive content analysis and discuss the findings regarding the described research goals and questions. Finally, the last section explores study limitations, discusses future directions, and draws a conclusion.

2. Research methodology

The authors adopted the Preferred Reporting Items for Systematic Review and Meta-Analysis, referred to as the PRISMA framework later in the text. Originally published in 2009, updated in 2020, and republished in 2021, the PRISMA framework follows a strict procedure using textual and graphical guidelines and diagrams (Page et al., 2021). The PRISMA framework, although initially designed for review papers within healthcare (Page et al., 2021), has demonstrated versatility beyond its original scope, promoting not only methodological consistency but also an interdisciplinary approach to new research perspectives and discoveries. The PRISMA framework involves four phases following the predefined guidelines: (i) identification, (ii) screening, (iii) eligibility, and (iv) inclusion. Whole process is explained in detail below and broad illustration is shown in Figure 1.

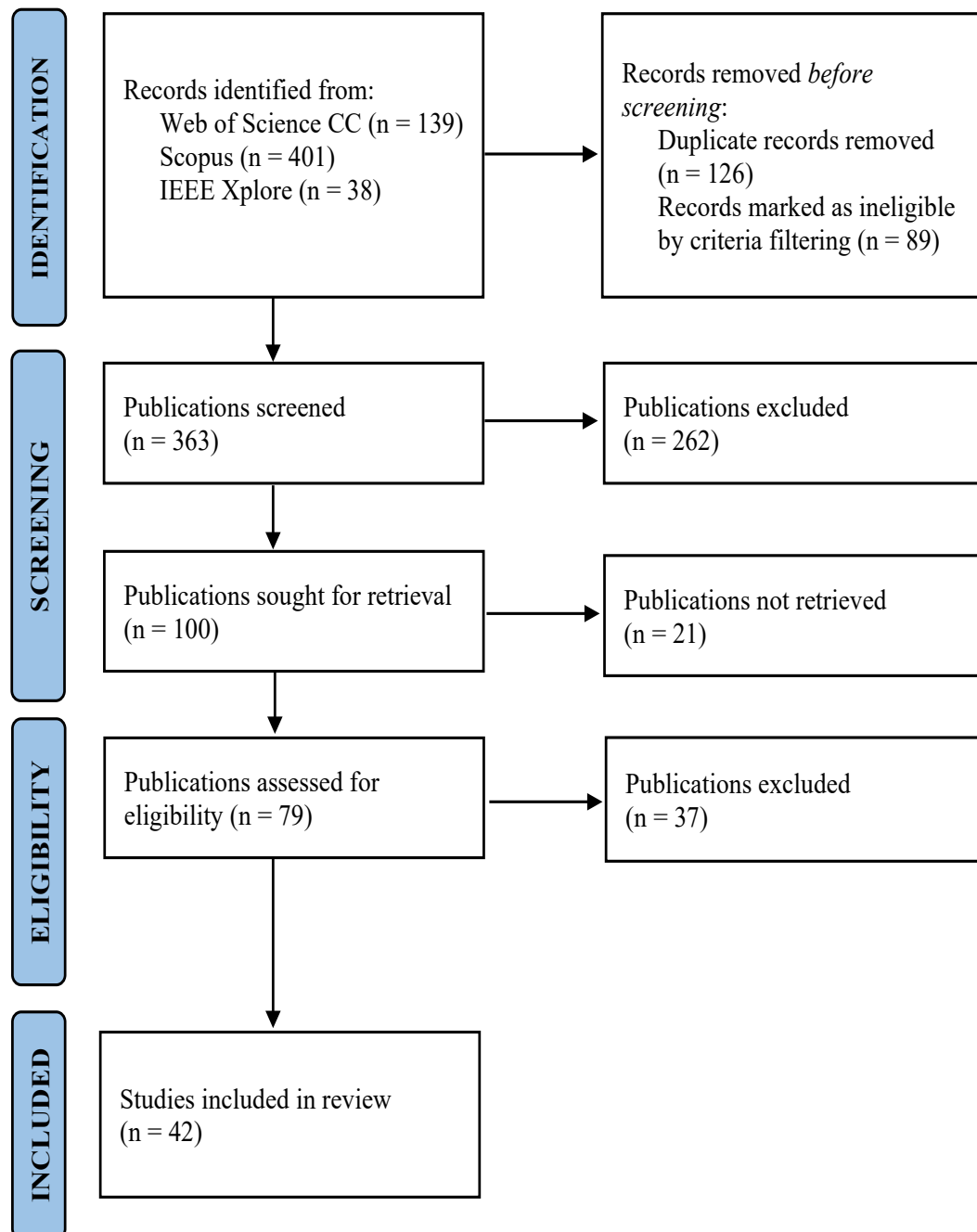


Figure 1 PRISMA flow diagram based on Page et al., 2021

The identification focused on the selection of electronic databases and search query testing, followed by literature retrieval and data exportation required for content analysis. The databases included were Web of Science Core Collection, Scopus, and IEEE Xplore Digital Library. The Ministry of Science, Education, and Sports of the Republic of Croatia provided access to the electronic databases. The search was performed iteratively, and data exportation was conducted on March 1st, 2024. Based on the latest research studies on artificial intelligence taxonomy (Graziani et al., 2023; Schwalbe & Finzel, 2023), the authors formed search queries as follows: (i) ‘artificial intelligen*’ OR ‘machine learning’ OR ‘deep learning’ OR ‘neural network’ AND (ii) ‘*commerce’ AND (iii) ‘consumer*’ NEAR/3 ‘behavio*’, with minimal adjustments depending on the database searched. The number of publications identified was 578 across three databases combined. Table 1 displays the number of publications per year and search queries used for each database.

Table 1 Scientific databases, search queries and the number of publications identified per year

Db	All time	2024	2023	2022	2021	2020	2019	2018	2017	2016	2015	2014	2013	<2013
Web of Science	TS=(“artificial intelligen*” OR “machine learning” OR “deep learning” OR “neural network*”) AND TS=(“*commerce”) AND TS=(“consumer*” NEAR/3 “behavio*”)													
	139	4	30	39	26	13	6	3	6	4	-	1	1	6
Scopus	TITLE-ABS-KEY (“artificial intelligen*” OR “machine learning” OR “deep learning” OR “neural network*”) AND TITLE-ABS-KEY (“*commerce”) AND TITLE-ABS-KEY (“consumer*” W/3 “behavio*”)													
	401	21	94	89	49	27	23	19	11	11	5	6	3	43
IEEE Xplore	(“Abstract”:“artificial intelligen*” OR “machine learning” OR “deep learning” OR “neural network*”) AND (“Abstract”:“*commerce”) AND (“Abstract”:“consumer*” NEAR/3 “behavio*”)													
	38	1	13	8	4	4	1	1	1	2	1	1	-	1

The data was extracted in .csv format and then imported into Microsoft Excel for additional analysis. The imported categories included authors’ names, publication titles, publication languages, publication types, authors’ keywords, publication abstracts, and digital object identifiers (DOIs). Furthermore, as various databases use different categorization systems for indexed publications, the authors implemented a unique publication type categorization that secures consistency for all the exported publication data.

Table 2 Publication type categorization

Publication type	Originally listed document type in Web of Science Core Collection, Scopus, and IEEE Xplore Digital Library
Journal Article	‘Article’, ‘Article Early Access’, ‘IEEE Journals’, ‘Article Proceedings Paper’
Conference Paper	‘Conference Paper’, ‘IEEE Conference’, ‘Proceedings Paper’
Review	‘Review’
Book or Book Chapter	‘Book’, ‘Book Chapter’
Other	‘Article Retracted Publication’, ‘Conference Review’, ‘Editorial’, ‘Editorial Material’, ‘Retracted’

A preliminary search of the three databases resulted in 283 journal articles, 247 conference papers, 17 reviews, 17 book chapters or books, and 14 other documents. Next, the authors identified and removed 126 duplicates, leaving a total of 452 publications for criteria filtering. The publications were filtered according to the following inclusion/exclusion criteria: (i) publication type – IN: Journal articles and conference papers; EX: Reviews, Books or Book chapters; Other; (ii) Publication time span – IN: 2014/01/01 – 2024/03/01 (yyyy/mm/dd); EX: Outside of the proposed period; (iii) Publication language – IN: English; EX: Other languages. After the criteria filtering process, 89 publications were excluded, leaving 363 publications available for abstract screening. During this phase, the authors developed a set of guidelines to aid in identifying eligible publications. Furthermore, during the abstract screening phase, the authors focused on research keywords and approaches rather than the results addressed in the abstract. These guidelines comprised three conditions for excluding publications based on abstract screening: (i) ‘No [research keyword] is mentioned in the abstract.’ (ii) ‘The abstract mentioned [research keyword] but redirects the study focus in a different direction.’ (iii) ‘The abstract mentioned [research keyword] as part of a comparative analysis between different

approaches rather than its practical implications' (e.g., utilizing consumer behaviour data to compare different methods). Keywords included artificial intelligence and its subfields or methods (e.g., machine learning, deep learning, neural networks, etc.), consumer behaviour, e-commerce, online retail, and their synonyms. As a result, 262 publications were excluded. Among these publications, 140 did not meet the first condition, 107 did not meet the second condition, and 16 did not meet the third condition, leaving 100 publications available for the eligibility phase. Following the abstract screening phase, publications underwent a full paper review. During the eligibility phase, the authors established two conditions for research progress toward the final analysis. First, the full version of publication had to be accessible for download. Second, publications that deviate from the research goal were excluded from further analysis. Following the described approach resulted in the dismissal of 58 publications, leaving 42 publications eligible for inductive content analysis. Besides unavailable publications ($n = 21$), most of the excluded publications were focused on collecting data about consumers' perceived value of potentially incorporating artificial intelligence in e-commerce rather than investigating the practical implications of artificial intelligence adoption on consumer behaviour. A few excluded publications briefly discussed practical implications and focused more on method comparisons using e-commerce data, while others did not meet minimal technical criteria. Finally, the authors implemented an inductive content analysis for publication review. Inductive content analysis (Vears & Gillam, 2022) involves developing a content template and setting rules for textual analysis to find relevant information related to the research questions. The content template summarizes information on authors, publication title, publication year, application, thematic area, data source, data type, artificial intelligence method, and additional approaches.

Table 3 The content template used to summarize information from the included publications

Category	Value	Description
Authors	Text	Names and surnames of listed authors
Publication title	Text	Titles of the included publications in the content analysis
Publication year	Integer	A field indicating the publication year
Application	Text	Short description of the practical application of the research
Thematic area	Text	Broad categories that research is focused on
Data source	Text	Description of how data is collected
Data type	Text	Description of the type of data used in research
Artificial intelligence method	Text	Reported practical applications of artificial intelligence methods and techniques for analyzing consumer behavior in e-commerce
Additional approaches	Text	Additional methods, tools, or techniques used to complement AI methods for analyzing consumer behavior in e-commerce

3. Analysis and discussion

RQ1: What are the research themes and practical applications regarding utilizing artificial intelligence to analyse consumer behaviour in e-commerce?

Upon reviewing the full text of the included studies, the thematic analysis revealed three main research areas falling under the 'umbrella' of behaviour analysis. In descending order of frequency, the authors identified consumers: (i) purchase analysis ($n = 26$); (ii) behaviour analysis ($n = 13$); (iii) sentiment analysis ($n = 3$). Overlaps between thematic areas are possible; therefore, further explanation of these areas of consumer behaviour analysis is provided. Purchase analysis emerges as the most dominant thematic area, encompassing various approaches to predict consumer purchase intention, conversion, and repurchase behaviour. Several studies

analyse purchase behaviour in a more general manner. Three studies focused on repurchase analysis (Lee, 2020; W. Zhang & Wang, 2021; C. Zhu et al., 2022), while one study focused on compulsive buying analysis (Ye & Ching, 2023). Additionally, one study discusses the value of predicting consumer purchasing intention in precision marketing as a decision-making tool for building a competitive advantage in the market (Gao, 2023).

The most diverse thematic area is behaviour analysis. Under this term, the authors compiled various behaviour predictors and approaches. Two studies discuss anomaly behaviour detection (Fan et al., 2022; Lai & Yang, 2023), followed by two studies analysing consumer preferences using the neuroanalysis-based approach to track and measure brain activity regarding reactions to different products (Ramirez et al., 2022; Zamani & Boniadi Naieni, 2020). Other studies included consumer pattern analysis (Amin et al., 2020; Xu et al., 2024), engagement analysis (Vaičiukynaitė et al., 2021), participation analysis (Darbanibasmanj et al., 2019), long and short-term behaviour analysis (Sreenivasa & Nirmala, 2023), consumer browsing analysis (Chen et al., 2023), and other broader approaches (Gumasing et al., 2023; Li et al., 2022; Safara, 2022).

Finally, consumer sentiment analysis includes three studies with a similar practical application toward understanding the opinions and emotions expressed by consumers using online reviews on e-commerce platforms (Balaji & Vadivazhagan, 2024; Kaur & Sharma, 2023; Nguyen et al., 2021).

RQ2: What are the data sources and types used to explore practical applications regarding utilizing artificial intelligence to analyse consumer behaviour in e-commerce?

Open-source datasets represent the prevalent data sources employed for conducting and analysing consumer behaviour in e-commerce using artificial intelligence methods. Out of the 42 publications, more than 50% ($n = 22$) used open-source datasets as their source for the data analysis. These datasets combine details concerning user behaviour, product attributes, online reviews, clickstream data, and heterogeneous data types. Notably, Kaggle.com emerged as the 'number one' online platform, used in six studies for data acquisition.

Additionally, participant analysis studies ($n = 7$) provided valuable insights by collecting and analysing EEG and fNIRS data alongside survey responses, providing insights into consumer cognitive processes, emotional responses for sentiment analysis, and self-reported behaviour conducted through questionnaires.

Finally, the third commonly used data sources are private online data sources ($n = 6$) that include transactional records, access logs, and clickstream data from retailers, offering higher granularity levels than other, manually manipulated and arranged data sources, into consumer interactions with retailers on online platforms and their purchasing behaviour. Most of the private online source comes from Asian retailers (China, Taiwan, Japan), while open data sources are various, with Kaggle being the most popular one. Three studies did not specify their data source, while two used combined data sources.

Some studies combine more than one data type; therefore, Table 4 presents all the combinations regarding data sources and types per thematic area of the study.

Table 4 Breakdown of data sources and types per thematic area

		Thematic area					
		Purchase analysis		Behavior analysis		Sentiment analysis	
		Amount	%	Amount	%	Amount	%
Data source and type	Open source dataset						
	Binary classification data	1	6,3				
	Clickstream data	2	12,5	1	16,7		
	Images	1	6,3	1	16,7		
	Mixed			1	16,7		
	Online review data (text)	2	12,5	1	16,7	3	100,0
	Structured data	7	43,8	1	16,7		
	Transactional data	2	12,5	1	16,7		
	Weblogs	1	6,3				
	Total: Open source dataset	16		6		3	
	Participant analysis						
	EEG data			2	50,0		
	fNIRS data			1	25,0		
	Survey	3	100,00	1	25,0		
	Total: Participant analysis	3		4			
	Private online data source						
	Access logs			1	50,0		
	Clickstream	1	20,0				
	Structured data	2	40,0	1	50,0		
	Transactional data	1	20,0				
	Online text data (product desc.)	1	20,0				
	Total: Private online data s.	5		2			
	Other						
	Not specified	1	25,0				
	Images	1	25,0				
	Mixed	1	25,0				
	Unstructured data			1	100,00		
	Transactional data	1	25,0				
	Total: Other	4		1			
	TOTAL	28	-	13	-	3	-
		(63,6%)		(29,6%)		(6,8%)	

RQ3: What are the reported artificial intelligence methods and fields regarding consumer behaviour analysis in e-commerce?

This research question aims to answer which artificial methods and techniques are most dominant for analysing consumer behaviour in e-commerce. The authors have structured their investigation by categorizing these methods in descending order, prioritizing those with the highest frequency of use. This approach provides insights into the prevalent methods and analyses their consistency in understanding consumer behaviour within the e-commerce landscape. It's worth mentioning that some studies combine multiple methods into a single artificial intelligence method, potentially leading to overlaps among different artificial intelligence approaches. Additionally, many studies employ various artificial intelligence methods to test and compare adopted solutions, and these methods are not part of a detailed discussion in this review. However, it's important to note that publications solely focused on comparing various artificial intelligence methods using consumer behaviour data and not providing new solutions or discussing practical implications of artificial intelligence adoption

were excluded in the earlier phase of this research. Upon reviewing the findings, it is evident that supervised machine learning methods and neural networks emerge as the predominant solutions for predicting consumer behaviour, whether as standalone models or integrated into hybrid models. For that matter, Table 5 features a breakdown of artificial intelligence methods and additional approaches employed in the studies.

Table 5 Breakdown of artificial intelligence methods for analysing consumer behaviour in e-commerce

AI method	Additional approaches (<i>information</i>)	Sources
Decision Tree (DT)	Extreme Gradient Boost classifier (XGB)	(Roychowdhury et al., 2021)
	Boosting and Bagging algorithm (BB)	(Safara, 2022)
	Improved stacked decision tree (ISD)	(Trivedi et al., 2022)
	-	(Amin et al., 2020; Chen et al., 2023; Exenberger & Bucko, 2020; Vaičiukynaitė et al., 2021)
k- Nearest Neighbor (KNN)	Silhouette coeficient (SC)	(Darbanibasmanj et al., 2019)
	-	(Gao, 2023; Roychowdhury et al., 2021; Yasin et al., 2023)
Random forest (RF)	Extreme Gradient Boost classifier (XGB)	(Avula et al., 2023)
	Hybrid Weighted Random Forest (WHRF)	(Lilhore et al., 2021)
	Improved Deep Forest (ImDRF)	(W. Zhang & Wang, 2021)
	-	(Gumasing et al., 2023; Hu & Shi, 2020; Javaid et al., 2022; Necula, 2023; Niu et al., 2017)
Support Vector Machine (SVM)	One Class Support Vector Machine (OCSVM)	(Fan et al., 2022)
	Extreme Gradient Boost classifier (XGB)	
	Discrete Wavelet Transform (DWT)	(Zamani & Boniadi Naieni, 2020)
	-	(Nguyen et al., 2021)
k-Means (KM)	-	(Exenberger & Bucko, 2020; Wang et al., 2023)
Association Rules (AR)	-	(Exenberger & Bucko, 2020)
Transfer Learning (TL)	-	(Xu et al., 2024)
Generative Model (GM)	Consumer Search Model (CSM)	(M. Zhang et al., 2016)
Artificial Neural Networks (ANN)	Multiple regression (MR)	(Lee, 2020)
	Structural Equation Modeling (SEM)	(Ye & Ching, 2023)
	-	(Gumasing et al., 2023; Sarkar et al., 2020)
Recurrent Neural Network (RNN)	Gated Feedback (GF)	(Pryzant et al., 2017)
	Gated recurrent unit model (GRU)	(Xu et al., 2024)
*Deep Recurrent Neural Network (DRNN)	-	(Lai & Yang, 2023; Luo, 2021)

Convolutional Neural Network (CNN)	Graph Convolutional Network (GCN) Feature Engineering (FE) Hierarchical Labels and Prediction (HLP)	(Liu et al., 2022)
	Region-based CNN (rCNN) Human Computer Interaction (HCI)	(Li et al., 2022)
	Gated Feedback (GF)	(Sheth & Thaker, 2023)
	ResNet-50	(Xu et al., 2024)
	Entity Embedding (EE)	(B. Zhu et al., 2020)
	Extreme Gradient Boost classifier (XGB)	(C. Zhu et al., 2022)
Quantum Deep Neural Network (QDNN)	Resilient Grey Wolf Optimization (RGWO)	(Balaji & Vadivazhagan, 2024)
Long Short-Term Memory (LSTM)	2-layered LSTM based model (2-LSTM)	(Utku & Akcayol, 2020)
	Extreme Gradient Boost classifier (XGB)	(C. Zhu et al., 2022)
	-	(Hu & Shi, 2020; Kaur & Sharma, 2023; Lai & Yang, 2023; Ramirez et al., 2022; Roychowdhury et al., 2021)
Deep Learning Super Sampling algorithm (DLSS)	-	(Hou & Tang, 2023)
Recommendation Systems (RS)	Risk-aware Recommendation model (RARE)	(Ge et al., 2020)
	Hybrid Time Centric Prediction Recommendation System (HTCP-RS)	(Sreenivasa & Nirmala, 2023)
Natural Language Processing (NLP)	Bidirectional Encoder Representation for Transformers (BiGRU)	(Sheth & Thaker, 2023)
	-	(Kaur & Sharma, 2023)

Among the supervised machine learning algorithms, random forest was the most frequently used ($n = 8$), followed by decision trees ($n = 7$). Furthermore, long short-term memory (LSTM), a type of recurrent neural network architecture, emerged as the most utilized neural network algorithm ($n = 8$), followed by convolutional neural networks (CNNs) ($n = 6$), recurrent neural networks (RNNs) ($n = 4$), and artificial neural networks (ANNs) ($n = 4$).

Each of these algorithms integrates additional methods to boost its performance, with the extreme gradient boost classifier (XGB) being the most frequently utilized algorithm ($n = 5$). This classifier is integrated with various algorithms, including decision trees (DT), random forests (RF), support vector machines (SVM), convolutional neural networks (CNN), and long short-term memory networks (LSTM).

Several algorithms emerged as standalone solutions, while others were frequently combined with additional algorithms and methods. Random Forest stood out as the most commonly used standalone algorithm ($n = 4$). On the other hand, Convolutional Neural Networks (CNNs) emerged as the most frequently combined algorithm ($n = 6$), indicating compatibility with a wide range of optimization solutions.

Table 6 Breakdown of artificial intelligence methods per thematic area

		Thematic area					
		Purchase analysis		Behavior analysis		Sentiment analysis	
		Amount	%	Amount	%	Amount	%
Artificial intelligence methods	Decision Tree	3	9,1	4	23,53		
	k-Nearest Neighbor	3	9,1	1	5,88		
	Random Forest	7	21,2	1	5,88		
	Support Vector Machine			2	11,76	1	25,0
	k-Means	2	6,1				
	Association Rules	1	3,0				
	Transfer Learning			1	5,88		
	Generative Model	1	3,0				
	Artificial Neural Network	3	9,1	1	5,88		
	Recurrent Neural Network	2	6,1	2	11,76		
	Convolutional Neural Network	4	12,1	2	11,76		
	Quantum Deep Neural Network					1	25,0
	Long Short-Term Memory	4	12,1	2	11,76	1	25,0
	Deep Learning Super Sampling	1	3,0				
	Recommendation Systems	1	3,0	1	5,88		
	Natural Language Processing	1	3,0			1	25,0
	Total	33 (61,1%)	100,0 -	17 (31,5%)	100,0 -	4 (7,4%)	100,0 -

Interestingly enough, despite being tested in six different studies, naive bayes (NB) consistently underperformed in each study (Amin et al., 2020; Lilhore et al., 2021; Nguyen et al., 2021; Safara, 2022; Sheth & Thaker, 2023; Trivedi et al., 2022), making decision tree (DT), convolutional neural networks (CNNs), support vector machine (SVM), and random forest (RF) much better solutions for consumer behaviour analysis. This trend suggests that naïve bayes (NB) may not be well-suited for the complexities of consumer behaviour data in comparison with decision trees (DT), convolutional neural networks (CNNs), and random forest (RF) algorithms, as they demonstrate superior performance and effectiveness in consumer behaviour patterns analysis.

4. Conclusion

This study investigates the practical application of artificial intelligence methods for analyzing consumer behavior in e-commerce using the PRISMA framework and inductive content analysis. Despite growing attention in academia, there is a limited number of studies that extend to the empirical level due to the many constraints such as research funding these types of research acquire (C. Zhu et al., 2022). Nevertheless, the study analyzed 42 publications focused on the practical value of artificial intelligence adoption through consumer behavior data analysis provided by various sources.

The publication analysis identified three thematic areas concerning consumer behaviour analysis: (i) Purchase analysis - includes consumer purchase intention, conversion, and repurchase behaviour; (ii) Behaviour analysis - includes anomaly behaviour detection, preference analysis,

pattern analysis, engagement analysis, participation analysis, long and short-term behaviour analysis, browsing analysis, among others; (iii) Sentiment analysis. Purchase analysis emerged as the most prevalent thematic area, followed by behaviour and sentiment analysis. The most frequent data source was open-source databases, followed by participant analysis via surveys, EEG and fNIRS data from brain response analysis on specific products, and self-reported questionnaires.

The synthesis on artificial intelligence revealed that supervised machine learning methods and neural networks are prevalent solutions for predicting consumer behavior, whether as standalone models or integrated into hybrid models. Among the supervised machine learning algorithms, random forests (RF) and decision trees (DT) feature prominently in research studies. In addition, long short-term memory (LSTM) is the most used neural network algorithm, followed by convolutional neural networks (CNNs) and recurrent neural networks (RNNs). Although LSTM is a type of recurrent neural network (RNN), it's often discussed separately due to its distinct architecture and capabilities compared to traditional RNNs. Each of these algorithms integrates additional methods to boost its performance, with the extreme gradient boost classifier (XGB) being the most widely used machine learning algorithm for this purpose.

This study has several limitations in its research approach. First, there is a possibility for biased decisions in the screening and eligibility phase as authors did not test reliability nor use any consistency ratio measure to mitigate potential bias, particularly often for this type of research (Cook & Beckman, 2006). Second, the authors searched only three electronic databases, namely Web of Science, Scopus, and IEEE Xplore, potentially missing out on other relevant studies indexed in different databases. Furthermore, it's important to note that qualitative text-based research analysis may introduce uncertainties in determining research themes and artificial intelligence categories, as observed in this study. Consequently, some decisions may lack objectivity due to the subjective nature of interpreting textual data.

By managing the reported study limitations, future research direction may include further analysis of reported practical results, rather than only application, using artificial intelligence methods to achieve specific goals reported by the studies. Additionally, this study lacks a descriptive analysis of publications included in the content analysis. Adding a higher number of scientific databases would provide more comprehensive information for conducting such descriptive analyses in the future. In order to manage potential bias in the future, a reliability test using Cohen's Kappa coefficient (McHugh, 2012) may be included in the research methodology.

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INDUSTRIAL CONCENTRATION AND PROFITABILITY OF THE BANKING SECTOR IN THE REPUBLIC OF CROATIA

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Abstract. Industrial concentration of the banking sector is a key element used to analyse the competitiveness and market power within the banking sector, while the profitability of the banking sector indicates the measure of its business success.

This paper aims to identify, investigate and describe the link between industrial concentration and profitability in general and in the case of the Croatian banking sector, from 1998 to 2023, in particular. The paper gives an overview of the theoretical background and literature review of the relevant academic research on the banking sector profitability and concentration nexus followed by empirical research. Within the analysed period, the number of banks in Croatia decreased while the concentration of the banking market increased substantially, resulting in a highly concentrated banking sector. After analysing the concentration of the banking sector and its profitability, the Pearson correlation coefficient was employed to examine the relationship between the selected indicators of industrial concentration (namely concentration ratio and the Herfindahl-Hirschman index - HHI) and indicators of the profitability of the Croatian banking sector (measured by the rate of return on assets - ROA and rate of return on capital - ROE) followed by Pairwise Granger Causality tests in order to detect the causality between two sets of indicators.

Research results indicated the existence of a positive correlation between industrial concentration and the profitability of the banking sector, however the correlation itself seems to be rather low, which is the case for both the full sample, using yearly data, as well as for the 2016:Q2-2023:Q4 subsample, using quarterly data. Unlike similarities with correlation diagnostics, Granger causality tests indicated that ROE Granger caused HHI for the whole sample at the 10% significance level (even when outliers were excluded) which was not the case with the subsample data indicating a change in the relationship between profitability and concentration of the banking sector in recent years. Our results bring forward the importance of defining dependent and independent variables when testing for the relationship between industrial concentration and profitability of the banking sector.

Key words: *Croatian banking sector, industrial concentration, profitability of banks*

1. Introduction

When evaluating performance of banks, profitability is one of the most important criteria (Alrabei 2013). The profitability of banks represents a measure of their business success, resulting from the interplay between the business strategy adopted by each individual bank (internal factors) and its economic environment (external factors) (Gul et al. 2011).

Although a high degree of concentration usually indicates an inefficient market, research on concentration in banking markets has not yet confirmed this assumption. When it comes to the

relationship between the degree of concentration and the development of the financial system, there are two opposing views in theory. The first argues that with increasing concentration, a financial institution (bank) increases its power and earns extra profit, while the other argues that a certain level of monopoly power in the banking sector is beneficial because it implies that financial institutions are large enough to offer a wide range of financial products and services (Dimić, 2015).

Numerous studies have examined hypotheses regarding the impact of market structure on various metrics of bank performance, particularly return on assets (ROA) and return on equity (ROE) (Petriia, Capraru & Ihnatov, 2015) yet, many of these studies failed to consistently support the notion of a direct correlation between concentration and profitability defying a singular conclusion that can be universally applied across all countries (Santoso et al., 2023).

Croatian financial system is a bank-based continental system, where banks play a crucial role in transferring funds to the economy (Fotova Čiković & Cvetovska, 2022) while the relationship between market structure and bank profitability holds significant policy implications. Banks can enhance their profitability by either enhancing their cost efficiency or leveraging their market power. However, the latter method of profit-seeking may diminish overall social welfare. If evidence suggests that a concentrated market structure boosts bank profitability (rather than efficiency) it may warrant a focus on competition policies and regulatory interventions to reduce bank concentration (Tregenna, 2009).

Given the above, the aim of the paper is to examine the link between industrial concentration and profitability of the Croatian banking sector analysing the period between 1998 and 2023 during which the total number of banks fell from 60 to 19. Unlike previous research, this study covers a longer period of time taking into account most recent relevant data, especially the last five years during which the number of banks stopped dropping significantly while, at the same time, total bank assets increased by as much as 50%.

The paper is organized as follows: section 2 gives an overview of the theoretical background underlying the link between the profitability of banks and banking market concentration whereas section 3 brings forward most relevant research in the field. Data and methodology are presented within section 4 followed by the empirical analysis of the Croatian banking sector with the emphasis on profitability measures and concentration indicators as well as their interplay, given in section 5. The last section provides a conclusion along with a suggestion for future research.

2. Theoretical background

The determinants affecting bank profitability can be categorized into two main groups: internal and external factors. Internal factors (including capital, liquidity, and expenses) are within the control of a bank's management while, on the other hand, external factors (such as concentration, inflation, and gross domestic product growth) are beyond the direct influence of bank management. Typically, banks aim to optimize profits by effectively managing internal resources while also leveraging external factors to their advantage, despite not having direct control over them.

Considerable effort has been invested in exploring the relationship between banking market structure and performance with numerous studies in the banking literature identifying a positive correlation between profitability and market structure metrics, such as concentration or market share. Two competing hypotheses regarding market structure and performance are (as displayed by Diagram 1) the traditional Structure-Conduct-Performance (SCP) hypothesis (also known as the market power hypothesis) and the Efficiency (Structural) Hypothesis (ESH), both of which have been employed in international studies.

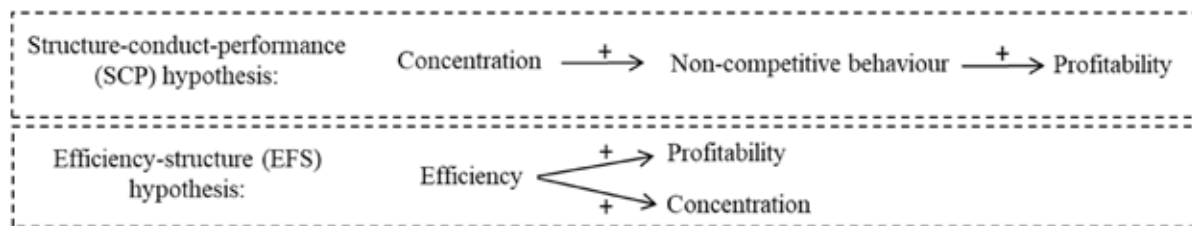


Diagram 1: Key competing hypothesis on market structure and profitability in the banking sector

Researchers frequently use the SCP hypothesis to determine whether a positive relationship between market concentration and bank profitability exists (Chen & Liao, 2011). In markets characterized by high concentration levels, firms are inclined to engage in collusive behaviour, consequently enhancing their performance (Goddard et al., 2004). Profits of these firms are determined by the concentration level of the market which shapes firm conduct, thus proposing a positive correlation between market concentration and profit (Mishra & Sahoo, 2012). Therefore, the SCP theory posits a positive correlation between market concentration and profitability, regardless of a firm's efficiency (expressed by its market share). Similarly, SCP related Relative Market Power (RMP) theory proposes that banks possessing substantial market shares and offering a wide range of financial products tend to operate more efficiently and can generate higher profits. Essentially, banks with relatively large market shares benefit from their market power regardless of overall market concentration (Nissan, 2003).

In contrast, the Efficiency (Structural) Hypothesis posits that market concentration results from industries where some firms possess superior efficiency. This hypothesis contends that efficient firms expand in size and market share due to their ability to generate higher profits, leading to increased market concentration (Smirlock, 1985). The theory is further divided into two models: The X-efficiency model and the Scale Efficiency Hypothesis (SEH). The X-efficiency model suggests that the most efficient firms tend to be more profitable, capturing larger market shares, potentially leading to higher market concentration without implying causation with bank performance (Leibenstein, 1966). Under the SEH assumption, all banks operate with the same production technology, with performance differences attributed solely to varying economies of scale. The SEH implies that banks utilizing similar production and management technologies operate at optimal economies of scale levels (Goldberg & Rai, 1996).

While SCP theory emphasizes market concentration, ESH hypothesis considers market share as a more critical parameter of market structure, as suggested by Molyneux & Forbes (1995). For the EFS hypothesis to hold true, efficiency must exhibit a positive relationship with concentration and/or market share. Both the conventional SCP and ESH hypothesis posit a correlation between structure and performance, however, they present starkly contrasting implications concerning merger and antitrust policies (Berger, 1995). If the SCP hypotheses hold true, mergers might be driven by the desire to establish prices less advantageous to consumers. Conversely, if the ESH hypotheses is accurate, mergers might be pursued for efficiency gains, leading to an increase in overall surplus. Consequently, proponents of the SCP hypotheses typically view antitrust enforcement as socially advantageous, whereas advocates of ESH tend to regard policies that impede mergers as socially detrimental.

3. Literature review

Following early studies by Short (1979), Bourke (1989) and Molyneux (1993), the intricate relationship between market concentration and bank profitability gained significant attention from researchers and policymakers worldwide.

Molyneux's (1993) pooled country estimates suggested collusive profits in Belgian, French, Italian, Dutch, and Spanish banking markets from 1986 to 1989 with a number of scholars finding support of the SCP hypothesis. Berger & Hannan (1989) consistently found empirical evidence supporting the implications of the SCP hypothesis as did Lloyd-Williams et al. (1994) for Spanish banks. Katib (2004) supported the SCP hypothesis based on a panel of 20 Malaysian commercial banks as did Nabieu (2013) for 19 Ghanaian commercial banks. Bourke (1989) and Molyneux & Thornton (1992) provided empirical evidence of a positive and statistically significant relationship between the bank concentration ratio and the profitability of a bank, in line with the traditional SCP paradigm. Adversely, Smirlock (1985) argued for a non-relationship between market structure and profitability, highlighting the connection between market shares and profitability instead. Evanoff & Fortier (1988) supported the ESH hypothesis. Demirguc-Kunt & Huizinga (1999), and Staikouras & Wood (2004) indicated a negative relationship between banking sector concentration and profitability as did Horobet, Radulescu & Belascu (2021) for CEE countries. Jansen & Haan (2003) found no evidence linking concentration indicators to profitability in European banking, while Jan & Khan (2014) found that traditional SCP hypotheses were not applicable to Southeast Asian banking. Evidently, the level of concentration, indicating the competitive environment in the banking industry, can influence banking profitability both positively or negatively (Northcott, 2004). Unfortunately, existing literature indicates that the effect of the banking consolidation cannot be simplified into a single conclusion applicable across all countries (Santoso et al., 2023).

A number of studies explored the factors influencing bank profitability within the **EU banking system**, with works by Bourke (1989), Molyneux and Thornton (1992), Girardone et al. (2009), Goddard et al. (2004) and Athanasoglou et al. (2006) being notable examples. Additionally, there has been a growing interest in evaluating profitability within emerging markets, as demonstrated by scholars such as Hassoune (2002) and Khedhiri & Khedhiri (2009). However, investigations into the relationship between profitability and market power in emerging markets have been relatively limited. Ćurak et al. (2012) illustrated the adverse impact of banking market concentration on profitability in Macedonia. Athanasoglou et al. (2006) examined banking profitability in the SEE region from 1998 to 2002, highlighting a positive relationship between banking market concentration and profitability. Căpraru and Ilnatov (2014) corroborated these findings across the CEE banking sectors for all three profitability measures - ROA, ROE, and net interest margin (NIM). Conversely, Claeys & Van der Venet (2003) found a positive association between banking market concentration and profitability in Western Europe but not in Eastern Europe. Naruševičius (2017) reported no significant relationship between the concentration ratio of the banking sector and banking profitability in Lithuania, while Athanasoglou et al. (2008) found inconclusive results.

Existing research in the Croatian banking sector used different types of banking sector performance indicators in order to determine the market structure as well as the concentration of the banking sector. **Studies on market concentration of the Croatian banking sector** (including; Gogala & Pejić-Bach (1998; 1992-1996) Tipurić, Kolaković & Dumičić (2003; 1993-2002), Ljubaj (2005; 1999-2005); Kraft (2017; 1994-2004), Dumičić, Pavković & Akalović Anić (2012; 2004-2011); Dimić (2015; 2007-2012) and Galetić & Obradović (2018; 2005-2017)) used different types of market concentration indicators, with concentration ratios (CR_x) and HHI being most frequently used, while bank assets prevailed as the measure used to calculate market concentration indicators. Though there are specifics and differences in the aforementioned studies and their conclusions, they generally indicate an increase in the banking sector market concentration during the last three decades, reflected by a number of bankruptcies, mergers and acquisitions resulting in a significant decline of the total number of operating banks and an oligopolistic banking market structure.

As for the existing **research linking industrial concentration and bank profitability in Croatia**, Pejić Bach & Simičević (2006) provided evidence on the significant influence of the market share of a particular bank on its profitability measured by ROE also indicating that macroeconomic conditions had no influence on banking profitability. Examining the profitability determinants of Croatian banks between 1999 and 2005, Pejić Bach, Posedel & Stojanović (2009) found that, in the short run, under stable macroeconomic conditions, higher profitability was achieved by well-capitalized banks with larger market shares. Empirical investigation by Pervan, Pervan & Guadagnino (2010) during the period 2002-2009 supported the classical SCP hypothesis for the Croatian banking sector. Furthermore, Kundid, Škrabić & Ercegovic (2011) employed dynamic panel analysis on a sample of 28 commercial banks from Croatia during the period 2003-2008 and found statistically significant effects of concentration (measured by HHI) on bank profitability (ROA). Krivačić, Smederevac & Vujnović (2013) investigated factors influencing bank profitability in Croatia between 2007 and 2010, revealing positive relationships between capital adequacy and profitability, as well as bank size and deposits, with profitability. Analysing the impact of bank market structure on firms' leverage in the Republic of Croatia (2002-2011), Pepur, Pervan & Ćurak (2014) found that the bank concentration positively affects firms' leverage, regardless of the firms' size. Pervan, Pelivan & Arnerić (2015) analysed Croatian banks from 2002 to 2010, identifying various factors affecting bank profitability measured by ROA. Their dynamic panel model highlighted statistically significant positive influences of profitability from the previous year, bank size, solvency risk, intermediation, industry concentration, market and GDP growth, while credit risk, inflation, and operating expenses management had negative impacts on profitability. Covering the period between 2007 and 2014, Sergi et al. (2018) analysed selected Croatian banks reporting a positive correlation between market concentration and bank profitability. Finally, Učkar & Petrović (2021) concluded that performance indicators (ROA and ROE) of four largest Croatian banks (2014-2019) were, on average, higher and less volatile in favour of the size of the bank being a significant factor of its profitability.

Overall, previous studies, mostly focusing on developed countries with some exceptions, present rather mixed and inconsistent results. Therefore, the challenge lies in deriving valid conclusions and designing optimal regulatory policies at national level.

4. Data and methodology

The very concept of concentration represents the basis for the analysis of competitiveness, or the market power in an industry. **Concentration indicators** show changes in the market power of banks as a result of the entry and exit of banks, as well as changes based on mergers and acquisitions (Bikker & Haaf, 2002). For a detailed overview of the most frequently used concentration indicators cf. Bikker & Haaf (2002, pp. 5-16).

Being the simplest and most common measure of concentration in the literature, **concentration ratio** is the indicator of the market share of the k largest banks in the overall banking industry. The ratio is calculated as follows:

$$CR_k = \sum_{i=1}^k S_i \quad CR_k = \sum_{i=1}^k S_i \quad (1)$$

where k is the number of largest banks whose total share is calculated, while S indicates the market share of the i -th bank. Following the conclusions of Ljubaj (2005, pp. 28; stating that a high level of correlation and “similarity” between concentration indices shows that for a quality analysis of the concentration of the Croatian banking sector it is enough to analyse a few most representative indices) as well as the bank supervision data of the Croatian National Bank, we

limit to the use of concentration ratios CR_2 and CR_5 as well as the HHI. Taking the specifics of the Croatian banking sector under consideration, CR_2 and CR_5 are chosen for the purpose of the research, indicating the market shares of the two and five largest banks, respectively. All market shares are calculated using bank assets of a particular bank in relation to total banking sector assets, excluding both savings banks and housing savings banks.

As for the **Herfindahl-Hirschman index**, it is calculated by summing up the squared values of the market shares of all the banks in the market as indicated by the formula:

$$HHI = \sum_{i=1}^n S_i^2 \quad HHI = \sum_{i=1}^n S_i^2 \quad (2)$$

where S is the market share of the i -th bank and n is the total number of banks. The main advantage of HHI, in relation to CR , is that it takes into account all companies in a particular industry, while its main disadvantage is insufficient attention to small companies, i.e. banks, although it is undeniable that the competitiveness of a market is determined by market leaders (Dimić, 2015, pp. 123). The application of HHI in practice is frequent. In the USA, HHI has a significant role in making the decision on whether to allow the concentration (mergers/acquisitions) of certain banks. The US central bank (FED) defines the conditions according to which the value of HHI after a merger or acquisition must not exceed 1800, i.e. the HHI value change must not exceed 200 (Ljubaj, 2005, pp.5).

Additionally, in the banking sector, it's common practice to assess **profitability** using return on assets (ROA) and return on equity (ROE) ratios (Davcev & Hourvoulides 2009). ROA and ROE are considered dependent variables, while internal and external factors are regarded as independent variables. **Return on assets** is a metric that compares net profit to total assets, also referred to as return on total assets. ROA reflects the firm's management ability to generate profits from its asset portfolio (Lee, 2014). However, the relevance of total assets has diminished due to the growing significance of derivatives and other off-balance-sheet items (Rumler & Waschiczek 2012). Dividing net profit by owner's equity, **return on equity** reflects both profitability and the efficiency of management in utilizing shareholders' investments (Muda et al. 2013). ROE provides a reasonable approximation of return potential within a limited time frame and facilitates comparisons that are challenging when using other return indicators (Frezatti, 2007). While ROA offers valuable insights into bank profitability, bank owners typically prioritize ROE, reflecting how much the bank earns relative to shareholders' capital investments (Davcev & Hourvoulides, 2009).

Apart from the qualitative analysis generated from the literature review, a quantitative analysis including descriptive statistics was carried out as well. Following Černohorsky & Prokop (2016), correlation matrices were derived using CR_2 , CR_5 , HHI, ROA and ROE yearly data for the Croatian banking industry for the period between 1998 and 2023, as well as using quarterly data between 2016:Q2 and 2023:Q4 (the necessary tests for normality were calculated previously). Subsequent analysis also included Pairwise Granger causality tests in order to detect the direction of the link detected by correlation coefficients. The data was generated and calculated using the official statistics and publications of the Croatian National Bank (banking asset data as well as banking sector performance indicators). Empirical analysis was carried out using EViews 8 statistical software.

5. Industrial concentration and profitability of the Croatian banking sector

Croatian banking sector has undergone severe changes during the last three decades. After gaining its independence from Yugoslavia, the Republic of Croatia encountered excessive use of banks as a source of financing as a result of war, privatization, the lack of independence of the

economic system and the inability to adequately fill the state's fiscal budget. During the period from 1990 to 1993 a total of 45 banks operated, of which the 4 largest banks held 2/3 of the market. It was a socialist banking system that was under great political influence, characterised by debts, unsettled claims and bad loans (Družić, 2001).

Figure 1 gives an overview of the total number of domestic and foreign banks from 1998 to 2023, as well as total banking sector assets. In 1998 a major crisis hit the banking system with the period until 2000 being influenced by numerous changes, mostly in the political system; banks were going through the recovery process and were faced with the entry of foreign banks into the domestic market (Družić, 2001). In the consequent years, the trend of decreasing of the total number of banks continued, starting from 60 in 1998 and settling at 19 in 2023. At the same time, the ratio of total bank assets held by foreign banks increased substantially from 6,7% at the end of 1998 (end of 1999 - 39,9%, end of 2000 - 84,1%, end of 2001 - 89,3%) to 90,2% at the end of 2002 (CNB, Banks Bulletin No.7) after which it stabilized. So as the overall number of banks decreased during the period from 1998 to 2023, total assets increased as much as 600% with foreign banks (whose number decreased as well) asset shares keeping rather constant at around 90% of total banking assets. A constant decrease in the number of banks after 2008 was a reflection of numerous mergers, acquisitions and bankruptcies following the global crisis in 2008 which influenced bank operations as well.

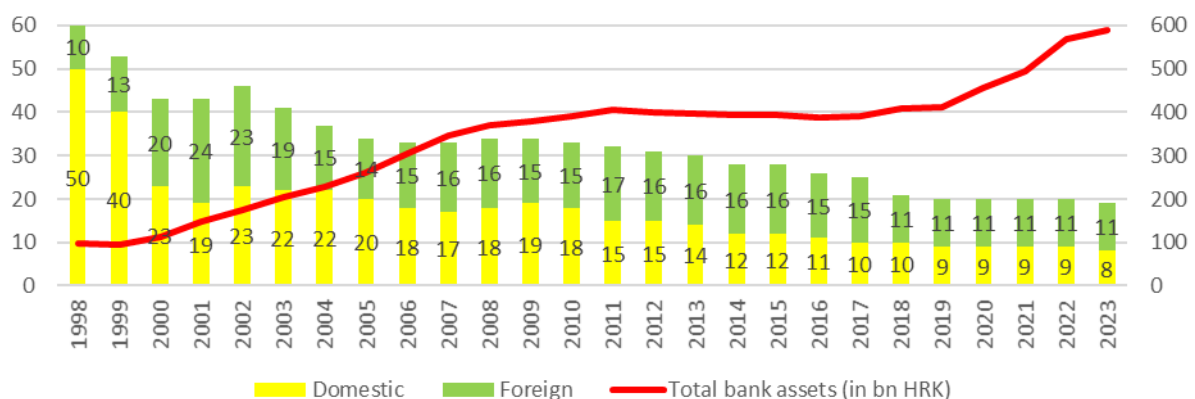


Figure 1: Number of banks according to ownership (domestic/foreign) and total bank assets (right axis)

Figure 2 gives an overview of the concentration indicators of the Croatian banking industry between 1998 and 2023, namely CR_2 , CR_5 and HHI.

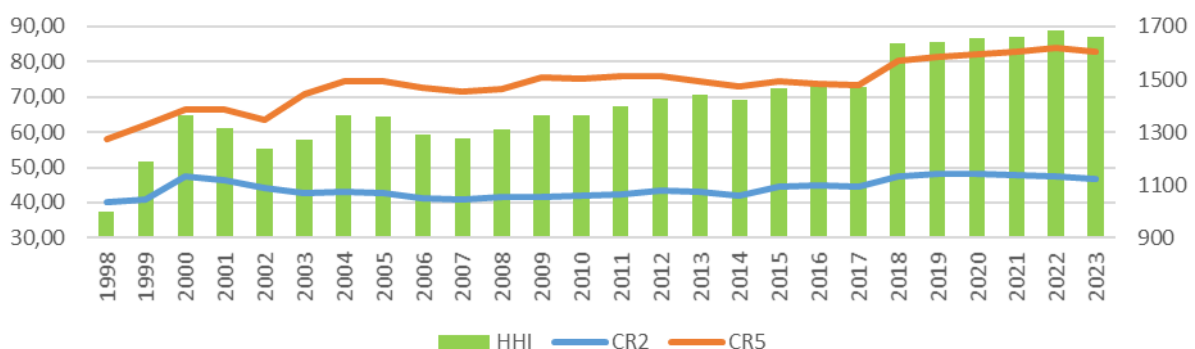


Figure 2: Concentration ratios of the largest two (CR_2) and largest five (CR_5) banks and the Herfindahl-Hirschman Index (HHI) of the Croatian banking industry

The biggest two long-term dominant banks, Zagrebačka banka and Privredna banka Zagreb held, on average, 44% of the total assets during the period in question, while CR_5 increased from 62% in 1998 to 83% in 2023 indicating competitiveness of the 3rd, 4th and the 5th bank, while the two biggest banks successfully defended their market position throughout the observed period and even increased it during the last six years. The HHI also indicates dramatic changes (potentially even more than the concentration ratios) since its value increased from 1000 in 1998 to 1660 in 2023. At the beginning of the period HHI fluctuated till 2007, after which it grew rather steadily with the exception of 2018 where an increase in its value (by 161) indicated the acquisition of Splitska banka by the OTP Bank. This had led to an increase in the market share of the 4th biggest bank which was Raiffeisenbank bank up to that point (with Erste bank being the 3rd largest bank during the last two decades).



Figure 3: Return on assets (ROA) and return on equity (ROE) of the Croatian banking sector

As for the profitability measures of the Croatian banking sector, Figure 3 gives an overview of ROA (left axis) and ROE (right axis) values. The first thing easily noticed is, as expected, the high correlation between the two indicators. Secondly, there are two pronounced negative spikes indicating negative ROA and ROE values for 1998 and 2015, respectively. The 1998 spike was a result of the banking sector crisis, however, it should be noted that the four largest banks holding 53% of total assets at the time (ZABA, PBZ, SB and Riječka banka), did make a profit. Their ROA was 0,8 with ROE being 12,2. Apart from the biggest banks, all other banks made a loss in 1998 (CNB, Banks Bulletin No.1). The second negative spike, in 2015, was a result of the Swiss franc credit conversion. As a result of credit conversions, losses were reported by 15 banks whose assets made up almost 2/3 of the total assets (CNB, Banks Bulletin No.29). A recession period of the Croatian economy from 2009 to 2014 also reflected bank profitability, as did the COVID-19 crisis in 2020. Therefore, profitability measures of the Croatian banking industry started their recovery after the end of the domestic recession, with the exception of 2020, with the highest ROA and second highest ROE being recorded in 2023, in which Croatia adopted the euro as its official currency.

Table 1 presents descriptive statistics for the whole sample. Within the sample period, the average value of ROA (as indicated by the descriptive statistics provided by Table 1) was 0,97 while the average value of ROE was 7,26, indicating a rather stable banking sector.

Table 1: Descriptive statistics, 1998-2023, yearly data

	CR2	CR5	HHI	ROA	ROE
Mean	44.04	73.77	1413	0.97	7.26
Median	43.15	74.35	1383	1.19	8.33
Maximum	48.22	83.83	1683	1.76	16.10
Minimum	40.00	58.00	1000	-2.80	-16.10
Std. Dev.	2.59	6.55	167.90	1.01	7.12

As for the concentration measures, the average value of CR2 and CR5 amounted to 44% and 74%, respectively. More importantly, their standard deviations (2,59 p.p. and 6,55 p.p.) were rather small in relation to their average value indicating that market shares of the biggest two and five banks kept rather stable throughout the observed period. Standard deviation of HHI was somewhat greater which is expected given its value range, and more pronounced positive trend in relation to CR2 and CR5.

Next we turned to calculating correlation coefficients between concentration indicators and banking sector profitability measures, as evidenced by the correlation matrix presented by Table 2. High correlation is observable between HHI and concentration ratios, as is the case with the two profitability measures, ROA and ROE. However, correlation between concentration and profitability measures is positive but rather low, with correlation coefficient values ranging between 0,21 and 0,37 indicating positive but low correlation. This could easily be a result of a rather modest number of observations as well as the fact that, most certainly, market concentration is not the sole nor the most important banking sector profitability factor.

Table 2: Correlation matrix, yearly data (1998-2023)

	CR2	CR5	HHI	ROA	ROE
CR2	1.000000				
CR5	0.570356	1.000000			
HHI	0.803249	0.920392	1.000000		
ROA	0.233757	0.376620	0.330097	1.000000	
ROE	0.211764	0.310388	0.253456	0.966591	1.000000

Since correlation does not give insight into causality, and, as explained previously, one of the main questions in bank performance vs. competition hypotheses is whether efficiency (profitability) results in larger market shares or vice versa, we next turned to checking causality between our concentration indicators and profitability measures using pairwise Granger causality tests. Our results, presented within Table 3, indicate mostly insignificant results with the exception of (bolded) ROA and ROE Granger causing HHI, both significant at the 10% level.

Table 3: Pairwise Granger Causality Tests (1998-2023)

Lags: 1			
Null Hypothesis:	Obs	F-Statistic	Prob.
ROA does not Granger Cause CR2	25	0.23181	0.6349
CR2 does not Granger Cause ROA		0.12902	0.7229
ROE does not Granger Cause CR2	25	0.80684	0.3788
CR2 does not Granger Cause ROE		0.25918	0.6158
HHI does not Granger Cause CR5	25	0.51449	0.4807
CR5 does not Granger Cause HHI		0.29781	0.5908
ROA does not Granger Cause CR5	25	0.16484	0.6887
CR5 does not Granger Cause ROA		0.28280	0.6002
ROE does not Granger Cause CR5	25	0.12127	0.7310
CR5 does not Granger Cause ROE		0.79769	0.3814
ROA does not Granger Cause HHI	25	2.95545	0.0996
HHI does not Granger Cause ROA		0.37346	0.5474
ROE does not Granger Cause HHI	25	3.68449	0.0680
HHI does not Granger Cause ROE		0.61719	0.4405

The results after the exclusion of 1998 and 2015 are given by Table 4. As evident, ROE still Granger causes HHI at the 10% significance level while the same goes true for ROA at the 12% significance level. These results could be considered as a viable robustness check of our

previous Granger Causality analysis.

Table 4: Pairwise Granger Causality Tests (1998-2023)

Sample: 1998 2023 IF ROA>0; ROE>0			
Lags: 1			
Null Hypothesis:	Obs	F-Statistic	Prob.
ROA does not Granger Cause HHI	24	2.73288	0.1132
HHI does not Granger Cause ROA		0.42401	0.5220
ROE does not Granger Cause HHI	24	3.40201	0.0793
HHI does not Granger Cause ROE		0.70872	0.4094

Following Ljubaj (2005, pp. 10) who states that the frequency of data matters when measuring concentration in the banking sector since market shares change immediately and given that CNB started publishing quarterly data on profitability measures and concentration indicators in 2016, we next turned to generating correlation matrix for the period between the 2nd quarter of 2016 and the 4th quarter of 2023 (even thaw it would be advisable to check if there would be a difference in correlations between two sets of indicators depending on whether they were generated on quarterly or on yearly basis, yearly data would consist of as much as 8 observation making any conclusions unreliable). Correlation coefficients calculated using quarterly data, as indicated by Table 5, are in line with what was previously attained analysing the whole period of the analysis (1998-2023) with correlation coefficients ranging between 0,19 and 0,37, still indicating a positive low correlation.

Table 5: Correlation matrix, quarterly data (2016:Q2-2023:Q4)

	CR2	CR5	HHI	ROA	ROE
CR2	1.000000				
CR5	0.923422	1.000000			
HHI	0.941455	0.996346	1.000000		
ROA	0.196286	0.266295	0.279666	1.000000	
ROE	0.231118	0.367386	0.372141	0.968772	1.000000

The next step was to check for Granger causality (results excluded to preserve space) where, in this case, our results indicated no Granger Causality whatsoever. This can also be attributed to the fact that between 2019 and 2023 bank assets increased substantially while concentration of the banking market, thaw high, remained rather stable. Moreover, banking sector profitability increased substantially in 2023 which was not related to market concentration as much as to the fact that CNB decided to pull the excess liquidity (due to high inflation rates) by offering banks a 4% overnight deposit rate (at least four times as much as the banks gave out to their clients) which enabled banks to make a profit of 478,9 millions of euros on these interests in 2023 alone (out of the total sector profit of 1,4 billion euros). Driven by the strong growth of interest income, banking sector profit rose by 91% in 2023, with ROA increasing from 1.0% to 1.8% and ROE from 8.2% to a staggering 15.5%, with a marked contribution to this growth coming from income from overnight deposits with the CNB (CNB, 2024).

All in all, regardless of the analysis period as well as the data frequency, our results point to a positive weak correlation between the concentration indicators and profitability measures of the banking sector in Croatia. Granger causality results also indicate that banking sector profitability measures (mainly ROE) Granger cause HHI when dealing with the whole sample period, even when 1998 and 2015 are excluded on grounds of having negative values, unlike when dealing with our subsample. These results could be viable grounds to conclude that in fact

there is a positive link between market concentration and banking sector profitability, however the direction ie. causality is rather data/sample dependent.

As for the concentration indicators, the results point to HHI as being the most relevant one since it is highly correlated with the remaining indicators in all the samples. This being said, since the number of variables used for the analysis can be a liability when dealing with a small number of observations, it is preferable to use HHI as it also takes market shares of all the banks under consideration when being calculated.

6. Concluding remarks

Croatian banking sector, characterised by oligopolistic market structure, is dominated by a handful of foreign owned banks handling the vast majority of total banking assets. The consolidation process of the Croatian banking market produced a high concentration of total assets making it extremely competitive for new banks entering the market (Učkar & Petrović, 2021).

Unlike previous similar research, this research covered a longer period of time covering most recent years characterized, among others, by the stabilisation of the total number of banks which was rather variable earlier on. After analysing concentration indicators as well as banking sector profitability measures, our correlation matrix results indicated a positive, but a rather low correlation between market concentration and banking profitability with ROE (and ROA to some extent) Granger causing HHI for the whole period in question (1998-2023), even after the exclusion of outliers. At the same time, our subsample (2016:Q2-2023:Q4), thaw indicating a positive weak correlation, indicated no Granger causality between concentration indicators and profitability measures whatsoever, again, defying the SCP hypothesis. Our results defy previous research results that mostly confirmed SCP hypothesis (or the Relative Market Power hypothesis, if bank level data/market share was used). In this sense, defining dependent and independent variables in studies that explore the relationship between concentration and profitability of banks should be carried out with great caution. Moreover, central bank regulatory influences should also be accounted for since, as evidenced, CNB enabled domestic banks to gain substantial profits in 2023 as a result of regulatory policy measures. Future research should also focus on quarterly (high frequency) data, as well as bank level data starting from 2016, creating a data panel consisting of all operating banks in the market, using their market shares as well as the overall market concentration indicator. This would enable a true enquiry into the nature of the relationship between the concentration of the banking sector (market share of banks) in Croatia and its (their) profitability, ie. enable the verification of the SCP and RMP hypothesis. Moreover, the rationale behind this recommendation is further amplified by the fact that the number of banks in the market has been rather stable since 2018. In addition, it would be advisable to use the same logic to verify the influence of cyclical fluctuations on bank profitability, mainly, GDP and inflation rate.

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STORYTELLING - THE TOOL FOR CO-CREATING PERSPECTIVE OF A TOURISM EXPERIENCE DESIGN

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Abstract. The growing competition in the tourism market and altered preferences of tourists' consumption have shifted the focus of tourism businesses and destinations from selling tourism products to crafting tourism experiences. Experience economy experts are studying a new generation of consumers who are motivated by experiences and prefer to engage in activities rather than just observe them. Experience quality increases when tourist consumers participate in activities; therefore, professionals and researchers in the field of tourism pay special attention to experience design. The experience designers use techniques that engage visitors with the people, culture, and environment, involving all their senses in the destination experience. In this way, visitors become active participants in the co-creation process of the tourism experience. Tourism businesses use storytelling to engage tourists in the experience design process. Research has shown that stories influence tourist experiences by evoking emotions and enhancing comprehension. A story has the power to connect people who experience it together and through a universal message, increasing the likelihood that they will remember that shared experience. In this context, the research aims to explore the potential of incorporating storytelling in tourism experience design from a co-creation perspective. In addition to the theoretical framework, this paper will also present an example of good practice in applying storytelling to design tourism experiences. The Administrative Department of Tourism, Maritime, and Transportation in Split-Dalmatia County developed the project "Dalmatia Storytelling Destination". The project aims to enhance the quality of cultural tourism by utilizing storytelling tools to present and interpret heritage. The project brings historical events, legends, myths, and historical characters to life in authentic locations. Acting ensembles, heritage interpreters, and digitized visualization play a role in heritage revival and interpretation. Authentic stories engage visitors by involving them in various activities, stimulating all their senses, and encouraging their participation in co-creating the design of the tourist experience.

Key words: *tourism experience, experience economy, co-creation perspective, storytelling, Dalmatia Storytelling Destination*

1. Introduction

To remain competitive on the tourism market, all stakeholders involved in the tourism system must reorient from selling tourism products to providing tourism experiences. This statement is derived from the essential postulates of the experience economy, the fundamental concepts of which were presented by Pine and Gilmore (1998). The experience economy is considered the starting point of a new economic era characterized by the rise of a new generation of consumers looking for experiences.

People experience different experiences in their everyday life and create new ones repeatedly. The lived experience of everyone is shaped by his personality traits, behaviours and acquired knowledge (Pereira, 2019, 27).

In tourism, the emphasis on realized experiences is even greater, due to the characteristics of tourist trips. Tourist travel is undertaken voluntarily to satisfy personal and hedonic needs. Tourists travel not because they have to, but because they want to. Tourists invest their time, effort, and money in shaping their experience at all stages (before, during and after) of their trip with the aim of creating an enjoyable moment of time regardless of their primary goals, motivations, interests, experiences, and skills (Prebensen et al., 2018, 2). Tourists are thus looking for authentic experiences, from which they can learn and in which they can participate in different types of activities.

The tourism experience is therefore fundamentally different from a product or service, since it is a personal, interactive, and complex phenomenon, which results from personality traits behaviours and knowledge and at the same time requires the enjoyment and active participation of the individual. In this context, it is important to understand that tourism operators cannot create an experience for tourists, but they can stage the context around it so that the tourist achieves the best experience as a mental response to the stimulus in the environment (Mossberg, 2007, 61).

Such a higher level of tourism experience is indicated by the phrase “extraordinary tourism experience”. Extraordinary experiences are unforgettable and consist of functions of the memory process, since the experience is strong enough to be encoded into long-term memory. Rarely do such experiences arise solely from a single event; rather, they typically are often the result of many circumstances and include surprise, level of challenge and engagement, interaction with the host, personal significance, and other stimulations. (Mei et al., 2020, 95). Therefore, it is the task of all stakeholders in tourism to create a stimulating environment in which tourism operators will design the stage for creating extraordinary tourism experiences.

Considering the characteristics of tourism experiences as well as the emphasized aspiration of tourists to participate in the experiences design, through learning and participation in different activities, the use of storytelling in tourism is more than welcome (Matošević Radić et al., 2021, 179). Storytelling holds exceptional potential in conveying diverse messages to the target audience and crafting unforgettable tourism experiences.

In this context, the aim of this paper is to theoretically explain the potential of storytelling as a useful tool in the process of designing a tourism experience from the perspective of co-creation. Co-creation refers to the process of creating products or services in which the customer has invested resources, such as time, effort, or skills (Beevor, 2021, 9).

This paper is organized as follows. After the introductory considerations Chapter 2 provides an overview of the literature that supports the importance of co-creation in tourism. In the same chapter, storytelling will be explained based on existing theoretical knowledge. The contribution of storytelling in the design of tourism experiences from the perspective of co-creation is explained in Chapter 3. Chapter 4 will present an example of good practice in the application of storytelling in the design of tourism experiences, while concluding considerations will be presented in Chapter 5.

2. Literature review

2.1. Co-creation in tourism

To explain the concept of co-creation in tourism it is necessary to understand one of the fundamental economic concepts known as market exchange, which differences two basic ways of creating value: “value in exchange” and “value in use”.

“Value in exchange” is produced by a company that then distributes it to the consumer on the market in exchange for goods or money, which is the basic idea of the goods-dominant logic

(Hayslip et al., 2013, 305). This perspective separates the role of “producer” and “consumer”, and value is considered to derive from a series of activities performed by the company (Prebensen et al., 2018, 3).

On the other hand, in the service-dominant logic (S-D), the roles of consumers and producers are not separated, which implies that value is always created jointly through the interaction of providers and consumers (Hayslip et al., 2013, 305) or between customers through the integration of resources and the use of different competencies (Prebensen et al., 2018, 3).

To create an exceptional tourism experience, it is necessary to encourage the creation of value that the tourist will perceive as extraordinary. Vargo and Lusch (2008), starting from the assumption that the value is determined by the customer who bought something produced by someone and values it as such, point out that the customer is always a co-creator of value. This implies that there is no value until the product/service is used because the customer’s perception and previous experience are key to determining value.

In this context, the notion of co-creation, as outlined by Campos et al. (2018, p. 391), refers to the psychological processes, that tourists undergo when actively engaging, both physically and mentally, in activities and interacting with other individuals in the experience environment. From the above, it is important to highlight two factors that are of great importance in the co-creation of the tourist experience: the experience environment and competences and the previous experiences of consumers.

Experience environment describes the physical environment in which an experience is created, and which can influence the atmosphere through certain elements such as sight, smell, sound, touch (Xiang, 2020, 94). Experience environment characteristics influence the way tourists shape the experience as it integrates the physical features of the environment, social actors, and participants as well as organizational dynamics and service delivery features (Campos, et al., 2018, 374). Therefore, experience environment is extremely important in tourism because it allows the tourist to stay for a longer time in the environment that shaped his experience (Mossberg, 2007, 69).

Since in the process of co-creation it is necessary to include a customer who differs from other customers in terms of his characteristics and experiences, the process of co-creation depends precisely on the qualifications and previous experiences of all participants. More creative consumers who, based on their previous experiences, have developed a higher level of expectations will have a greater need and willingness to actively engage in the co-creation process. In order to encourage customers to actively participate in the process of co-creation, tourism companies should encourage the development of interactive tools as a means of co-creation, because only if the tools are stimulatingly designed will consumers feel empowered and will be willing to act in order to fulfil their expectations (Chathoth et al., 2018, 39).

Although it is not the only tool that can be used for this purpose, storytelling has been recognized as one of the most useful tools for co-creation that engages the audience and directs them to extraordinary tourism experiences (Campos et al., 2023, 2).

2.2. Storytelling in tourism

Storytelling is deeply rooted in human nature, as people tell stories during their daily activities, both business and leisure, to facilitate communication and interaction with other people. However, storytelling is often used not only to convey facts and information, but also to enhance and revive the meaning of facts (Mei et al., 2020, 94).

“Telling” in storytelling does not just mean simply “speaking”, but storytelling also involves other senses such as the sense of sight, touch, taste, and smell (Choi, 2016, 1). Relying on all the senses through storytelling increases the likelihood that people will remember the story, because stories can be retained in memory in different ways (visual, factual, or emotional) (Youssef et al., 2019, 4).

While storytelling has long been a subject of extensive study within the scientific area of psychology and sociology, its comprehensive investigation within tourism research has only initiated in recent times (Beavor, 2021; Beavor et al, 2002). Two groups of studies prevail in the tourism literature. One focusing on the role of storytelling in the development of a tourism destination brand (Choi, 2016; Pereira, 2019; Youssef et al., 2019; Beavor et al, 2002).

Choi (2016) determined the way in which storytelling affects the brand value of a destination and the behavioural intentions of tourists. Storytelling has positive effects on the brand value of the destination as follows visitors can more easily accept the story through a picturesque and colourful expression that emphasizes a lot of interesting things about the destination. The brand value of the destination directly affects the behaviour of visitors, like that the intention to return to the destination as well as recommendations to visit the destination will increase if the destination tells a story that is connected to the attractions and at the same time is educational in the field of history, culture, and social relations. In the research conducted by Youssef et al. (2019), authors demonstrated that storytelling is effectively used as a tool to convey messages about the characteristics and brand identity of a destination, which directly affects visitor satisfaction and loyalty.

The other group of studies investigated the contribution of storytelling to the development of new products (Korez-Vide, 2017; Frost et al., 2020; Xiang, 2020; Matošević Radić et al, 2021; Santos et sl., 2022). In their research, Mei et al. (2020) pointed out that the way in which stories are created in farm tourism depends on the available resources, the history of the farm, the authenticity of the story, and the physical environment. Storytelling can be enhanced by tangible elements of the physical environment as well as intangible elements that include interaction and dynamics between host and visitor. Santos et al. (2022) point out that telling stories about wine is key to stimulating visitors’ imaginations in wine tourism. Visitors appreciated the storytelling experience, especially in situations where the narrative was unscripted and flexible, which allowed the storytelling to be more natural and spontaneous (Frost et al., 2020).

Both directions of research into the role of storytelling in tourism have actually the same mechanism of influence, the contribution of storytelling to the design of the tourism experience.

To promote the potential of destinations and design the tourism experience, storytelling becomes crucial. When stories are used through storytelling as a method of dramatizing products and services, it is called storyfication (Alapuranen, 2015, 20). Then the story becomes the main element that connects all the components of the experience and makes it extraordinary and unforgettable.

Since there is a lot of competition between destinations, which have their own unique set of attractions, it is necessary to find unique local stories and promote them in a creative and interesting way. In this way, storytelling becomes a resourceful key tool that enables tourists to become familiar with the local history, culture, and values of the destination in a pleasant and educational way.

The most common storytellers who connect destinations with visitors are tour guides, cultural workers, as mentors and promoters of culture, but also residents, who can convey the atmosphere and values of the destination in the best way. Before the visit, tourists are exposed to stories that spread through various media channels, which influence the creation of an image

of the destination (Roque, 2022, 29), and after the visit they return to their home environment and inspired by stories about the destination also become storytellers. They tell stories about their own experiences in the destination to their friends and family, stimulating their curiosity or imparting relevant knowledge (Pereira, 2019, 36).

Considering the different actors involved in the storytelling process, where even though they are in the same environment, they bring to it different previous knowledge and experiences, as well as expectations, it is almost impossible that the experience of storytelling can be repeated. For this reason, it is important to involve visitors in the co-creation of their experiences so that they remain permanently stored in the visitors' memory.

3. Co-creating perspective of storytelling

Storytelling is a powerful audience engagement tool (Wiyonoputri, 2022, 54) that has the potential to encourage visitors to actively engage in co-creating their experience. Co-creation in the context of storytelling can be defined as visitors' joint inventiveness, joint design and interaction, which positively affects the visitor's engagement, sense of belonging and attachment to the elements of the gradually developing story (Campos et al., 2023, 4).

From a co-creation perspective, storytelling maximizes value for visitors by involving them in the value creation process itself. The co-creation perspective is recognized in research on marketing and business strategies and refers to how visitors' knowledge and skills are used during the tourism experience to influence behaviours that maximize visitor value creation (Mathisen, 2018, 138).

The value of the tourism experience is influenced by several aspects of the quality of storytelling. Telling evocative stories engages participants because it encourages emotional engagement of participants (Moin, 2020, 2) which requires stories to contain strong emotional elements (Beever et al., 2022, 2). Recognizing and sharing the same values through stories helps participants to understand the stories more clearly, which is a prerequisite for involvement in co-creation. Some values that are communicated through storytelling can have similar interpretations in different cultures, so the personal values of tourists can serve as a starting point in creating more authentic tourism experiences. Telling stories with a message that aligns with tourists' values can change the way tourists think about and react to tourism activities (Mathisen, 2022, 7).

Tourists seek for authentic and attractive experiences (Korez-Vide, 2017, 380), and participation in certain experiences contributes to a higher perceived authenticity (Campos et al., 2023, 16). To engage visitors effectively, a narrative must incorporate authentic and emotionally resonant elements that align with the purpose of their visit (Santos et al, 2022, 5). Tourists value authenticity the most when they go on guided tours where authenticity can be emphasized by re-enacting authentic events or interactions with local people. During a guided tour, storytelling contributes to the co-creation of the value of the guide and the tourist because audience participating in the guided tour independently fill in the narrative gaps, reconstruct events in the context of their own experiences and actively involve their imagination (Frost, 2020, 5).

One of the available means for easier value creation is the implementation of information and communication technology that facilitates the connection of producers and consumers in real time (Prebensen et al., 2018, 6). It is easier to get participants interested in participating in the co-creation of experiences in interactive ways. Multimedia support facilitates the creation of a stimulating environment that will enable active participation in the stories. On the other

hand, since tourists shape their memories of people and places into stories based on their lived experiences, information and communication technology enables them to create and publish stories about the destination even in real time (Youssef et al., 2019, 5). Therefore, extraordinary tourism experiences are (re)presented, (re)produced and (re)created with the help of storytelling, photographs, videos, and other forms of communication between people (Guleria et al., 2024).

4. Dalmatia Storytelling destination

Dalmatia Storytelling Destination is a project of the Split-Dalmatia County Administrative Department for Tourism, Navigation and Transport, which aims to promote the cultural and historical heritage of the Central Dalmatia region through storytelling. This initiative aims to create immersive experiences for visitors that highlight the rich tales, legends and history of Dalmatia. This includes guided tours, multimedia presentations, educational programmes and collaboration with local storytellers, historians, artists, travel agencies, tourist boards, museums, eco-ethno-villages and landlords to bring the stories of Dalmatia to life. The project focuses on reviving historical events, phenomena, legends, myths and historical figures in authentic places using the method of storytelling. The aim is for tourists to experience Dalmatian culture through memorable, authentic and emotional stories that are rooted in Croatian culture.

The slogan of the project “One pebble, one story” refers to the richness and depth of storytelling in the Dalmatian region. It implies that each pebble, each fragment of the landscape, has a unique story that contributes to the overall narrative picture of Dalmatia. This slogan is reminiscent of images of discoveries, with each pebble representing a new story waiting to be discovered and shared with visitors.

Launched in 2020, the project has helped to develop forty (40) new tourism products in four years (two of them under COVID) (Dalmatia Storytelling, 2024). These products include thematic narrative tours that explore different aspects of Dalmatia’s history, culture and folklore. The tours are co-created with trained and licenced tour guides and museum curators involved in the project. These products are available online at www.dalmatiastorytelling.com. This is a unique platform for thematic experiences and heritage stories. On the website can be found Dalmatian story or experience, that are commercially available throughout the year.

4.1. Co-creation of storytelling tours

Co-creating storytelling tours requires collaboration between different stakeholders to develop engaging and immersive experiences that highlight the stories, history and culture of the Central Dalmatia destination. The process of co-creation involves several phases, such as recruiting project participants, conducting educational programmes, developing stories, testing products and marketing the products.

The target group of the project are licenced tour guides and museum curators who live and work in Central Dalmatia. The Split-Dalmatia County issued a public call for participation in the Dalmatia Storytelling programme. The aim was to jointly develop two types of tourism products, namely thematic storytelling walks and guided tours reviving historical figures in museums and important cultural sites. These products had to be commercially available all year round, offered in Croatian and English and based in the museum and tour guide’s home area.

The first generation of interpreters has forty members. The Dalmatia Storytelling interpreters must complete an intensive training programme. The first programme consists of 40 hours of training. Participants learn the methods of interpreting and narration based on the Freeman-

Tilden principles of interpreting (Tilden, 1977). They then have to take an exam to obtain the Interpret Europe certification.

The second part of the programme involves creating a narrative for the tour, using the template for the narrative structure of cultural heritage tours designed within Dalmatia storytelling destination project. Creating a tour narrative requires extensive research, writing and rewriting until it is ready. During this process, participants are personally mentored by the project manager to co-create products that meet Dalmatia Storytelling's quality standards. The final phase of story development includes the practical and public presentation on a test tour in front of their peers and the Dalmatia Storytelling team.

The test tour is the final step before receiving the Dalmatia Storytelling Quality Certificate. The tour takes place in an authentic location where interpreters must use the approved narrative and apply their storytelling skills to deliver a powerful thematic heritage tour. If they do not perform at the required level, interpreters must repeat the test tour.

4.2. The power of story and co-creation of tourism experience

Throughout history, stories have been used to entertain, educate, persuade, preserve cultural heritage and shape values. Storytelling has the power to awaken the imagination and emotional connection that leads to eternal memory. Through myths, legends, folklore and oral traditions, societies pass on their collective wisdom, history and identity. Therefore, the collective memory of a society is deeply rooted in storytelling and vice versa. Collective memory shapes collective values, which in turn strongly influence individual values.

Individual understanding of the world is derived from one's own values and is closely interwoven with collective values. This becomes particularly clear when you present the same story to visitors from different countries. Visitors from the same region react, interact and interpret a story in a very similar way to their compatriots, but differently to people coming from other regions of the world. Therefore, it is important to understand the interpretation process when creating and presenting stories, especially if your goal is to build cultural empathy and strengthen a sense of belonging.

Dalmatia Storytelling develops products that offer visitors authentic personal experiences while building cultural empathy and a sense of belonging. The story development process involves the creation of narratives that provide for 'two-sided' interpretation.

On the one hand, the narratives are based on universal themes and emotions, so people can always associate the stories with something that is personally meaningful to them, regardless of individual or cultural differences. These stories allow visitors to experience different perspectives and understand the experiences of others, while using some familiar concepts and emotions that allow them to see things from a different point of view. The aim is to promote empathy, compassion and tolerance, contributing to greater understanding and unity between different groups of people.

Another aspect of the narrative structure is the inclusion of a dialogue that encourages discovery. Visitors answer and ask questions and search, touch, smell and taste. In this way, the guide/curator stimulates all the senses to evoke imagination and create a lasting emotional connection with the subject of interpretation. Through this inclusion and personal engagement, the visitor helps co-shape the experience, which makes it an authentic personal experience.

In addition, shared stories bring people together and reinforce social bonds that build a sense of belonging. The sense of belonging also contributes to a strong connection with the theme of the interpretation and the place, and therefore to the experience as a whole.

In essence, the power of the story lies in its ability to touch hearts, stimulate minds and shape the way we perceive and interact with the world around us.

5. Conclusion

The tourism market is faced with a change in the key economic paradigm, which replaces the sale of tourism products with the creation of tourism experiences. This change is accompanied by an increase in the number of studies that seek to understand and explain the change in the behaviour of tourism consumers, but also to find ways to maximize the value of the tourism experience.

Tourists increasingly appreciate “use value” and value the tourism experience according to the interaction they had with the service providers in the tourism destination. Therefore, tourism service providers face the challenge of how to encourage tourism consumers to actively participate in the co-creation of the tourism experience.

In this context, the intention of this paper was to theoretically explain the potential of storytelling in the design of the tourism experience from the perspective of co-creation. Storytelling increases the value of the tourism experience by encouraging tourists to be involved in the value creation process. Using a combination of all senses and a narrative that promotes local authentic stories in a creative and interesting way, storytellers strive to permanently connect tourists with the destination so that they too tell stories and contribute to the good reputation of the destination. Storytelling encourages co-creation of the tourism experience by choosing authentic stories that are told in an evocative way and that are in line with values that tourists can identify with. The application of information and communication technology can create a stimulating environment in which tourists feel more comfortable and more easily decide to actively participate in the co-creation of the experience.

Recognizing the contribution of storytelling to the development of the tourism product, the Administrative Department of Tourism, Maritime, and Transportation of Split-Dalmatia County developed the Dalmatia storytelling destination project. The project has been implemented since 2020 and resulted in the development of 40 new tourism products that encourage an active process of co-creation, providing visitors with authentic personal experiences, but also encourage the building of cultural empathy and a sense of belonging.

The project is an example of good practice because it implements internationally recognized principles of heritage interpretation that they apply in the process of creating authentic stories. The stories are created to encourage visitors to actively co-create the tourism experience since the narratives are created based on universal themes and emotions so that people can always connect the stories with something meaningful to them regardless of individual or cultural differences. The project contributes to enriching the offer of tourism products as well as the reputation of the destination, since it inspires new storytellers who will tell new stories about the destination in their environments.

Although this paper proves, not only theoretically but also on an already developed project, that storytelling can be effectively used to involve tourists in the co-creation of the tourism experience, there is no methodology that can evaluate the actual effect of this contribution. Therefore, as a recommendation for future research can be proposed the development of a methodological framework that will quantify the mentioned contribution.

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UNDERSTANDING THE IMPACT OF INTERACTION BETWEEN TOURISM AND TRADE IN GENERATING WASTE IN CROATIA

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Abstract. According to statistical data, Croatian tourism has contributed a higher share of GDP than any other European Union (EU) member state. Therefore, this sector is considered as a vital part of the national economy, which affects other industries, such as transport, trade, construction, etc., and the tourist destination as well. This paper presents a relationship between tourism and trade, which is mostly evident in the increase of shopping as a motivating travel activity and its significant contribution to retail trade. However, with this positive aspect of the interaction of tourism and trade, Croatia has experienced a substantial increase in waste generated by tourists, which ranges from food, beverages, souvenirs, etc. Since a large part of Croatia has insufficient or a lack of waste management infrastructure, it leads to improper waste disposal and local environmental problems, such as groundwater or soil contamination, harm to wildlife, etc. The main goal of this paper is to investigate the impact of this interaction between tourism and trade in generating waste in Croatia. For the purpose of this paper, the methodology used included an analysis of available data and reports on tourism activity as well as attitudes and expenditures of tourists in Croatia. The results contributed to an understanding of tourists' consumption patterns and their attitudes towards waste management in Croatia, which is essential for improving waste management and waste infrastructure at the level of the tourist destination. Besides some implications for the administrators of tourist destinations to better understand how to minimize negative consequences of increasing tourists' consumption on waste generation, this paper also contributes to deepening the scientific knowledge on the correlation between trade, tourism and waste management.

Key words: *tourism, trade, waste, impact, Croatia*

1. Introduction

For the last 75 years there has been a rapid development in the tourism industry in the world and nearly a constant increase in the number of international arrivals. Despite the evident importance that tourism has for the economy, much literature is devoted to the negative impact tourism has in tourist destinations. The topics range from a negative cultural impact (Agarwal et al., 2023; Shahzalal, 2016), socio-cultural impact (Jehan et al., 2022; Liu et al., 2023), to environmental impact (Aslam, 2020; Baloch et al., 2023; Singh, 2012) and therefore, the overall quality of life of the local population as well. (Andereck & Nyaupane, 2011; Yulan, 2013). The environmental damages caused by tourism include environmental degradation, high emission of carbon dioxide, pollution, littering, etc.

At the end of the 20th century, there was an increase in awareness and knowledge not only about the many positive effects that tourism has in destinations, but also about its numerous negative impacts arising as the result of mass tourism. Therefore, in conducting its activities, tourism is searching for principles which will provide long-term and sustainable tourism development in some areas (Bučar & Vujević, 2020). Accordingly, tourism has the strongest alarming potential to cause a serious global footprint. This paper considers the problem of increasing waste generated by tourism activities. Namely, tourism, as one of the fastest growing sectors (Statista, 2023) affects other industries, such as transport, trade, construction, etc., resulting in an increasing demand for their services and dramatically increasing waste generation as well. Tourism generates waste in many different ways, from transportation (e.g. airline companies with food and beverage containers, plastic packaging, glass, food waste), hospitality (food waste, food packaging such as cans, glass, plastic, packaging of cleaning agents, used textiles, paper, etc.), to tourism activities and tourist shopping during their stays in a destination (Muller, 2004). Accommodation generates the largest amount of waste. According to the data, one hotel room per one tourist a night generates from 0,515 to even 3,1kg of unsorted municipal waste (Pirani & Arafat, 2014). Hockett et al. (1995) suggest that retail sales (with the components of restaurant sales, merchandise, food stores and clothing stores) are a measure of tourism and waste generation. As Gruber et al. (2017) state, every tourist generates 1.67 kg waste per day.

In 2022, Croatia reported a total of 18,9 million tourist arrivals, with an average stay of 5,1 days (CBS, 2023). Tourism has a very important role in the economy, accounting for almost 19 percent of Croatia's gross domestic product (GDP) which was among the highest share of GDP compared to other European Union (EU) member states (Statista, 2023). Specifically, the majority of tourist overnight stays (85,5 percent) were realised from June until the end of September in Croatia (CBS, 2023). However, as a parallel with the increasing number of tourist arrivals, the quantity of generated waste increased as well, especially during the busy summer months which raised another set of problems for the waste management in tourist destinations. According to WWF Report (2019) Croatia has the 3rd highest waste generation per capita in the region. This data is truly worrying if we consider that the official statistics have recognised a relationship between waste generation and increasing consumption. The purpose of this paper is to investigate the impact of the correlation between tourism and trade in generating waste in one of the most popular destinations in Europe, Croatia (HTZ, 2023).

A UNEP (2024) tourism forecast will result in increases of energy consumption by 154 percent, greenhouse gas emissions by 131 percent, water consumption by 152 percent and solid waste disposal by 251 percent by 2050. With this in mind, a new waste management policy was created in compliance with EU regulations. It identifies the measures to protect the environment and human health by preventing or reducing waste production. Following this introduction, the next section gives a literature review on the impact that tourist consumption, shopping and other activities have on the environment. Next, an analysis of available data and reports on tourism activity, attitudes and expenditures of tourists in Croatia are shown. The section that follows provides a discussion on the most important findings. Finally, a conclusion and direction for the future research are given.

2. Literature review

The impact of tourism is complex and well investigated in the literature from both positive and negative points of view. For the purpose of this paper we will focus on the review of works about the negative impact that tourism and its related activities have on the environment, particularly waste generation. Waste has been defined as any product or material which is

useless to the owner and the owner would want, plan or has to dispose of (OG, 2023). The main sources of waste generation in tourism are accommodation and supplies, major events, shopping activities, restaurants, etc.

Considering the predictions (Statista, 2024) about the increasing number of international tourist arrivals in Croatia (in total seven million arrivals (+13.22 percent) between 2024 and 2029), increasing tourist consumption which is correlated with waste generation, we may notice an evident lack of scientific works about this topic in Croatia. There are valuable works (Anić Vučinić et al., 2018a, 2018b; Kiš et al., 2021; Mance, Vilke and Debelić, 2020) on the impact of tourism on waste generation in Croatia's coastal areas where the authors found out that the relative waste disposal impact of tourists is up to 50 percent greater than of local residents. One group of works (Damjanić, 2013, 2014; Šulc and Valjak, 2012) focus on the Croatian islands of Mljet and Krk and conducted research among the residents which confirmed rapid degradation of the environment caused by excessive tourist activities.

Similar to the Croatian authors, the majority of foreign works investigate the consequences of increasing tourist activities on waste generation in coastal areas. Analysing the problems that arose during summer months on the Corfu Island, Koliotasi et al. (2023) stressed the mutual negative effects of mass tourism and inefficient waste management of the island. The group of authors direct their attention and research focus on the Spanish island. Mateu-Sbert et al. (2013) estimated the impact of tourists on municipal solid waste for the Spanish island of Menorca and found out that on average, a 1 percent increase in the tourist population causes an increase of generated waste by 0.282 percent. Martins and Cro (2021) had the same research intention and estimated the impact of tourist activities on solid waste generation in Madeira. Their empirical evidence showed that tourism activities are responsible for more than 40 percent of the solid waste generated per resident in Madeira. In their case study in the Canary Islands, Santamarta et al. (2014) demonstrated the problem of uncontrolled disposal of waste and a high production of waste annually as tourist activities on the Canary Islands do not have seasonal character, instead they take place during the whole year. Ezeah et al. (2015) also based their work on the case study of the Canary Islands, along with three other Mediterranean tourism destinations: Mallorca, Kefalonia and Rhodes.

Countries that have experienced significant development in the tourism industry have also experienced many benefits of increasing tourist arrivals but are struggling with the problem of the increased generation of waste, mostly of packed items such as food, snacks, and beauty products purchased by tourists. Giang et al. (2017) explained that tourism commercial activities, including lodging, dining, travelling, shopping and entertainment, accounted for 65 percent of the total municipal solid waste in Vietnam. Malra (2015) emphasised that a higher number of tourists caused an increase of solid waste from 12 to 20 tonnes in Uttarakhand, one of the Indian states at the high peak of the tourist season. Pandey et al. (2023) investigated the role of tourists related to plastic waste generation which could lead to many water-born diseases and found out that on average, more than 300 g/day of plastic waste was generated at each selected shop in which tourists were the major source for generation. Just like Pandey et al. (2023), Wang et al. (2021) concluded that tourist knowledge, awareness and behaviour towards waste generation are the key factors for effective waste management. Many works warn about the inefficient, unsustainable and sometimes confusing waste management system and waste management practices (Baloch et al., 2023; Karwan Obaid Hamad, 2022; Koski-Karell, 2019; Manomaivibool, Panate, 2015; Pham Phu et al., 2019; Shamshiry et al., 2011; etc.). Moreover, some authors suggest that the growing number of tourists may threaten economies that are strongly dependent on the quality of the environment (Comerio et al., 2021; Solmaz et al., 2019) and their image (Koliotasi et al., 2023).

3. The role of tourism and retailing in generating waste in Croatia

The early beginnings of Croatian tourism development were documented in the first half of the 19th century, but its rapid development was evident in the second half of the 20th century. For example, in 1970 there were 2,8 million tourist arrivals and 28,5 million tourist overnights in Croatia, while 19,5 million tourist arrivals and 92,5 million tourist overnights were reported in 2023. (CBS, 2024.). In general, Croatia can still be proud of its preserved environment. However, its long period of tourism development and increased number of tourist arrivals and overnight stays in the last two decades have caused some obvious negative consequences. For example, developments in the specific areas, such as excessive construction or problems with waste disposal (Bučar et. al., 2020).

Decisions regarding waste management in Croatia are based on waste management plans. The first plan was adopted in the period from 2007–2015 (OG 85/07, 126/10 and 31/11) and included the construction of 11 waste management centres (hereinafter: WMCs) for treatment of mixed municipal waste and other waste that was not previously recyclable in Croatia. Besides that, according to this plan, each local self-government unit was responsible for providing its own waste management system. The second plan was adopted for the period 2017-2022 (OG 85/17) continuing the same direction of waste management, although after ten years there were only two of the expected 11 WMCs (by the first waste management plan) were in function. At the beginning of 2023, a new waste management plan for the period of 2023-2028 was adopted and followed the same strategy of waste management as the two previous plans. (OG 84/23).

Bearing in mind that the EU average of municipal waste per capita is 521 kg, and Croatia has 454 kg per capita respectively, that is about 10 percent more waste collected than it was in 1995 (Sunce, 2023). Accordingly, 1,5 kg of waste per capita was produced in 2020, of which 10 percent in the service industry (OG 84/23). Table 1 suggests a direct relationship between waste generating and tourism. In 2020, due to the COVID-19 pandemic, there was a significant decline (23,7 percent) in tourist overnight stays and the quantity of waste generated by tourism. With an increasing number of tourist arrivals and overnight stays in 2021 and 2022, growth is evident in total quantities of generated waste from tourism. (Table 1). Moreover, waste from tourism increased its share from 6 to 9,9 percent in total quantities of waste (Table 1), which is the same as 10 percent of the total number of Croatia's residents. Due to the data for 2021, Croatia has 3,8 million residents (CBS, 2023). The Croatian Agency for the Environment and Nature data (HAOP, 2023) shows that the quantities of waste produced from tourism increased from 2015 to 2022 by slightly less than 100 percent. At the same time, the number of tourist overnights increased by nearly 33 percent. Although the waste management plans (OG 84/2023) consider local self-government units responsible for waste management and the execution of waste prevention measures, this data suggests that Croatia has no adequate waste prevention measures for local residents and for tourists visiting Croatia as well.

Table 1. Waste generated in tourism (2014 - 2022)

Year	Tourist overnights (millions)	Generated waste (tonnes)	Share in total municipal waste (%)	Population equivalent
2015	71,6	98.960	6,0	256.374
2016	78,0	139.535	8,3	355.956
2017	86,2	155.958	9,1	374.899
2018	89,7	165.251	9,3	382.525
2019	91,2	171.505	9,5	386.273
2020	41,0	83.794	5,0	200.464
2021	84,1	136.512	7,7	312.384
2022	104,8	181.642	9,9	383.211

Source: HAOP, 2023; MINT, 2023

Up to 2023 and the introduction of the new waste management plan, only three waste management centres were established. All of them are in the Primorska tourist macroregion, as follows: WMC Kaštijun in Istria, Mariščina in Rijeka, and Bikarac near Šibenik (OG 84/23). The Primorska tourist macroregion is a Croatian region with the highest number of tourist arrivals and overnights. For example, 67,2 million tourist overnights were realised in this tourist macroregion in 2021, which represented the largest share (95,7 percent) of total realised overnights in Croatia that year (70,2 million).

Croatia has been administratively divided into 20 counties and the city of Zagreb (CBS, 2023). Seven counties, which belong to the Primorska tourist macroregion, produced on average more quantities of municipal waste per capita in 2021 than the Croatian average reported quantities of 454 kg per capita. A direct relationship between producing waste and tourism in Croatia can be seen if we compare data on realised tourist overnight stays and municipal waste production per capita, by counties (Figure 1).

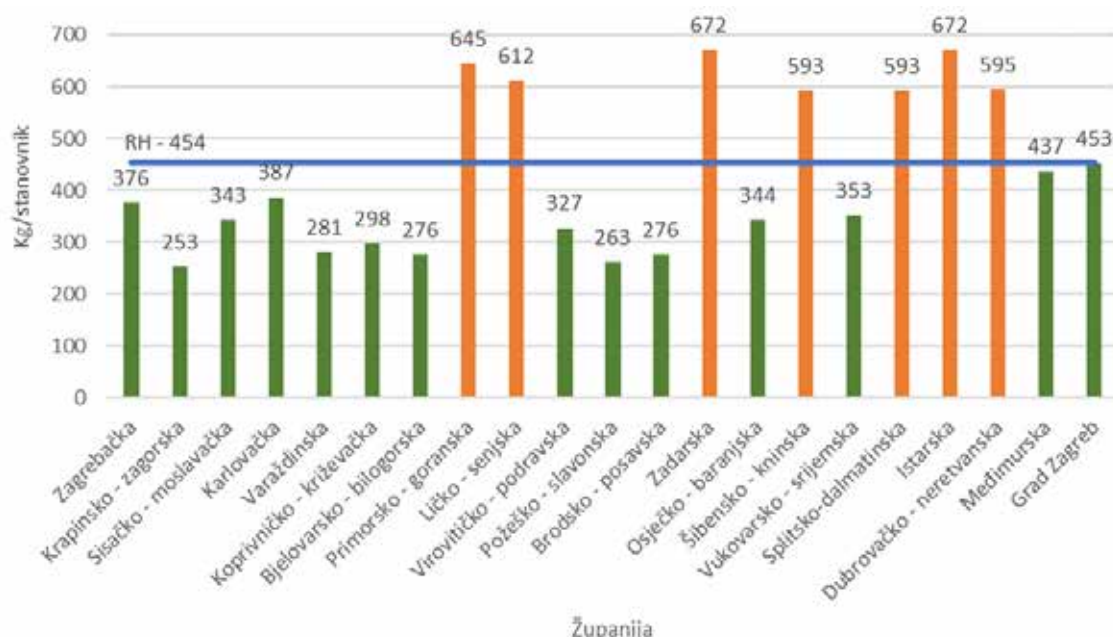


Figure 1 Annual amount of generated municipal waste per capita in 2021, by county
Source: Official gazette of the Republic of Croatia (2023)

Although tourism makes up nearly 20 percent of GDP in Croatia's economy, and retail is a main component of the tourist offer (Knego et al., 1999.), there is no specific research that deals with the role of retail in tourism. The only research in Croatia that deals with the question of tourist consumption in Croatia is the TOMAS research which has been carried out continuously every couple of years since 1997. TOMAS's stances and tourist consumption in Croatia (2023.) show how the average tourist in Croatia 2022/2023 made the consumption of 140 euros, of which 48 percent of the expenses are from accommodation services, 20 percent on food service and drinks outside of the place of residence, and 32 percent on all other services (TOMAS, 2023). According to that same source, tourists showed dissatisfaction for the shopping options, and so from the total consumption of 140 euros, just 16,5 percent of it is used for shopping by tourists. Nevertheless, it is still noticeable that tourists rate the shopping options better compared 2017, when they rated the shopping choices in the Primorska touristic macroregion poorly, in 2019 average and in 2022/2023 satisfactory (TOMAS, 2023.). Even so, TOMAS research shows how tourists pointed out inadequate waste disposal, unpleasant smells (from containers and trash cans) and the inability to separate waste as elements that affected their stay the most in the tourist destination (TOMAS, 2023.)

It is very likely that these kinds of tourist evaluations were influenced by the fact that not only was 90 percent of all tourist arrivals and overnights realised in one tourist macroregion – Primorska, but also the fact that in Croatia from June to September 2022, 85,5 percent of total tourist overnight stays were achieved (CBS, 2023.) This kind of situation with the distribution of tourist arrivals and overnights is nearly identical for the past three decades. (CBS, 2023.).

An undisputable fact is that in Croatia the largest share of tourist arrivals and overnights is accomplished mostly in the summer months and the Primorska tourist macroregion significantly weighs down efficient planning and waste management. It is very difficult to implement effective waste management in Croatia because in a short time frame, and in a relatively small space, a large amount of waste is created through tourism (Bučar et al. 2020.). The only way to achieve better waste management in Croatia is implementing a more efficient solid waste system, as well as better education of all participants in tourism to simultaneously decrease waste production.

4. Discussion

Tourism causes numerous positive and negative effects in the areas where it occurs. Each tourist destination is specific by its characteristics and it is not possible to implement one standardized solution for minimizing negative and maximizing positive effects of tourism activities, respectively (UNEP and UNWTO 2012). Waste prevention and waste management are among the main challenges for environmental preservation worldwide. This problem is especially evident in the tourism industry, as during their travel tourists expect preserved nature and tourist resources (UNWTO, 2024). Therefore, many different actions are conducted in an order to point out prevention possibilities for waste produced by tourists. Thus in 2004 UNWTO released a document with indicators for measuring the waste volume produced by destination and recommendations on how to decrease the waste generated due to tourism activities (UNWTO, 2004). At the EU level, in 11 cities, the project “URBAN WASTE – Urban Strategies for Waste Management in Tourist Cities” was conducted from 2016-2019 (EC, 2024). This project showed that waste management was quite challenging for all areas with significant tourist activity and the various countries and cities have different approaches to waste management (EC, 2024). As a result of the project, some proposals about how to reduce the waste production generated by tourism were identified as well as how to improve waste management in highly visited tourist destinations (EC, 2024).

At the same time, tourism is a very complex socio-cultural phenomenon where many stakeholders with different views about tourism operate and are involved. Stakeholders include any individual or group with interest in or the potential to impact the process and have a positive or negative effect on the outcome of a business (Freeman 1984; Savage et al. 1991). In the case of the tourism industry, stakeholders are customers (i.e. tourists in tourism) and governments, local communities, company suppliers (directly and indirectly involved in tourism) such as transport, hospitality, the food industry, retail etc. (Freeman, 1984; Swarbrooke 2001; Čavlek et al. 2011). Each of these stakeholders should take some social responsibility (SR) in order to conduct tourism in the long-term with positive effects. For the first time, the term social responsibility in tourism appeared at the beginning of 1980s based on the term corporate social responsibility (CSR) (Barišić and Bučar, 2022). CSR appeared in the 1960s when society asked companies to adapt their business and become more socially responsible due to some pressure about changes lifestyles (Saylor Academy 2012). Social responsibility in tourism means that all stakeholders, at all levels will be directly or indirectly involved in tourism activities, accept their responsibilities and adapt their business in order to be more sustainable in the long-term and less harmful to environment (ISO 2010; Paskova & Zelenka, 2019; Barišić & Bučar, 2022).

Retailing is the main component of the tourist offer (Knego et. al. 1999; Čavlek et. al. 2011). WTTC (2023) pointed out that retail tourism is much more than just simply buying souvenirs, it contributes to overall economic growth in areas where tourism takes place. There are numerous positive effects for retail tourist destinations, such as alternative employment and revenue options. At the same time, the opening of new shopping malls, tourists could be redirected towards less popular tourist destinations (WTTC, 2023). However, we should take into account that as the results of tourist shopping in certain destinations, retail tourism generates additional waste quantities which have to be prevented and adequately managed. Accordingly, retailing is considered as one of the important stakeholders which should be included in the reduction of waste. WTTC (2023) suggests that the relationship between retailing and waste generation is not a highly explored area. There are mostly works related to food waste management (Huang et. al., 2021; Riesenegger et. al. 2022, WTTC, 2023). Therefore, more effort should be made to address this gap.

However, we should not disregard the role of tourists as active stakeholders in waste production at tourist destinations due to some activities and shopping. Also, we should not ignore the fact that every tourist generates large quantities of waste on a daily basis. "Waste production" is increasing since tourists are purchasing more and more in some tourist destinations. At the same time, tourists do not feel responsible for the waste generated during their travel as they use to spend limited time in a specific tourist destination (Mateu-Sbert et. al. 2013). However, tourists are stakeholders in the tourism industry, and thus, they are socially responsible for the effects their visits and overnight stays make in a tourist destination (Čavlek et al., 2011). Personal Social Responsibility (PSR) represents "the daily life behaviour of the individual, as a member of society and describes an individual's behaviour toward and the effects on his/her social and ecological environment through his/her daily decisions" (Lopez Davis et al. 2017, p. 148).

Therefore, proper waste management at the destination level is an essential problem (UNWTO, 2024) which should be solved. Besides the necessity to improve the waste management system, some efforts to decrease the waste generated from tourism and retailing should constantly be made. However, tourist destinations often do not have enough financial resources and a clear focus to apply proper waste management methods. It is necessary that all stakeholders in the tourism industry make some efforts to reduce the amount of waste generated (Obersteiner et al., 2021). This will only be possible when all participants (stakeholders) in tourism take over PR for their actions within the tourism industry. All stakeholders that are directly or indirectly involved in the tourism industry should figure out that all their actions could have positive or negative consequences and that it is necessary to find way to maximize the positive and minimize the negative effects in order to make tourism sustainable in the long run.

5. Conclusion

Tourist destinations with preserved and attractive tourist resources are the most visited by tourists. Thereby, many positive effects must be made. On the other hand, mass tourism characterizes some negative effects in practice. They are mainly seen in inappropriate construction, noise pollution and traffic congestion in tourist destinations, as well as generated waste that should be properly managed. Accordingly, tourism faces a "closed circle" in some tourist destinations where tourists expect preserved nature and top quality tourist offerings. However, due to the increasing number of tourists, it is getting harder to meet such tourists' demands and to prevent the degradation of the environment. In other words, it is not easy to provide long-term tourism activities with all stakeholders satisfied. One of the biggest issues in tourist destinations is finding a way to establish efficient waste management, particularly in those destinations with large numbers of tourist arrivals in the short term. Croatia is one of such destinations.

This paper shows the ineffectiveness of the Croatian waste management system, especially in Primorska, the main tourist macroregion with the largest number of tourist arrivals. Therefore, this paper can serve as a quality base for further research about all the destinations with mass tourism characteristics. Moreover, the findings of the paper are important for all that work in the tourism industry because they have to understand the necessity of the changes needed in the management of waste from tourism. Self-government units are not solely responsible for establishing an efficient system, rather all other stakeholders should accept their part of the responsibility in order to make the conditions for generating less waste and for its proper storage once when an efficient system is established at the level of a tourist destination.

The paper has its limitations, since it does not include any empirical research and the findings were made on secondary data analysis. Besides that, there is a lack of data available on waste produced by tourists in different periods and counties.

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THE SDG LABORATORY OF THE VALENCIAN COMMUNITY: AN EXAMPLE OF PUBLIC-PRIVATE COLLABORATION AND A LEARNING EXPERIENCE TO SUPPORT SMES AND ENTREPRENEURS.

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Abstract. In 2021, as part of an initiative of the government of the *Generalitat Valenciana*, together with four educational institutions, created the *Laboratorio ODS de la Comunitat Valenciana* (Valencian Community Sustainable Development Goals' Laboratory). The Lab constitutes an institution of social transformation that was born with the vocation of being a space for research, transfer, and dissemination of research results related to Sustainable Development Goals (SDG) to the Valencian society. The importance of this topic lies in the fact that we are approaching 2030 and despite the commitments voluntarily made, there are notable delays in the implementation of the SDGs in the Valencian business fabric. The SDG Lab project of the Valencian Region is an excellent example of how public-private initiative is useful when it comes to advancing sustainability issues. This paper is relevant as it describes an initiative that effectively contributes to raising awareness among Valencian businesses about an issue of transcendental importance and it shows an example of how Valencian organisations receive support in incorporating the SDGs into their strategies.

1. Introduction.

In 2015, because of social, economic, and environmental changes and the great challenges facing humanity in the 21st century, the United Nations approved the Sustainable Development Goals (SDGs). A total of 193 countries committed to addressing the major global challenges comprehensively and urgently, embodied in an agenda with 17 goals and 169 targets to be met by 2030. The Sustainable Development Goals have meant a turning point in existing public initiatives of a social and environmental nature (Cermelli & Trápaga, 2021).

With almost half of the time covered by the 2030 Agenda having elapsed, the implementation of actions committed in the agreement has suffered some delay, partly due to the difficulty of understanding and implementing the required changes. This problem, which affects all organizations is even more acute in the case of micro, small and medium-sized enterprises, which do not have the economic and human resources to keep up with the circumstances (ESEADE & Fundación La Caixa, 2018; Gobierno de España, 2021; Cuñat Giménez et al., 2022; García Ortiz et al., 2022).

In this context, in the year 2021, the *Laboratorio ODS de la Comunitat Valenciana* was born, an initiative of the government of the Valencian Community together with four educational institutions, Florida Universitaria, Universitat Jaume I, ESIC Business & Marketing School and the University of Valencia. The Laboratory constitutes an institution of social transformation that was born with the vocation of being a space for research, transfer, and dissemination of

research results to the Valencian society. Likewise, this laboratory has had as its fundamental mission to promote and analyse the participation of companies in the achievement of the SDGs and their implementation in the territory of the Valencian Community.

The aim of this paper is multiple: i) to comment on the central aspects related to the creation and the evolution of the SDG Laboratory, ii) to comment on the activities that were developed, the results achieved and their relationship with the established objectives, iii) to explore the activities developed by the laboratory and the results achieved, iv) to mention the academic and professional output and main activities developed, and finally, v) to comment lessons learned, assess the possibilities of scalability of the program and make some concluding remarks.

2. The Creation and the evolution of the Laboratorio ODS Comunitat Valenciana.

2.1. The SDG in perspective.

In 2015, the United Nations proposed a new SDG agenda, based on 17 goals, 169 targets and 232 indicators, aimed at ending poverty (economic sustainability), protecting the planet (environmental sustainability), and ensuring prosperity for all (social sustainability) (United Nations, 2015). The SDGs cover a wide range of issues including poverty, hunger, health and well-being, education, gender equality, water and sanitation, energy, growth and employment, industry and innovation, inequalities, sustainable cities, responsible consumption and production, climate action, oceans and underwater life, biodiversity and terrestrial life, peace and inclusiveness, and global governance (Figure 1).



Figure 1 The Global Goals of Sustainable Development

Source United Nations.

The SDGs are an integral part of the 2030 Agenda for Sustainable Development, a roadmap that seeks a common social objective, sustainable global and human development. This agenda is supposed to engage and commit into sustainability countries, organizations, public administrations, and other actors, operating both at the international and the local level. Furthermore, these goals now constitute a blueprint for a sustainable future for all. They are interrelated and incorporate the global challenges that humanity faces daily, including issues such as poverty reduction and inequality, climate change, environmental degradation, prosperity,

peace, and justice; the main challenge of the SDGs is to accomplish sustainable economic growth, full and productive employment, and decent work for every person in the world, in developed and emerging countries (United Nations, 2015; DGPOLDES, 2018; United Nations, 2018; Broz Lofiego, et al., 2020; Cermelli & Trápaga, 2021; Cuñat Giménez et al., 2022; García Ortiz et al., 2022).

The United Nations recognizes that each country has the primary responsibility for its own economic and social development and encourage member states to formulate national responses for its implementation (United Nations, 2015; United Nations, 2018; Gobierno de España, 2021; Navarro Moros & Broz Lofiego, 2022). Cerdá (2020) considers that “the conditions facing the achievement of the SDGs are very different and depend on the circumstances of each country, and even within countries, the conditions can be very varied and sometimes insurmountable, so the degree of difficulty of this task takes on features in each region. Nevertheless, if there is commitment and political will on the part of the actors involved, the goal or the greatest progress can be achieved.” (pp. 153). Dziubaniuk et al. (2021) argue, there is a huge challenge in SDG management, which includes a great complexity regarding the interaction in international stakeholder networks in the context of projects focused on the implementation of the Sustainable Development Goals.

The new way of understanding and exercising business management that the Sustainable Development Goals represent, has aroused the interest of different organisations and institutions at local, national, European Union and international level. These, little by little, have begun to issue different pronouncements, communications and documents that have become the reference framework for understanding the SDGs and why sustainability must be promoted in companies. In this sense, is important to remark that responsible business brings an innovative approach to accelerate the implementation of the SDGs among companies. Companies have turned out to be a key factor in promoting more sustainable development and in managing social and environmental impacts. Business concern about the SDGs stems from the demand of an increasingly aware society, as well as from the search for new opportunities to develop the competitive advantage (Sénit, 2020; Cuñat Giménez et al., 2022; García Ortiz et al., 2022; Cuñat Giménez & Pizarro Barceló, 2023).

The importance of incorporating the SDGs into the business fabric and the vicissitudes that micro, small and medium-sized enterprises face in adjusting their strategies to the new requirements, has made it essential to implement public-private initiatives aimed at generating positive externalities. Within this framework, focused on organizations in the Valencian Community, is the creation of the *Laboratorio ODS de la Comunitat Valenciana*.

2.2. The context of the SDG Laboratory of the Valencian Community and its relationship with other local government initiatives.

In September 2020, the Generalitat Valenciana launched three social transformation laboratories to measure the degree of social transformation in Valencian companies and public administration:

- i) *Laboratorio ODS de la Comunitat Valenciana* (the Valencian Community SDG Laboratory),
- ii) the *Laboratorio de la Participación Social en la Empresa* (the Social Participation in Business Laboratory) and,
- iii) the *Laboratorio de la Participación Pública-Cooperativa* (the Public-Cooperative Participation Laboratory).

The aim of these three laboratories was to disseminate the principles and good practices of the social economy and to transfer them to actors in the rest of the Valencian productive sectors. Likewise, the goal of these initiatives was to respond to the need to go deeper and obtain data to measure the degree of social transformation that existed in Valencian companies and in the public administration, in a framework of economic reconstruction after the impact of COVID-19.

- i) The “**Laboratorio ODS de la Comunitat Valenciana**” oversaw the study of the Sustainable Development Goals (SDGs) and the implementation of these goals in the strategy of Valencian organizations; furthermore, the laboratory, the first SDG observatory in the Valencian territory, involved the cooperation of four local academic and research institutions: Florida Universitària, the Universidad Jaume I of Castellón, the University of Valencia, through the Chair of Agri-Food Cooperatives and the Business and Enterprise Schools of ESIC. The SDG Lab aimed to measure the degree of involvement with the Sustainable Development Goals that existed in Valencian companies, to assess the alignment of local organizations with the objectives and how the implementation of them can be promoted among them.
- ii) The ***Laboratorio de la Participación Social en la Empresa*** was led by the *Centro Internacional de Investigación e Información sobre la Economía Pública, Social y Cooperativa* (CIRIEC) and oversaw analysing the policies of social participation in Valencian organizations and the access of workers to the methodology for decision-making. Under this framework, good practices developed in different models of business transformation were studied, as well as the systems of worker participation in the boards of directors of companies that existed in some European countries.
- iii) Finally, the ***Laboratorio de la Participación Público-Cooperativa*** was developed by the *Instituto Universitario de Economía Social, Cooperativismo y Emprendedurismo* (IUDESCOOP) and has been focused on the analysis of public policies and their involvement with the social economy and cooperative sectors. The aim of the project was to develop different models of participation that would favour the development of types of enterprises within the social economy in those sectors where the legislation foresaw a greater involvement: education, welfare services and culture.

These Valencian government’s initiatives served as a catalyst for strengthening the relationship among people, companies, and its environment, with the final aim of developing a Valencian cluster for social innovation and introducing it into the intelligent development strategies, as recommended by the European Union.

2.3. Creation and evolution of the ***Laboratorio ODS de la Comunitat Valenciana***.

In 2021 as part of an initiative of the government of the Generalitat Valenciana together with four educational institutions (Florida Universitària, the Universitat Jaume I, ESIC Business & Marketing School and the University of Valencia.) created the ODS Laboratory of the Valencian Community. The Lab constitutes an institution of social transformation that was born with the vocation of being a space for research, transfer, and dissemination of research results to the Valencian society. Likewise, this laboratory has had as its fundamental mission to promote and analyse the participation of companies in the achievement of the SDGs and their implementation in the territory of the Valencian Community. This space for research and action has been a meeting point among different stakeholders (university-business-public institutions), to bring research and to launch innovative proposals to the productive fabric of the Valencian community to fulfil the ODS.

Through different research, transfer and training activities, it was possible to demonstrate to the Valencian productive fabric the real competitive advantages of acting sustainably, in line with the SDGs. Furthermore, this strategy contributes generating environmental and social returns and at the same time guarantees the valuation of this effort by society and the different public administrations, whether at the regional, national or at EU level.

The overall objective of the laboratory was that the research carried out in collaboration by the four academic institutions would help to promote and increase the degree of contribution of Valencian companies to the achievement of the SDGs.

Additionally, some specific goals can be mentioned including:

- To diagnose the degree of progress achieved in the performance of the SDG by Valencian organizations, as well as to detect the critical points perceived by them to implement SDG in their strategy.
- To generate research that enables the measurement of the business contribution to the different sustainable development goals. This research has the aim of enabling the visualization and communication of business contributions to sustainability and, in turn, enabling the Public Administrations to establish effective mechanisms for generating incentives for those who comply with the objectives.
- To design specific action plans for different types of companies to increase the participation of Valencian companies in the process, reviewing the possibility of different measures and incentives, whether public or private, aligned with leveraging policies and transformational measures promoted by other national and supranational institutions.

A gradual implementation plan has been established based on a compact working group of 25 researchers, to which each entity that makes up the laboratory has contributed expertise.

Several steps have been defined, including:

- i) Understanding the SDGs: it was important that people familiarize with the SDGs and understand the opportunities and responsibilities they represent for their business or activity.
- ii) Defining priorities: to benefit from the opportunities and challenges provided by the SDGs, it was crucial for organizations and local entities to define where priorities lie for focusing efforts. These priorities were based on an assessment of the positive and negative (current and potential) impacts of the SDGs on the value chains of different organizations.
- iii) Setting targets: target setting was based directly on step ii and is essential to driving good performance. It is fundamental for the success of the business or activity; and helps to promote shared priorities and improved organizational performance. Aligning the goals of the company or the public sector with the SDGs shows commitment to sustainable development.
- iv) Integrating goals into the business: because of goal setting, specific KPIs and targets were identified, and goals were set for each of the strategic priorities of different organizations. It was essential to integrate sustainability into the core activity of organizations and to include SDG targets across organizational functions to address these goals.
- v) Reporting and communicating it was important to continuously report and communicate on the progress made in fulfilling the SDGs, through common indicators, to understand and meet the needs of different stakeholders.

3. Activities developed in the *Laboratorio ODS de la Comunitat Valenciana*, results achieved and their relationship with the established objectives.

The activities of the laboratory were carried out in two phases, which cover year 2021 and 2022. During phase I, carried out throughout 2021 (Table 1), basically two lines of work were followed:

- **The diagnosis of the contribution of Valencian companies to the SDG.** This line comprised two activities: the general diagnosis of the situation of the contribution of the Valencian productive fabric to the SDGs and the preparation of an annual report in a scientific and informative format.
- **Knowledge promotion of the SDGs in the Valencian productive fabric.** This line comprised three activities including: i) presentation of the SDG and the Laboratory to the Valencian productive fabric, ii) generation of micro-training pills and, iii) holding of a conference to disseminate the results of the project to companies and business organizations in the province of Castellón.

During phase II, carried out throughout 2022 (Table 2), basically three lines of work were followed: i) **information and training**, ii) **research** and iii) **diffusion**. Inside each line of work there were some packs containing the strategy to be implemented to develop the activities during this period.

Table 1. Diagram of Phase I.

Line 1. Diagnosis of the contribution of Valencian companies to the SDG		Line 2. Knowledge promotion of the SDGs in the Valencian productive fabric.		
<p>Activity 1. <i>General diagnosis of the situation of the contribution of the Valencian productive fabric to the SDGs.</i> The strategic diagnosis was in compliance with the SDGs in Valencian companies through different methodologies for extracting scientific and collaborative knowledge, including a review of the state of the art, surveys and semi-structured interviews or focus groups. Identification, specification and assessment by different interest groups or stakeholders of the main reasons that promote (motivations or accelerators) and hinder (barriers or decelerators) the implementation of sustainability in the Valencian Community. To this end, the sample was made up of stakeholders belonging to the productive economy, the so-called market actors, companies of different types, business organizations, social organizations, and public administrations. To achieve these guidelines, those universities participating in the laboratory were the institutions in charge of facilitating communication and knowledge extraction through the different activities and questionnaires programmed with the rest of the stakeholders. <i>The aim was to obtain a general picture as real as possible of the situation in the Valencian Community.</i></p> <p>Each team was responsible for coordinating the assigned work packages with the rest of the laboratory's work teams.</p>	<p>Activity 2. <i>Preparation of an annual report in a scientific and informative format.</i> By means of a shared drafting process, the information generated in the different research work packages was worked on in two reports, one with a scientific character, to provide the results of the diagnosis with rigor, and the other with an informative character, to reach the different stakeholders in the process. Responsibility: the four universities participating in the project.</p>	<p>Activity 1: <i>Presentation of the SDG and the Laboratory to the Valencian productive fabric.</i> The different activities to be carried out in the engagement processes to be implemented were presented to generate an atmosphere of mutual trust and co-creation of proposals.</p>	<p>Activity 2: <i>Generation of micro-training pills.</i> Partners worked on the production of knowledge pills on the 17 SDGs, their targets, their influence on social and economic development, ways of contribution and progress indicators. The four teams that made up the laboratory participated in this activity, distributing the different SDGs among them according to their experience and generating a work methodology in which content was created and reviewed by peers and the companies that collaborated, as well as language was systematized and homogenized.</p>	<p>Activity 3: <i>Holding of a conference to disseminate the results of the project to companies and business organizations in the province of Castellón (dual face-to-face and virtual).</i> In collaboration with some external institutions an online conference (webinar) was celebrated.</p>

Table 2. Diagram of Phase II.

Line 1. SDGs information and training.	Pack 1	Study for the design of optimal training strategies. From the first analysis (quantitative and qualitative) carried out in the SDG Laboratory of the Valencian Region, it was detected that most companies were aware of the SDGs, although their degree of knowledge and application decreased significantly as the organization became smaller. This aspect, together with difficulties related to lack of time and funding, hindered implementation and commitment for contributing to the SDGs. For this reason, it was important to provide companies with appropriate information to enable them to identify what they need to do and how they can contribute to those goals that are most relevant to their organization. This line of work focused on identifying the strategies that would enable Valencian companies to acquire a good level of knowledge of the SDGs in an effective way and, on the other hand, to study the optimal training structure that would help them to understand how to apply the SDGs in their activities.
	Pack 2	Design of pilot training such as virtual reality, webinars, hybrid training and face-to-face training. Based on the analysis in the previous package.
	Pack 3	Elaboration of training pills using different technologies and teaching innovation methodologies so that the result of the training could be implemented in the companies of the Valencian Community. They were disseminated through the website and social networks.
Line 2. Research	Pack 1	Focus group methodology based on the analysis of the risks, limitations and drivers associated with the due transition for the inclusion of the SDGs in the strategies of Valencian companies. After the presentation of the SDG Laboratory of the VC to organizations of the Valencian productive fabric, an environment was generated in to extract knowledge about the impact (limitations and drivers) in regulatory, cultural, measurement and market terms, and to establish the capacities and resources that should be provided to the productive fabric for the correct inclusion of the SDGs in their strategies. Three focus groups were held.
	Pack 2	Data mining. After the exploratory analysis of the data obtained in the survey carried out in 2021, a database was generated that allowed a broader understanding of the reasons, situations, level of penetration and strategies carried out by a representative sample of the Valencian productive fabric in relation to their knowledge of the SDGs. A first output was the elaboration of an infographic that gathers the results of the research carried out during the previous year. The in-depth exploitation of this database allowed Laboratory members to carry out a more in-depth analysis, using quantitative and qualitative analysis tools, which helped them to obtain more robust conclusions that would be particularly useful for public managers when designing strategies to support the sustainable transition of the productive fabric.
	Pack 3	Trends in SDGs (Windows of Perception). The objective of this line of research was to open a window of observation and to capture the current state of the art of the SDGs at national and international levels to show the most innovative trends in the alignment of companies with the SDGs. To discover and demonstrate the strategies that entities and organizations developed to introduce and evaluate the sustainability guidelines implemented. All of this forms a substrate of utmost importance to offer the productive fabric of the Valencian Community additional, innovative but realistic views of how the business world advances towards the 2030 Agenda, where economy, sustainability, environment, and life come together in a vocational and indelible way.

Line 3. Diffusion	Pack 1	Web + Public Relations. The objective of this work package was the dissemination of the results obtained since the start of the Laboratory. The dissemination activity included all actions related to sustainability and SDGs on the Web and on Social Networks.
	Pack 2	Good practice manuals. The availability of tools that allow Valencian companies to apply the SDGs and commit to them in their organizations was a key aspect for incorporating them into their management. Although there are tools developed by various institutions in this regard, it was necessary to support Valencian companies with instruments adapted to them, that helped them to identify what they were doing in relation to the SDGs and how they could adapt their activity to achieve greater commitments in this regard. On the other hand, it was important to identify and define indicators that provide information on the impact that enable Valencian companies to understand, prioritize, commit and act appropriately to integrate the SDGs in their organizations.
	Pack 3	Conferences. The main objective of this line was to carry out actions to disseminate and publicize the practice of the SDGs in Valencian companies and business organizations, through conferences and seminars aimed at the productive fabric of the Valencian Community. These seminars were specifically aimed at the different types of existing companies, grouped according to their institutional affiliation (capital companies and social economy companies), their size and their sector of activity. The methodology of the workshops combined the theoretical aspects (informative, descriptive, and attitudinal) involved in the alignment with the SDGs, with the participation of examples of good practices. Workshops were held in the different facilities of the institutions that constituted the Laboratory, and in spaces of public or private Valencian institutions.

Source: own elaboration based on the Laboratorio ODS de la Comunitat Valenciana.

4. Academic and professional output and main activities developed by the Laboratorio ODS de la Comunitat Valenciana.

As a result of the work carried out during the two years in which the Laboratorio ODS de la Comunitat Valenciana has been operational, a series of reports have been produced and a series of activities have been carried out, including the following:

1. Creation of the laboratory's website, which constitutes a repository of all the work carried out (<https://labods.es/>). This repository has included:
 - The characteristics of the laboratory and its constituent members,
 - A detailed introduction to the sustainable development goals, incorporating the characteristics of each of them and the targets they include,
 - A series of examples that allow us to understand the SDGs through the interaction with the metaverse,
 - Photos and commentary from all events held in the framework of the program,
 - All published studies of interest related to the work carried out by the laboratory,
 - Access to a blog,
 - Press articles related to the theme and to the work of the laboratory,
 - All the activities carried out within the framework of the laboratory,
 - Several examples of sustainable enterprises,
2. In terms of dissemination, the laboratory's website (<https://labods.es/informes/>) includes:
 - A dissemination report of the first phase of the laboratory developed in 2021.
 - A dissemination report of the second phase in 2022,
 - A practical guide for the implementation of the SDGs in Valencian SMEs (2022).
3. A self-diagnosis tool is also available on the website so that organizations can assess how much they know about the SDGs and how they are implementing and complying with them (<https://labods.es/autodiagnostico/>).
4. Participation in the process of creating the first register of socially responsible companies in the Valencian Community.
5. Finally, a practical implementation guide for SMEs is available, which includes examples for different organizations to use when incorporating the SDGs into their strategy (<https://labods.es/wp-content/uploads/2023/01/GUIA-PRACTICA-.pdf>).

5. General discussion, limitations and concluding remarks.

Having commented on the main outlines of the *Laboratorio ODS de la Comunitat Valenciana*, including its different component phases, the objectives related to its creation, the activities developed (including different lines of work) and the main intellectual outputs, it would be interesting to conclude analysing the values that shaped this initiative, its lights and shadows and the threats that arise from a project of these characteristics.

In terms of the positive aspects observed and the values underpinning it, it can be said that the laboratory's activity has been a milestone in terms of the Valencian Community and in the framework of Spain as a whole. The main aspects that can be mentioned are:

- I. The laboratory, the analyses carried out and the outputs obtained are the result of public-private collaboration, the first of its kind in this field. Aware of the importance of the subject and depending on the knowledge and skills required to make the project

- a reality, the Valencian public administration has turned to university research centres, both public and private, to carry out the initiative.
- II. The work carried out is part of a sequence of diagnoses, proposals for action and implementation of these proposals.
 - III. The diagnosis includes both qualitative and quantitative techniques that allow the laboratory to explore the subject and describe the reality of the Valencian business fabric, to define the level of knowledge about the SDGs, how they are implemented in the business fabric and what aspects the companies, whether micro, small, medium, or large, from the social economy or the capitalist economy, consider to be inhibitors to the required change. The diagnosis and proposals for action are included in the practical guide for the implementation of the SDGs in Valencian SMEs and in a self-diagnosis app that could measure the knowledge of the different organizations about the SDGs and their compliance with them.
 - IV. At the same time, a great deal of academic work has been carried out through the preparation of a series of reports and scientific papers.
 - V. In terms of dissemination, a multi-level strategy has been implemented, involving the use of networks, the creation of a blog, participation in different media and the organization of conferences and events, among other things.
 - VI. Regarding future proposals, the laboratory has participated in the whole process that will lead to the creation of the first register of socially responsible entities in the Valencian Community.
 - VII. Finally, it should be noted that, although the laboratory was created within the scope of a Spanish autonomous community, it is scalable to other communities in Spain, and to different administrative levels, such as the national, provincial, and municipal ones.

Regarding the positive and negative aspects of the experience, it is worth mentioning that the sensitivity and priorities that local and national authorities establish regarding this issue are fundamental for the progress of this type of initiative. This sensitivity is the first condition that allows initiatives such as the one discussed in this paper to be created or not. In this sense, the progress of these initiatives within the framework of the competencies of different political forces with different ideas and priorities, and where there is not yet a total consensus on sustainability, means that these initiatives suffer from a certain fragility that is projected on the fear of their continuity.

Another element that should be highlighted is that business sensitivity is asymmetrical: the different types of organizations (size, legal form, and sector of activity, among others) will determine the degree of awareness of the issue. Likewise, these characteristics will also be decisive when it comes to implementing the SDGs in the strategy of organizations.

In addition, although the studies show that there is an embryonic social sensitivity, it has certain characteristics of fragility and can be manipulated. This translates into greater influence of public sector policy and corporate initiative. The public-private interaction (public administrations and companies) is intended to increase the relevance of sustainability issues among citizens, so that they become a structural element of the needs of citizens and the rest of the economic agents.

Regarding the latent threats that the studies carried out have uncovered, there is a clear weakness of sustainability in the European Union's framework. In a context where great pressure from certain economic groups together with the emergence of political groups that deny some of the fundamental postulates of sustainability, it is essential to continue making progress in raising public awareness of this issue. Initiatives such as the SDG Laboratory of the Valencian Community play a fundamental role in this process of knowing, proposing, and applying.

The main limitation of this study is that it has only analysed the SDG Laboratory of the Valencian Community and has not been compared with other existing experiences both at the Spanish and global level. In addition, although the possibility of scaling up the project to other regions has been mentioned, the requirements and potential candidates have not been analysed. Finally, the future lines of work of the Valencian laboratory have not been developed, nor how to establish a continuity of actions in the medium and long term. Future studies should address these outstanding questions.

To conclude, the *Laboratorio ODS de la Comunitat Valenciana* is an excellent example of how public-private initiative is useful when it comes to advancing sustainability issues, being a clear example of the importance of Goal 17, which highlights the importance of partnerships for the implementation of the SDGs. With still a few years to go until 2030, initiatives related to the 2030 agenda are increasing, with the aim of raising public awareness and helping the productive sector and the business fabric to become aware of the SDGs and how they can integrate them into the framework of their strategy.

The Laboratorio ODS de la Comunitat Valenciana is a clear reference in this type of initiative, showing that when priorities and associated policies are established, good results can be achieved with a clear impact on society. Another lesson that is also clear is that these initiatives are easily scalable to different levels (nation, communities, provinces, municipalities) although it requires the firm commitment of all parties.

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TOURIST DESTINATIONS AND ACCESSIBILITY - WHETHER AND HOW ACCESSIBLE THEY ARE (THE CASE OF OHRID LAKE REGION)

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Abstract. Tourist trips have long been part of life habits or the desire to go on vacation to a tourist destination. Although the need to travel is universal regarding change and experience, still little attention is paid to the aspects that will ensure adequate accessibility in tourist destinations for people with disabilities. Accessible destinations should enable availability, accessibility and inclusiveness particularly to visitors with disability. And this tourism is inclusive because it provides equal access to tourist services for all people, to those with temporary or permanent disabilities, as well as families with small children or with specific medical diseases. As a concept, accessible tourism means adapted environment with tourist services and products that will be usable and accessible for all visitors. Similar to other types of tourism it enables tourists with disabilities to satisfy and fulfill their wishes, interests and demands, for which tourism services and facilities should be adapted to the needs of this tourist clientele.

Increasing the awareness about the importance of accessible tourism goes along with educated human resources for accessible tourism, and especially those who are directly involved in the process of delivering products and services to tourists. Such knowledge helps to understand different accessibility needs, depending not only on disability but also on age, mobility, sensory or communication limitations.

Providing a tourist stay with diverse content of tourist products and services by paying attention to different aspects, including accessibility, is especially important for tourist destination. The need for change among tourists with different accessible needs isn't much different from other tourists' needs for recreation, cultural or gastronomic experience or animation. But what differs is that their choice for destination depends on the enabling conditions for accessibility.

In Macedonia, not enough attention is paid to accessibility as a significant aspect of creating modern destinations. Therefore, this paper aims to investigate the situation and opportunities for the development of accessible tourism in the Ohrid Lake region as a leading tourist region.

Key words: *accessibility, special needs, accessible tourism, tourist destination, tourists with disabilities*

1. Introduction

As a socio-economic phenomena closely related to the development of modern society, tourism became a necessity of our lives for many decades. With its rapid and continuous increase it contributes in the process of image creation of tourism destinations and became an important feature of their development but constantly followed by various challenges, limitations and threats regardless of their nature. Although in the last five years more than ever

the focus has been on the challenge of tourism in terms of maintaining health, as a result of the Covid19 pandemic, it must not be forgotten that the most important challenge for tourism is to be accessible to everyone, giving the opportunity to experience and enjoy tourist trips because that is the basis of tourism. Therefore, the increase in the number of tourists is closely related to different factors that have important role to attract attention for visiting destinations.

Considering the large and diverse number of visitors in tourist destinations, and the heterogeneity of tourist demand from various aspects, the quality of the content of tourist services is increasingly important. Among them accessibility has primary importance and is bonded with destination's development. Within this content, transport modes and transport infrastructure, the quality and adaptation of accommodation facilities, sites and attractions in tourist destinations as well as other service providers should be emphasized with their contribution to the increase of destinations' accessibility. These aspects are important because one should be aware that there is no difference in people's need to go on a summer vacation, to stay in a mountain place, to experience the traditional moments of the countryside or to enrich the cultural sights. Such needs are universal despite the difference of peoples' opportunity for accessibility and affordability to be able to engage in tourism.

Large numbers of tourist destinations are facing the challenge of how to be accessible to everyone and how to achieve it since there are different accessibility needs, depending on age and disability, which may be temporary or permanent and which are related to mobile, sensory or communication limitations. Many examples show that this can be achieved and many destinations have experienced transformation as a logical step to their tourism development and increased tourist demand. Research about accessibility in development of tourist destinations is important for determining the meaning, place and role of the development of accessible tourism in the content of the tourist offer during the stay of tourists who have disabilities. The importance of the aspect of accessibility of destinations is particularly highlighted because it contributes to determining the factors and defining the conditions for the development of tourist destinations.

Macedonia doesn't position itself as an accessible destination to everyone, and looking from the perspective of people with disabilities, the question arises as to whether there are conditions and ambition to do so. Some of the tourism stakeholders have done some steps to accessibility of tourist services for people with disabilities. They are mostly in relation to the country's regulation that provides conditions for ensuring accessibility in tourism expressed through different legislation, starting from the Constitution of the Republic of Macedonia, laws and bylaws (Official Gazette of Macedonia; 2020; 2015; 2013; 2009; 2006). Providing tourist services with all segments that will meet the needs of tourists with disabilities demands stakeholders' commitment to the process of creating Macedonian tourist destinations to be distinctive and recognizable on tourist market. Taking into account the conditions that need to be provided for people with disabilities to use services in tourist facilities, the real situation in Macedonia indicates that there is a lack or absence of such services and facilities as a potential for accessible tourist destinations. Although there is an awareness for the importance of providing accessibility conditions, it is mostly related to the perception that certain space should be adopted for the movement of people with wheelchairs and in most cases they do not comply with the standards. Accessibility is mostly connected to this aspect by neglecting others related to institutions with cultural, recreational, sports, educational and informative content. There are very few that have specially adapted programs for visitors with disabilities such as impaired hearing, speech or voice. Among the most active are museums as Archeological Museum of the Republic of Macedonia, Museum of the Macedonian Struggle for Independence, Institute and Museum Bitola, Public Institution "Memorial House of Todor Proeski".

Although Ohrid Lake region has a relatively high share in the absorption of tourist arrivals in Macedonia with 38% (State Statistical Office, 2024) it should be emphasized that as one of the most developed tourist destinations it is not developed and recognizable as accessible tourist destination and many of tourist facilities don't have accessible conditions for tourists with disabilities. Therefore, the research of this paper aims to determine if and how accessible this region is as a tourist destination, what activities are carried out in the direction of attracting tourists with disabilities, regardless of whether initiated by local community, business community, educational, cultural, sports institutions or the non-governmental sector. It engages analysis of the current situation for provision accessible tourist services and opportunities for its future development as accessible destination and difficulties and barriers for accessible tourism services. For that purpose a research will be conducted for the characteristics, specifics and meaning of accessible tourism for tourist destinations in order to emphasize the meaning of provision of services to tourists with disabilities. Then, the research approaches to the analysis of the potentials for accessible tourism of the Ohrid Lake region as an accessible tourist destination. Consequently the findings will be elaborated and serve as a basis for determining the real situation of the region as accessible tourist destination.

2. Literature review

Gaining competitive advantages and attracting tourists lead to creation of distinctive offer of destination because competition is continuously increasing and has great importance for tourism development and promotion of diversified tourist offer (Um & Crompton, 1990; Bigne & Sanchez & Sanchez, 2001; Anholt, 2006; Croes, 2011). Destinations are more and more oriented to creation of competitive tourist offer with better quality of facilities and services according to their attributes that enable tourists to visit places according to the needs and wishes for achieving different experiences during the tourist stay (Buhalis, 2000; Nestoroska, 2022; Ritchie & Crouch, 2003). The development of destinations depends on such an offer, which should be based on selectivity, diversity, but also inclusiveness. In this context, accessibility is a significant attribute for tourist destinations. In its essence, this tourism is complex, consisting of many segments that need to be specialized to ensure accessibility. Providing a tourist service with all its segments that will meet the needs of tourists with disabilities makes the tourist destination distinctive and recognizable in the tourist market.

Accessible tourism is an increasing segment as tourism for all with great economic potential for tourist destinations and it enables all people to participate in tourist trips without obstacles in the chain of tourist services. According to the World Health Organization (WHO, 2023), an estimated 1.3 billion people – about 16% of the world's population – currently have a significant disability. Accessibility in tourism is necessary for about 10% of the population, for about 40% is useful and for all is comfortable. Different international organizations and associations take and support initiatives for encouraging cooperation between stakeholders to provide equal opportunities to access tourist destinations (UNWTO; ENAT; IUCN WCPA; EASPD; ISO; ICOMOS). Their activities aim to increase the awareness for the importance of accessibility no matter what is the reason for it. For many of them UNWTO (2024), as leading world tourism organization that acknowledges the most pressing challenges facing tourism, launches different documents and events to provide an insight into UN Tourism resources on accessibility with key inputs from civil society and tourism sector stakeholders following the web content accessibility guidelines.

The access to tourism facilities, products and services for all should be a central part of any tourism policy for responsible and sustainable destination, and accessibility should be seen as

opportunity for destinations' development. As Miller, Vandome & McBrewster (2010) state, the accessibility improvements are not helpful only to persons with permanent disabilities, but also to parents with small children, elderly people, people with temporary injuries and their companions. Their development is faced with challenges and involvement of many actors from business sector and responsible authorities that are committed to actions and initiatives for adapting their products and services to different consumer profiles.

The definition for accessible tourism by Darcy and Dickson (2009) where they argue that it enables people with access requirements to function independently and with equity and dignity through the delivery of universally designed products, services and environments elaborates that such tourism is for any segment of consumers which prefer accessing a tourism experience with ease. According to Nestoroska et al. (2023) accessible tourism enables tourism destinations, products and services to be accessible to all people, regardless of their limitations, disabilities or age. In this way, tourist services are provided with all segments that will satisfy tourist needs based on equal and non-discriminatory participation in tourist flows. Considering that tourist destination is defined as a complex network by Haugland, Gronseth & Aarstad (2007) where they elaborate that it needs an integrated multilevel approach, than consequently it can be concluded that a development of accessible destination is in relation to the involvement of large number of actors that provide various services and products. Further, Nyanjom, Boxall and Slaven (2018) explain that delivering quality accessible tourism experience in destination is complex and challenging process considering the fragmented structure of tourist industry. Destinations' development and dedication to provide accessibility needs to take into account the following main preconditions: barrier-free infrastructures and facilities, suitable transport for all users, high quality services delivered by trained staff, accessible web sites and services information to all and equal opportunities for participation in tourism activities, exhibits, and attractions. Such an approach provides the destination with sustainability and competitiveness because they are involved in a tough competition that forces them to think and act towards sustainable competitiveness.

3. Analysis of Ohrid Lake region as accessible tourist destination

Ohrid is a city in Macedonia and is located in the south-western part of the country, on the shore of Lake Ohrid, at an elevation of 695 meters above sea level, and extends about 2/3 along the lake for which the analysis for accessibility refers to Ohrid. Ohrid is known for once having 365 churches, one for each day of the year, and has been referred to as the "Jerusalem of the Balkans". The city is rich in picturesque houses and monuments, and tourism is predominant. In 1979 and in 1980, respectively, Ohrid and Lake Ohrid were accepted as Cultural and Natural World Heritage Sites by UNESCO. Ohrid is one of only 28 sites that are part of UNESCO's World Heritage that are Cultural as well as Natural sites.

Ohrid is rich in cultural heritage from ancient and medieval history, from the Ottoman period, but also from modern history, with churches and monasteries, fortresses, archaeological sites, memorial houses and museums and a large number of archaeological remains.

When designing the development of tourism, appropriate analyzes are made in accordance with the basic principles of UNESCO for protected areas, with the national legislation for the management of protected areas, as well as with other border and regional strategies and plans for the management of natural resources.

The development of Ohrid as an attractive tourist destination is based on the long tradition and dedication of all stakeholders who participate in the creation of the destination product. The sustainable development of tourism in this tourist destination has a special meaning because the

resources for development are of a special dimension. It is for this reason that the sustainable development of tourism should be accepted as an activity worth investing in, to specify the benefits of its development, to improve the interest of the domestic and international public and to be the basis on which other acts, plans and programs.

Encouraging the development of tourism, and especially accessible tourism, should contribute to improving the quality of life, raising the level of satisfaction from the visitors' stay, permanently improving the quality of services, winning new values, improving promotional activities and spreading on the domain of targeting of the tourist offer.

Therefore, as a major and most developed destination within the Ohrid Lake region, Ohrid should create tourist products that will be accessible to all potential tourists, including people with certain limitations or disabilities, to meet their needs based on equal and non-discriminatory participation in tourist flows. For this purpose, the awareness of the importance of accessible tourism and the different needs of tourists should be developed among the employed in the tourism sector, especially among those in direct contact with tourists. Such approach is important because the choice of tourist destination during the realization of tourist trip depends on the wishes, demands and expectations of the people. Namely, tourists with disabilities will choose destination that offers conditions that will enable them to use and enjoy the services, that is, a destination where they will feel safe. Since people with disabilities still encounter a number of obstacles that further complicate their everyday life, tourist centers in this region should pay special attention to accessible tourism.

Accessibility is one of the biggest problems in Macedonia and the Ohrid Lake region. Architectural barriers are still one of the most pressing issues facing people with physical disabilities. It is difficult for them to move with wheelchairs on the streets, access to the second floor, high sidewalks are an obstacle for them, and the curbs of the pedestrian crossings require additional assistance. Lower counters, accessible toilets, lifts and accessible doors are required. Better infrastructure is needed, but awareness in the country is unfortunately still low.

It is precisely for this that numerous researches are carried out and in cooperation with civil associations of persons with different disabilities, a series of activities are undertaken to improve or enable conditions for the accessibility of tourist places, destinations, means of transport, accommodation facilities, access paths, entrances, as well as architectural barriers. Namely, in August 2022, the Summer Inclusive Camp for children with and without disabilities, organized by the Veles Mobility Association, was opened at Ljubaniste Camping in Ohrid, as part of the activities within the project "Together we are better". Within the framework of the project, the first ramp for entering the waters of Lake Ohrid for people with wheelchairs, a suitable toilet, and several bungalows with spacious bathrooms and rooms for the stay of people moving with wheelchairs have been adapted.

The creation of such specific tourist products should enable the satisfaction of the specific needs and expectations during the trip and stay of persons with special needs in the tourist destination, and adaptation of the accessibility of tourist attractions, localities or catering-tourist facilities should be a function of overcoming on the barriers.

Similar to Ohrid, the other destinations in this region do not meet the conditions for the development of accessible tourism, but, on the other hand, face problems in creating appropriate products. Therefore, the conditions for access to tourist facilities and attractions, the concept and diversity should be taken into account as basic aspects in the creation of tourist products.

Tourist needs, the resolution of which requires a large number of different services, are equally represented among people with special needs, that is, among tourists with disabilities. Therefore when creating tourist product for Ohrid Lake region as accessible destination, one

should take into account their need to escape from the everyday routine of life, the desire to see and experience something new, to enable socializing and to have something exciting happen.

In fact, the need for change among tourists with disabilities does not differ in any way from the need of other tourists, especially when it comes to the wishes and needs for entertainment, animation, recreation, relaxation, cultural upgrading and experience, or new gastronomic experiences. Precisely for this reason, destinations in the Ohrid Lake region that want to develop accessible tourism should create a tourist product rich in diverse content, and at the same time meet the tourist needs of tourists with disabilities. A special approach is needed when creating tourist arrangements intended for people with disabilities, when organizing a visit to the destination, when organizing and realizing certain additional contents, such as an excursion, or the realization of visits to various cultural-historical attractions. Concept creation with accessibility and diversity (Nestoroska I. et al., 2023) are basic aspects for creation of such tourist arrangements for Ohrid Lake region.

When creating the **tourist arrangement** for people with disabilities, special attention should be paid to the choice of a destination that offers appropriate specific services for resolving their tourist wishes. During the compilation of the itinerary, the directions of movement, the places of stopping and holding should be specifically defined, while taking into account the conditions for accessibility to the services and contents provided in the itinerary.

Sightseeing, is an activity that attracts a lot of attention among tourists. To realize it, it is necessary to hire local tourist guides, who in turn must be informed about the basic characteristics of the group (size, language that will be used to guide the group, where the tourists come from, age structure), but also so it is recommended that they become familiar with the needs related to mobility or communication in the group.

An excursion is a very attractive content that enriches the stay of tourists at a tourist destination. When organizing excursions for people with special needs, the special conditions that the selected location should have should be considered to allow tourists to move freely, communicate and enjoy the activity.

Visiting cultural-historical attractions as integrated component of tourist arrangement is among the important component of the tourist destination' offer. In relation to accessibility these attractions should be selected upon the enabling conditions for visiting them by tourists with disabilities to experience the cultural heritage of Ohrid Lake region. And another very attractive content for enriching the stay in tourist destination **is an excursion**. When organizing excursions for people with disabilities, the special conditions that the selected location should have need to be considered are how to allow tourists to move freely, communicate and enjoy the activity.

4. Recommendations for tourism stakeholders

Accessible tourist destinations need to apply certain standards and build strategies for the development of this type of tourism. For example, in the EU Strategy for the Rights of Persons with Disabilities for the period 2021-2030 (Union of Equality: Strategy for the Rights of Persons with Disabilities 2021-2030, March 2021 Brussels), the focus is on the enjoyment of the rights of persons with disabilities in terms of accessibility, non-discrimination, quality of life and promotion of their rights. Also, the application of the International Standards for accessibility in tourism has a significant role. The most significant and current is the ISO 21902:2021 Standard, adopted in 2021. on which more than 85 experts from 35 countries of the world worked. It refers to tourism and related services, in terms of meeting the requirements and conditions for accessible tourism

for all. It includes guidelines and recommendations on accessibility, policy making, strategy, infrastructure, products and services, which are relevant to all types of tourism stakeholders. Guidelines for 'accessible tourism for all' are provided to enable equal access and enjoyment of tourism by the widest range of people of all ages and abilities.

The European Commission organizes a competition for accessible cities (Access City) to reward cities that prioritize accessibility for people with disabilities. Since accessibility is a prerequisite for the inclusion of persons with disabilities in tourist flows, tourist destinations should enable these tourists to obtain adequate information, use means of transportation, conditions for visiting parks and playgrounds, access to enter and around facilities, etc.

Therefore we highlight several recommendations that are applicable to all stakeholders in Ohrid Lake region who participate in the creation of the tourist product of destination, and can contribute to its development as destination that is accessible to all.

- Parallel and continuous monitoring and understanding of the rights of persons with disabilities, but also the legal obligations of stakeholders in tourism.
- Accessibility for one type of disability does not mean accessibility for other types of disability
- In the creation and promotion of accessibility strategies, it is necessary to include persons with disabilities
- Investing in the education and training of human resources in tourism to raise awareness of the importance of accessible tourism, as insufficiently knowledgeable and untrained employees can cause disappointment
- Realizing the possibility of employment of people with disabilities
- Promotion of facilities as accessible should be supported by accurate information in order to avoid misunderstandings and build a good image of the facility
- Support of the initiative for the inclusion of persons with disabilities in tourist flows
- Encouraging activities of facilities to invest in accessibility and inclusion to be an integral part of operations, policies and strategies for sustainable tourism
- Enabling easier movement and accommodation in facilities for persons with disabilities, i.e. adaptation of facilities and services for the needs of these persons, which can also represent a competitive advantage
- Paying special attention to the lighting of the objects, colors, noise and acoustics, especially for people with sensory disabilities and considering the possibility of a multisensory experience through smell, taste and sound
- During creating promotional messages for tourist products in destinations that develop accessible tourism, attention should be paid to all the specific needs of people with disabilities and a message that will be easily noticeable and understandable for these people
- Accessibility should be treated as an opportunity and not as an obstacle in the development of subjects. It is necessary for 10% of visitors, it is necessary for 40% of visitors, it is pleasant for everyone and nobody bothers

According to some research, people with disabilities are loyal to facilities and destinations where they are welcome and where accessibility is ensured. It is for this reason that they return together with their loved ones. The greatest success of the destinations is the creation of loyal tourists who promote the destination in their circles. Therefore, we recommend that you respect these tourists.

5. Conclusion

Creating an offer with accessible tourist services and products should be a priority of the tourist destination. The destination should involve all stakeholders in creating conditions for enabling, providing, organizing and implementing tourism resources for persons with disabilities. Of particular importance are the infrastructural solutions that should provide conditions that will enable accessibility and availability of the destination, not only for tourists with disabilities, but also for its citizens, because it is not only about the development of accessible tourism, but also about the attitude towards people with disabilities who are residents of the specific destinations.

The concept of accessible tourism refers to the adaptation of destinations and their tourism products to the needs of all tourists, including persons with special needs. Accessible tourism should be seen as an opportunity for selectivity and confirmation of the social character of tourism through the equality of all people, on an equal basis, to engage in tourism.

One of the most important aspects of accessible tourism is its human dimension, because it allows increasing awareness of the meaning of this type of tourism, its place and role in the development of tourism and the enrichment of the content of the tourist offer during the tourist stay for tourists who have disabilities. The biggest challenge for destinations is the removal of difficulties and barriers in order to provide accessible tourist services. The development of accessible tourism should improve the quality of life of people with disabilities and their equal participation in all spheres of social life.

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GENDER EQUALITY ON CORPORATE BOARDS: THE PATH TO EQUALITY, DIVERSITY AND INCLUSION

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Abstract: Topics about gender equality are becoming one of the most important issues in corporate world. Women have a huge potential like a labour force in the European Union Member States, but they are still not enough present at the highest leading levels in corporations. This situation will soon change, because of the “Women on Boards” Directive (Directive EU 2022/2381). According to this Directive, companies registered in EU Member States with more than 250 employees that are listed companies, will need to have at least 40% of non-executive director positions or 33% of all director positions. All EU Member States must incorporate this Directive into their national legislation by 28th December 2024. The Directive will come into force in 2026. This paper examines gender equality on corporate boards in EU Member States based on previous studies by academic researchers and critical analysis of recently published literature and secondary research data. The Gender Equality Index, the presence of women on boards in EU Member States and, in particular, the situation on boards in Croatia are discussed. Based on this data, it will be possible to identify gender equality issues in corporate leadership positions in EU Member States and to discuss gender quotas and their impact on equality, diversity and inclusion, as well as to identify expectations for future gender quotas on corporate boards.

Key words: *gender equality, gender quotas, corporate boards, EU Member States*

1. Introduction

In the last decades’ presence of women at the labour market has increased in the EU Member States. Women represent more than 60% of university graduates in EU Member States, but they are still not present in corporate boards of large European companies as it is expected. Even though this positive trend is present, gender inequality is persistent, especially regarding employment conditions and development of professional carrier, or on management positions where gender gap within corporate boards is evident. From secondary research data published by EU institutions it can be concluded, there are still more men than women on corporate boards and that is especially evident at highest level of management.

On International Women’s day in 2020. U.N. Secretary- General, Guterres told that “gender inequality is the overwhelming injustice of our day and that deep-rooted patriarchy and misogyny have created a yawning gender power gap in our economies, our political systems, our corporations, our societies and our culture.” He also emphasized that “women are still very frequently denied a voice; their opinions are ignored and their experience discounted.” (U.N. chief: Gender inequality biggest human rights challenge (2020). Retrieved May 2, 2024, from <https://www.politico.com/news/2020/03/08/un-chief-gender-inequality-biggest-human-rights-challenge-123536>)

This implicates that there is still huge gender gap in all sphere of our lives, and that development and implementation of different policies and strategies on supranational and national level is needed to decrease gender gap all around the globe.

In corporate sector EU legislation has done the path leading to equality, diversity and inclusion. The path leading to the Directive on “Women on boards” (EU Directive 2022/2381) was not at all easy even though EU promotes gender equality issues for years. For this Directive European Parliament needed 10 years to formally adopted it after the first proposal. The main reasons for this long process lie in different opinion of some EU Member States. Finally, after years of discussion, EU Parliament adopted the Directive on 22nd November 2022. The Directive was published on 7th December 2022 in the Official Journal of the EU and started with the application on 27th December 2022. All EU Member States are obligatory to assure that it will become a part of their national legislation by 28th December 2024.

There is no doubt that these laws will achieve their main objective, increase of women on corporate boards across EU Member States. Important question that arises is, can we expect broader impact of this Directive in corporate sector? Soon we will be able to see the positive influence and benefits of gender quotas in corporate sector.

The aim of this paper is created according to actual situation about women on corporate boards in EU Member States. It is focused to the critical analysis and discussion of literature review, as well as on the secondary research data on gender equality on corporate boards in EU Member States. Gender Equality Index, presence of women in corporate boards in EU Member States with the special emphasize on the situation in the corporate boards of the Republic of Croatia will be examined. Gender quotas at leading positions in corporations in EU Member States will be discussed as well as the expectations that everyone have from gender quotas.

The paper consists of sixth sections. After the introduction, literature review section is presented. The third section analyze the EU legislation framework based on gender equality and quotas. The fourth section is related to the analysis of Gender Equality Index while the fifth section present detailed analysis about women on boards in the EU Member States with the special emphasize on the example of Croatia. The sixth section are discussion and concluding remarks with the limitations and directions for future research.

2. Literature review

The issue about women on corporate boards has been investigated for more than two decades, as well as those about gender quotas, first of all from the scientific point of view but also by numerous professionals, especially its impact on firm performance. Different studies have shown different results but some of the conclusions are similar.

Studies done on board diversity that are published in scientific journals are mainly focused on empirical research and based of different theoretical approaches in corporate governance (agency theory, social identity theory, resource dependence theory, social network and human capital theory). Majority of those studies and critical analysis of their conclusions can be found in the work done by (Yu and Madison, 2021 and Suraj Kumar S. and Kumar Mishra, 2023). According to the creators of agency theory (Jensen and Meckling, 1976), agency theory supports gender diversity in the board room. In the context of agency theory, supervision of directors can be done with a rational number of diverse independent directors (Aggarwal et al., 2019). Diversity in corporate boards can led to lower agency costs (Ain et. al., 2020). It also reduces conflict of interest between managers and shareholders (Vrdoljak Raguž, 2017). Becker (1985) emphasized that the success of management boards lies in diverse and unique human capital. This conclusion is based on human capital theory. In the context of resource dependency theory, (Pfeffer and Salancik, 2003) pointed out that some corporations are more powerful than the others. They based this conclusion on positioning in social space. It is interesting to highlight that resource-based theory (Barney 1991) suggests a positive diversity-performance

relationship. Boyd (1990) explains two implications of resource theory for management board. As the first, he states that the composition of the board of directors depends on the position of the company in environment and demand for its products. The second is that diversity in the board of directors can have effects on the profitability of the company. According to Arena et. al. (2015), resource theory supports diversity in boards that contributes to the supply of critical resources to companies. Social identity theory (Tajfel 1978) suggests a negative diversity-performance relationship.

Other studies have analyzed impact of gender quotas on firm performance or decision-making process. After the implementation of gender quota in Norway, different studies have been conducted, especially about gender quotas and firm performance. One of the most cited is study by Ahern and Dittmar (2012). In that study they found out that implemented gender quota in Norway, led to constant drop in Tobin's Q as well as in stock performance. According to them, this result can be in the relation with inexperienced women on corporate boards that where present there just because of gender quotas. These finding also support investigation done by Bordalo et al. (2019). They concluded that gender quotas resulted with the decrease of quality in the board composition as well as to the decrease of shareholder value. Negative effect of gender quota is also presented by other authors in their studies (Matsa and Miller, 2011, Comi et al., 2017). Positive effect of quota implementation through positive stock market returns in Italy, emphasized Ferrari et al. (2016). Positive effects between gender diversity in the board room and firms performance have also been found in the studies done by Larsson and Olofsson, 2017, Lückerrath-Rovers, 2013, Liu, Wei and Xie, 2014).

Some of the research are mainly focus on gender quota and decision-making process. Positive effects have been found in the studies done by (Nielsen and Huse, 2010, Ahern and Dittmar, 2012), while negative effect was the conclusion of the study done by Adams and Funk (2011) which especially emphasize the importance of different leadership style as well as leadership behavior on decision-making process.

Other authors discussed about women integration and the integration impact on corporate governance. Special accent is oriented to new skills, ideas, perspectives and sensitivity of women to other employees and their work (Burke, 1993; 1994). Adams and Ferreira (2009) emphasized that diversity on corporate boards is connected with the monitoring processes and their allocation. Women participation at the labour market could improve economic growth and firm's financial performance (Christiansen et. al., 2016). Interesting conclusions are published in the study of Terjesen et. al. (2016). They highlighted that board independence is secondary if the corporations do not have women on boards.

As it can be seen from the results published by different scientist, the results of academic research are diverse. Based on the comparison of different studies, it can be concluded that diversity in corporate boards has more positive effects then negative ones as well as gender quota. Based on numerous positive effects of gender quota in companies the European Parliament has decided to introduce mandatory quotas to make equality, diversity and inclusion in the boardroom. The results of this decision will be visible soon after implementation and it will be possible to make comparison of secondary research data before and after the implementation and make critical conclusions.

3. The EU women on boards legislation framework

According to Vrdoljak Raguž, et. al. (2018) the issue of gender diversity has become one of the most important topics for European Commission and has over the last decade tried to reach a sustainable development within the European Union where gender equality is mentioned as one of the European Union's values.

European Women Lobby in 2012. published that Norway was the first country in the world to adopt a binding quota law in 2005. For this reason, women are present more than 40% on corporate boards in the Norwegian companies covered by the law. Now other European countries, especially EU Member States follow this practice.

The current legislation of EU is analysed in details and presented in table 1. From the table 1 it can be noticed that in the EU Member States there are three types of policies.

Table 1: Women on board policies in the EU member states

Country	Gender quota law	Gender diversity recommendation in CGC	Disclosure requirement about board diversity
Austria	Yes	Yes	Yes
Belgium	Yes	Yes	Yes
Bulgaria	No	No	Yes
Croatia	No	No	Yes
Cyprus	No	No	Yes
Czech Republic	No	No	Yes
Denmark	No	Yes	Yes
Estonia	No	No	Yes
Finland	No	Yes	Yes
France	Yes	Yes	Yes
Germany	Yes	Yes	Yes
Greece	Yes	Yes	Yes
Hungary	No	No	Yes
Ireland	No	Yes	Yes
Italy	Yes	Yes	Yes
Latvia	No	Yes	Yes
Lithuania	No	No	Yes
Luxembourg	No	Yes	Yes
Malta	No	No	Yes
Netherlands	Yes	Yes	Yes
Poland	No	Yes	Yes
Portugal	Yes	Yes	Yes
Romania	No	Yes	Yes
Slovakia	No	No	Yes
Slovenia	No	Yes	Yes
Spain	Yes	Yes	Yes
Sweden	No	Yes	Yes

Source: Women on Boards Policies in Member States and the Effects on Corporate Governance, EU, December, 2021., pp. 14-15.

In “Women on Boards Policies in Member States and the Effects on Corporate Boards”, published in December 2021. just a few countries have introduced gender quota laws for company boards by the end of 2020. Norway in 2005. introduced such quota, and it was the first European country to do that, even though it is not in the EU. Spain was the first EU Member State to introduce a quota in 2007. Other EU countries followed this practice: Belgium, France, Italy and the Netherlands in 2011. Germany adopted quota in 2015. and in 2017, Austria and

Portugal adopted a quota. In 2020. Greece adopted a quota. There are differences in these quotas. The highest quota level is 40% (Spain, France and Italy), 33% is in Belgium and Portugal, 30% in The Netherlands, Germany and Austria. Greece has 25% quota. These quota target levels are different when the effects on board composition are monitored.

The situation will dramatically change with the adoption of the “Women on Boards” Directive (EU) 2022/2381. With this directive EU seeks to establish minimum requirements in the form of quotas to improve the gender composition of boards in EU Member States and to correct all inequalities. But, in the practice it will include just listed companies with more than 250 employees. The targets will be members of the underrepresented gender in at least 40% of the non-executive director position or members of the underrepresented gender in at least 33% of all directorships, including executive and non-executive directors. All these objectives need to be achieved by June 2026. The Directive’s minimum needs to be implemented in national legislation of EU Member States by 28th December 2024. These requirements will be easy to perform for some countries, while others will probably have problems to meet the requirements, especially countries with low level of women presence in corporate boards such as Hungary, Romania etc.

4. Gender Equality Index – measurement of the progress of gender equality in the European Union

The Gender Equality Index is a tool to measure the progress of gender equality in the EU, developed by European Institute of Gender Equality (EIGE). It gives more visibility to areas that need improvement and ultimately supports policy makers to design more effective gender equality measures (Gender Equality Index, Retrieved May 5, 2024, from <https://eige.europa.eu/gender-equality-index/about>).

The Gender Equality Index gives the EU and the Member States **a score from 1 to 100**. A score of 100 would mean that a country had reached full equality between women and men. This index measures inequalities in different sectors divided in different categories and subdomains. Main categories are: all, health, work, money, power, knowledge, time and violence. In this paper only, categories “all” and “power” with the subdomain “economic” will be analysed and discussed.

From the figure 1 it can be seen that the Gender Equality Index in 2023 for the European Union (EU) has reached 70.2 points. According to the available data and calculations of Gender Equality Index, the increase in the overall EU index score is the highest year on year rise since the first edition of the Index in 2013. Just 11 countries have the highest score then EU, all others are bellow of the EU index score. Index score for Croatia is 60.7.

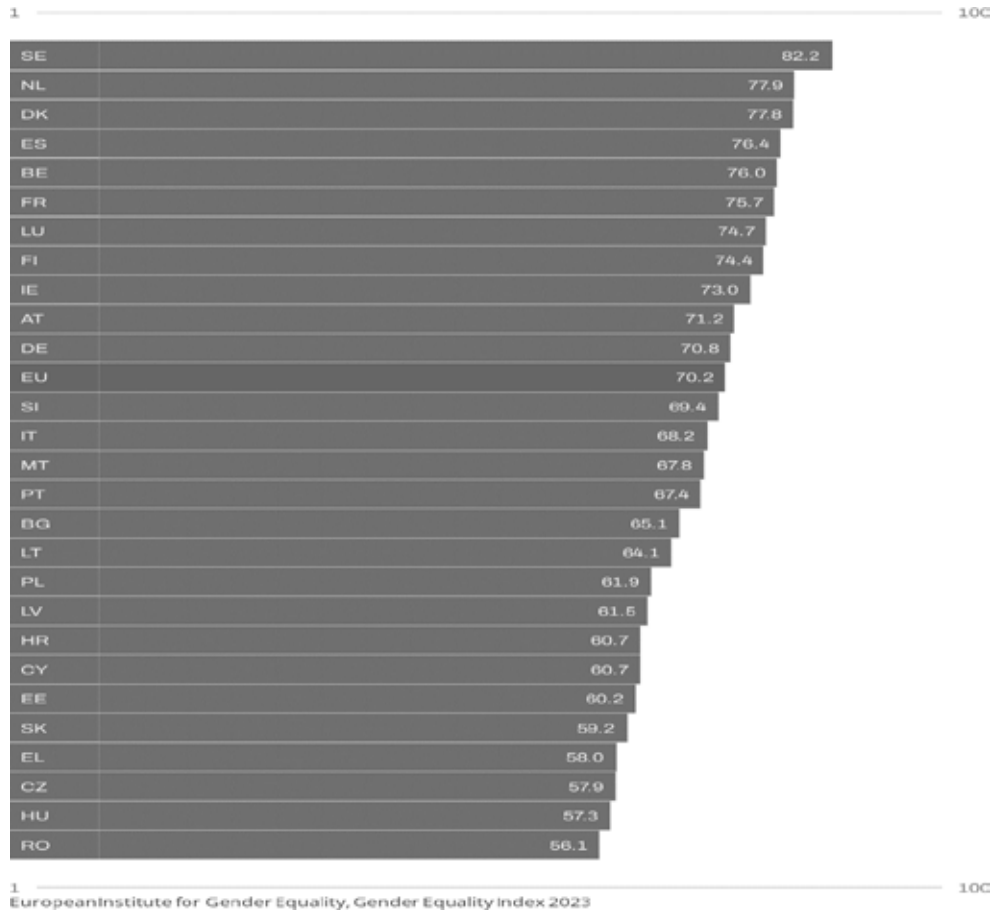


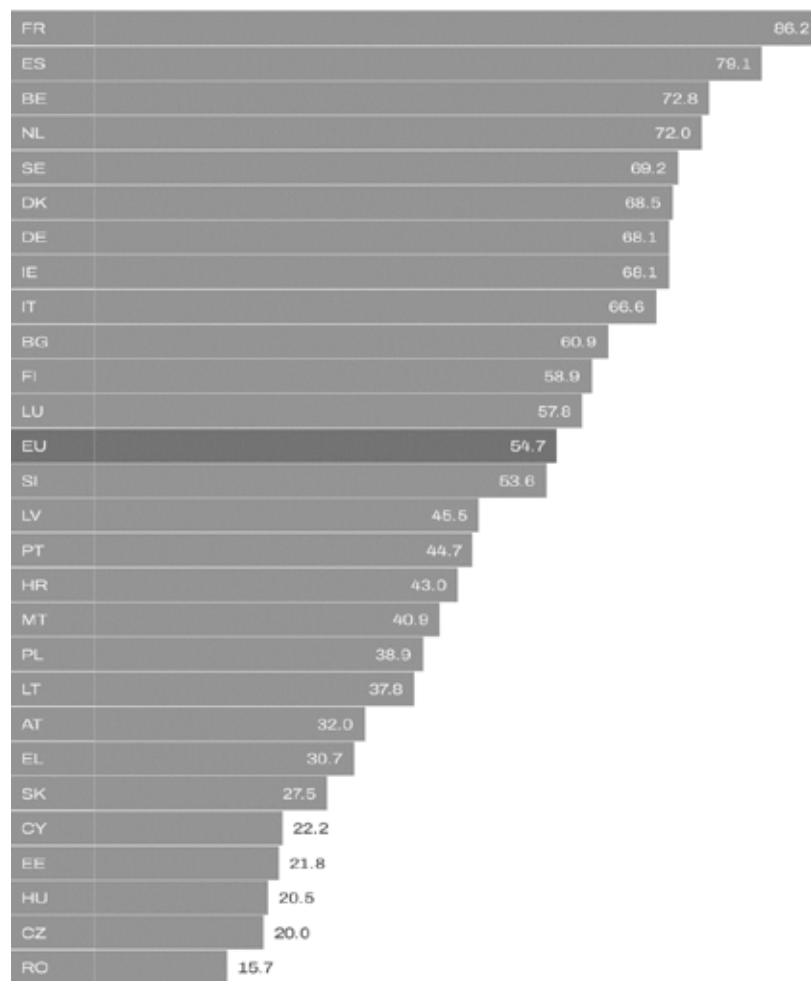
Figure 1: Gender Equality Index (category “all”)

Source: Author’s calculation based on the data available at statistical research data base, European Institute for Gender Equality, Gender Equality Index 2023. (data is mostly from 2021. and 2022.)

From the index scores presented in the figure 1, the highest index score is in Sweden (82.2) and according to this score it can be concluded that only Sweden is close to gender equality. Sweden is followed by Netherlands (77.9), Denmark (77.8) and Spain (76.4). The lowest index score for the category “all” is in Romania (56.1).

For the purpose of the research conducted in this paper, category of “power”, especially subdomain “economic” is also analysed. The domain of “power” measures gender equality in decision-making positions across the political, economic and social spheres. In the subdomain of gender balance in economic decision making is measured by the proportion of women and men on corporate boards of the largest nationally registered companies listed on stock exchanges and national Central banks (Gender Equality Index (2023). Retrieved May 4, 2024, from <https://eige.europa.eu/gender-equality-index/2023/domain/power>).

In the figure 2. Gender Equality Index in the category of “power”, subdomain “economic” in 2023. has been calculated and presented.



1 European Institute for Gender Equality, Gender Equality Index 2023 100

Figure 2: Gender Equality Index (category “power”, subdomain “economic”) in 2023.

Source: Author’s calculation based on the data available at statistical research data base, European Institute for Gender Equality, Gender Equality Index 2023. (data is mostly from 2021. and 2022.)

Comparing this data with the category “all”, it can be concluded that situation is even worse regarding the category of women and power. EU index score is 54.7 and Croatian 43.0. This means that Croatia is below EU index score. EU Member States that has highest index score is France (86.2). It is followed by Spain (79.1), Belgium (72.8), Netherlands (72.0) and Sweden (69.2) that have index scores higher than 70.0. The lowest index score is in Romania (15.7).

Additionally, comparing the two figures of Gender Equality Index, it can be concluded that the highest score in both categories is reserved for the same countries (Sweden, France, Spain, Netherlands, Denmark and Belgium), as well as the lowest one, which show us the same trend regarding the Gender Equality Index in different categories (Romania). Other countries with the low index score are: Hungary and Czech Republic.

According to the available data from EIGE the EU’s current score represents a moderate improvement of 1.6 points compared with the previous edition of the Index – the highest year-on-year rise since the first edition of the Index in 2013. The increase in the EU’s score since 2020 is mainly due to progress in gender equality in the domains of “time” (+ 3.6 points) and “work” (+ 2.1 points). Since 2010, the EU’s score has increased by 7.1 points, primarily driven by advances in the domain of “power” (+ 17.2 points) (Gender Equality Index, Retrieved May 5, 2024, from <https://eige.europa.eu/gender-equality-index/about>)

To illustrate the country level of gender parity, World Economic Forum in Global Gender Gap Report (2023) published which are top 10 countries in the different regions of the world based on their calculations done with the official data. In top 10 countries from EU Member States are: Finland on the third place, Sweden on the fifth place, Germany on the sixth place, Lithuania on the ninth place and Belgium on tenth place. The analysis includes overall gender gap, Political Empowerment power index, Economic Participation and Opportunity sub index as well as Health and Survival sub index.

From the analysis of all this data it is obvious that there is a lot of space for the improvement regarding gender equality in EU Member States. It can be expected that after the implementation of “Women on Boards” Directive (EU) 2022/2381 the situation will be better not just in the category of “power”, subdomain “economic”, but also in other categories like the reflection of this type of the decisions.

5. Women on corporate boards in European Union and Croatia

According to the Report of gender equality in the EU (2024) only 12 Member States have reached the target of at least 33% women amongst all board members: Austria (33.6 %), Portugal (34.9 %), Sweden (36.6 %), Ireland (37.4 %), Finland (38.3 %), Germany (38.7 %), Belgium (38.8 %), Spain (39.4 %) the Netherlands (41.0 %), Denmark (41.4 %), Italy (43.0 %), and France (46.1 %). The share of women nonexecutives in 8 Member States meets the proposed EU target of at least 40 %: Italy (49.0 %), France (48.2%), Spain (44.6 %), Ireland (43.9 %), Portugal (43.8 %), the Netherlands (42.4 %), Belgium (41.4 %), and Denmark (41.4 %). In other Member States, the gender-balance is unfortunately on the low level (from 8.2 % to 18.3 % of board members in the largest listed companies).

EIGE (2023) data is based on a representative sample of companies in the EU Member States, so these figures may not necessarily be identical once EU Member States start reporting to the European Commission under the Directive 2022/2381 (by 29th December 2025). The data is as follows: Spain (44.6 %), Ireland (43.9 %), Portugal (43.8 %), the Netherlands (42.4 %), Belgium (41.4 %), and Denmark (41.4 %). In other EU Member States, the gender imbalance is evident. Their representation of women in corporate boards is between 8.2 % and 18.3 %.

To get the insight to the situation regarding women on corporate boards in EU Member States, the analysis included the percentage of women on boards in EU, based on the last published data by EWOB (2024). For Croatia, SELECTIO women index is presented and analysed as well as the secondary research data from HANFA (Annual Corporate Governance Report from 2022.).

FIGURE 4

Overview percentage of women on boards

Source: EIGE, May 2023

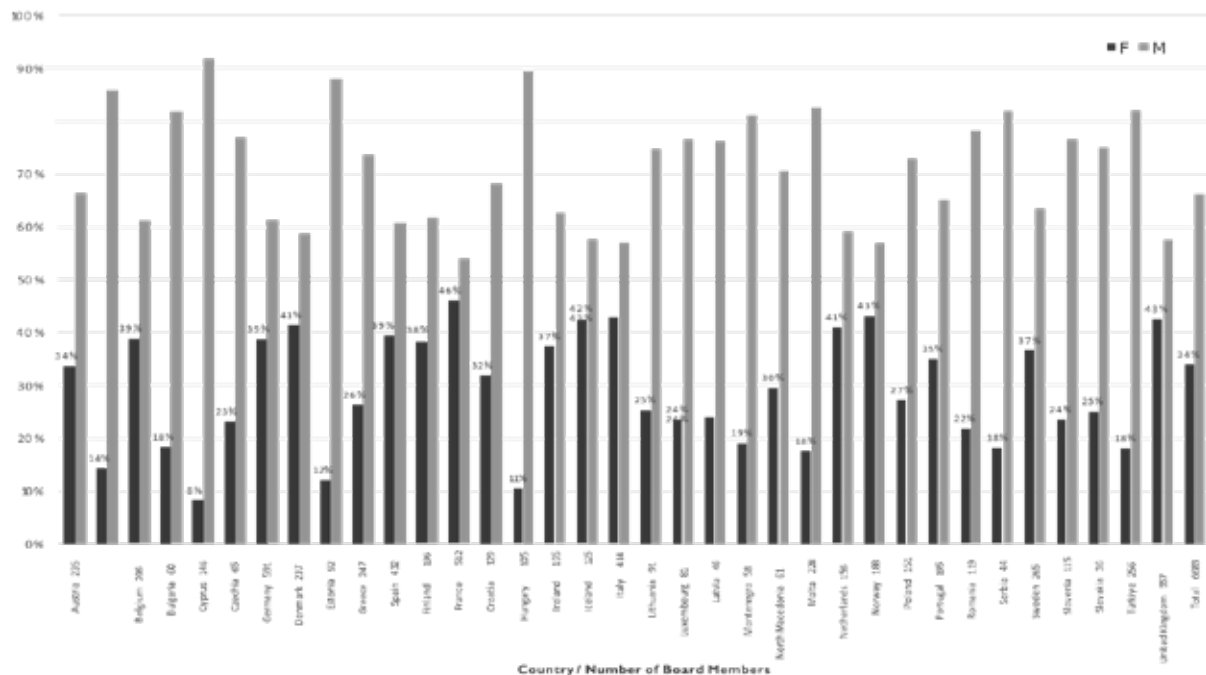


Figure 3: Percentage of women on boards in EU27

Source: EWOBO, Diversity on European boards, Gender balance is improving – no change must go deeper and wider, January, 2024., pp. 13.

From the figure 3 it can be seen that there are significant disparities between European countries. Nine EU Member States have an average of only 19% of women on corporate boards (EWOBO, 2024.). There is also the progress, but in a small number of countries. It can be said that there is slow rate of progress towards targets. To generate the progress Governments, need to take different actions (implementation of gender quota and other measures that will encourage corporations to the self-regulation). In 2023, women accounted for 38% of board members of the largest listed companies in countries with gender quotas, compared to 33% in countries where only soft measures have been applied, and just 19% in countries that have taken no gender balancing action at all. Croatia has 23% women on corporate boards. This data shows also huge progress for Croatian largest listed companies.

After conducted analysis is it obvious that progress is still needed in EU regarding gender equalities in corporate boards. It can be expected that the progress will be driven by legislative actions especially after 2026. when quotas will become mandatory for all EU Member States.

The analyses of the situation in Croatia regarding women on corporate boards is also presented in the paper. There are a few important statistical data bases that deals with this issue and they will be mentioned and explained.

The SELECTIO consulting company developed the SELECTIO women's index, which measures the share of women in the management of companies in the CROBEX index. In 2023, the SELECTIO index of women is 22.2%, which is equal like in 2022. Also, the percentage of CROBEX component companies, which do not have a single woman in their management, so-called zero companies, decreased by 9.57%. See figure 4.



Figure 4: SELECTIO index of women in business

Source: Indeks žena u biznisu najveći dosad, uvedena i nova direktiva (2023). Retrieved May 4, 2024, from <https://selectio.hr/selectio-vijesti/indeks-zena-u-biznisu-najveci-dosad-uvredena-i-nova-direktiva>

According to the conducted analysis and available data published by SELECTIO, although the number of women on boards has increased from 2005 until 2023, the number of companies with a female board president has decreased compared to 2023. Instead of five companies, in 2023, four companies have female presidents who are united and the only board members. They also emphasized that the positive trend in Croatia seems less positive when it is placed in a European context. According to data from the European Institute for Gender Equality from 2021, the share of women in the boards of the most important companies listed on stock exchanges in the European Union is 31.6%, so Croatia is still lagging behind the European average by almost 10%.

The Croatian Financial Services Supervisory Agency (HANFA) and Zagreb Stock Exchange prepared the Annual Corporate Governance Report, in which there is a visible level of corporate governance of the issuer whose securities are listed on a regulated market in the Republic of Croatia. According to the Annual Corporate Governance Report in Croatia that has been published in 2023, in the period from 2018 to 2022, there is a visible trend of a slight increase in the share of women in management (from 13% to 16 %) and the supervisory board (from 21 % to 23 %) of the issuer. Average share of women in management of the issuer in the observed years is 15%, and in the supervisory board of the issuer 22%. (Godišnji izvještaj o korporativnom upravljanju, 2022).

Whether the gender quota will be successful automatically after increasing the proportion of women on supervisory boards depends primarily on whether corporations will carry out the legal provision on increasing the proportion of women. Will this lead to secondary effects and in what sense, depends on breaking gender stereotypes? In corporations this will probably first of all bring changes in corporate culture. It can be expected that it will also contribute to different transformations in organization, especially those connected with culture and society. This will also create a competitive advantage because previously highly skilled talents will have an opportunity to present their whole working potential.

6. Discussion and concluding remarks

This paper offers new contribution to the literature about gender diversities and gender quotas on corporate boards in EU Member States. Effective corporate governance has a crucial role

for a reputation and profitability of corporation. Corporations need to have effective corporate governance if they want to fulfill main strategic goals. In the last two decades the interest for corporate governance issues has risen, especially those that are interrelated with diversity on corporate boards. Different theories presented in this paper have shown that presence of women in corporate boards do have significant impact while empirical research focused on gender diversity on corporate boards shows both, positive and negative impact. Also, different secondary research data presented in this paper, reveals that there is still a lot of space for the improvement of current situation regarding Gender Equality Index and proportion on women on corporate boards in EU Member States as well as SELECTIO index of women in business and Annual Corporate Governance Report for the current situation in Croatia.

In all EU Member States men are more represented on corporate boards and lack of gender diversity still remains one of the main problems based on equality in the EU. Gender diversity on corporate boards is very important for different reasons. It brings more experiences, perspectives and ideas to the decision-making process, that in corporate context can lead corporation to new and effective strategies as well as innovation in business. As it can be seen in this paper, majority of studies have shown that corporations with diverse boards perform better business results, both in financial sense and in terms of overall corporate governance.

There is no doubt that “Women on Boards” Directive (EU) 2022/2381 will bring more equality, diversity and inclusion in corporate boards. The most important will be to follow the participation of women in decision-making processes in corporations. It will be also interesting to evaluate, monitor and control, whether, as many published studies have already confirmed, the presence of women in the board room will have positive impact on corporation, especially regarding firm performance, leadership behaviour, quality and better interpersonal relationships as well as communication at the workplace. For the empowerment of women in corporations it is also necessary to include practices such as diversity trainings, mentoring and networking programs and different programs that include balance between private and professional life.

It is important to point out that gender quotas in corporations are just one mechanism among many others for the empowerment of women at the labor market. Quotas can be effective just if they are combined with other mechanisms, especially policies, strategies, programs and rules of corporation. Other problems still remain, such as inclusion of women at the labor market in patriarchal societies, especially in leadership positions, flexible working conditions, equal payment etc.

Whether quotas are the most effective approach depends on the context and objectives of corporation or whole society. At the end it is important to highlight that it is essential to continue working towards equal, diverse and inclusive society where people, especially regarding gender, have equal opportunities for success.

Analysis conducted in this paper is based on review of previous conducted studies and secondary research data, and that can be interpreted as a limitation of this paper, lack of empirical findings. Future research should be focused to more comprehensive analysis of proportion on women on corporate boards in EU Member States, primarily based on the primary research data. Additionally, in the future it will be interesting to investigate the effect of mandatory quotas, few years after its implementation in EU Member States, especially on effectiveness of corporate boards, firm's performance as well as on other mechanism of corporate governance.

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FORECASTING THE DEVELOPMENT OF THE TELECOMMUNICATIONS SECTOR UNTIL 2050 USING THE CTE MODEL

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Abstract. Telecom operators will have important roles in following years and decades. At the same time, new satellite mobile operators will be competitors and partners to existing terrestrial telecom operators. In order for the partnership to prevail, modern terrestrial telecom operators must adapt to new market conditions. In addition to a new approach in the development of products and services, a new approach in advertising, sales and customer care, a top-quality connection to the customers will be of great importance for the business of every telecom. This paper will present an analysis of the forecast of the development of the telecommunications market until 2050 based on the CTE Model. Through the CTE Model, the development of the telecommunications sector and the status and role of traditional telecom operators by area will be analyzed with an emphasis on the segment of signal coverage and accessibility to users and on the segments of product development and service development in following decades.

Key words: *telecom operators, Industry 4.0 era, CTE Model, forecasting.*

1. Introduction

Access to the customers will be one of the important issues in following years and decades for telecom operators. New services will require very fast access speed and very low latency. Because of these reasons, fiber optic access networks will be very important as one of the key items for each telecom operator. Fiber optic access networks will have two important parts:

- access to customers for satisfying their needs and for offering new advanced services and
- as support for mobile access to users at high speed and with little and insignificant signal delay.

In the Industry 4.0 era, telecom operators will have to be more ICT providers than classical telecom operators. It means that Telecom 4.0 will have to spread their business niches into information and communication levels and offer more different products and services to their customers than they have been offering until today.

This paper will provide a deeper and more precise explanation of the model for analyzing the potential of telecom operators, and will provide forecasting of fiber optic access network requests regarding new improved and advanced ICT services. It will be briefly analyzed telecommunication markets from 1990 to forecasting up to 2040 by using of Comprehensive techno-economic model and will be shown results of fiber optic access networks forecasting for following two decades.

The CTE Model is quite a complex model in its structure defined with three levels, eight areas that are composed of 14 segments and with items in each of the areas. Therefore, it is not easy to describe it here, if all the details can be found in the literature that precedes this paper. In the further part of the text, the basic facts and characteristics of the model will be briefly explained.

2. Main facts and figures of the CTE Model

2.1. Description of the CTE Model

A new Comprehensive Techno-Economic Model for analysis of telecom operator potentials (former EKF Analysis) is new approach for telecom operator analysis. The development of this model has been going on for some time and the basics and its development can be found and monitored by analysing papers published at SpliTech 2016, SoftCOM 2016, CIET 2018, FOAN 2019, ICETIS 2021 conferences and in Applied Sciences journal in 2023.

The aim of this research is to create a comprehensive model for the analysis of the potential of telecom operators, based on professional experience and knowledge, but also on previous scientific research. This model is easy to use in telecom operators in order to optimize business. Such a comprehensive model enables and facilitates the laying of the basis for making certain business and strategic decisions.

Comprehensive Techno-Economic model for analysis of telecom operator potentials is defined by levels, areas (fields), segments and different associated items in each segment. There are three levels:

- Technical Level (TL)
- Business Level (BL)
- Environmental Level (EL)

The number of different segment that will be defined in this model is fourteen. These fourteen areas are:

- Coverage and accessibility to users (TL),
- Technological development (TL)
- IT Development (TL)
- Products Development (BL)
- Services Development (BL)
- Sales (BL)
- Customer Care (BL)
- Human Resources – HR (BL)
- Political Environment (EL)
- Regulatory Environment (EL)
- Law Environment (EL)
- Finance Environment (EL)
- Quality of Brand (EL)
- Presence in public

The format of the model has been presented as “2 – 4 – 2 format”. That means fourteen segment have been distributed into eight areas (fields). This distribution is presented in Table 1.

Table 1. Distribution of areas in CTE Model

Technical Level	T.1. Coverage and Accessibility to Users		T.2. Technological Dev. and IT Development	
Business Level	B.3. Products Development	B.4. Services Development	B.5. Sales and Customer care	B.6. Human Resources (HR)
Environmental Level	E.7. Political, Financial, Regulatory and Law environment		E.8. Quality of Brand and Presence in publics	

Each area in this model will give individual results but also some areas will have interconnections with other different areas for getting more precise results. The results will be presented as:

- Total amount of CTE Model for individual telecom operator potential
- Total Field Value (the maximum value is of each area 1 or 100% and because of this reason it is still not defined number of areas)
- Each item in each area will allow more detailed analysis of sub-segments and comparison with competitors,
- The results will be presented in tabular and graphical forms,

The classification by category for each of the areas is as follows:

- from 0 to (inclusive) 25% - insufficient quality value
- from 25% to (inclusive) 50% - a satisfactory value
- from 50% to (inclusive) 75% - good value
- from 75% to (inclusive) 90% - a very good value
- from 90% to 100% (or over 100%) - excellent value.

These values worth for assesment of each area and for each item if some items are in the focus of evaluation of telecom operator (modular way of using the model).

3. Assessment of the development of the telecom market using the CTE Model

Comprehensive Techno – Economic (CTE) model will continue to grow and develop. CTE model is finished but will be changed in the future. How is it possible? If it will be analyzed how this model would look like if it existed in eighties, nineties of the last century and in the first and the second decade of this century, it will become clear that this model of “living matter” is subject to change over years and decades. It will be also analyzed how it will look like in the third, the fourth and the fifth decade of this century. It will be shown and clear that this model is alive and in constant change and adaptation of the telecommunications market. This article will explain in the simplest guidelines the potentials but also the dangers that telecom operators will face in the coming years in the Web3 environment, in the metaverse environment and in the Industry 5.0 era in several decades.

3.1. The layout of the CTE Model in past decades based on available information

At the beginning, the appearance of the CTE Model will be given in the eighties of the last century, which are considered the beginning of the development of modern telecommunications, because in that decade great changes in the telecommunications segment began (albeit quite slowly).

Table 2 shows the assumed appearance of the CTE model in eighties of the last century (how it would have looked like if it had existed then). An effort was made to present the appearance

of this model based on the available information what was the emphasis in telecommunications and how developed were telecommunications in general in that period. The development of the business segment of telecommunications was at a significantly low level in the eighties of the last century. Accessibility to users was based on fixed access to users, and there were no services with added value, and mostly everything was focused on voice calls via the fixed network and telegraphic traffic. It can be concluded that at the technical level there was only one area with items that included mainly connection to the user with copper pairs and coaxial copper cables. In the eighties of the last century, the telecommunications market was still in its infancy. As the commercialization of the first GSM mobile systems started after 1991 (in the 1990s), it can be noted that all items in the CTE model (in the eighties) would be based on fixed access to users.

The area of technological and IT development is combined with the area of accessibility to users. Items in the segment of IT development practically did not even exist, while items of technological development were based on current switching and transmission systems without some advanced functionalities.

The Business Level (BL) is divided into three areas because the Product Development and Service Development segments are merged into one area. It can be stated that there were no significant challenges at this level in the eighties and that these areas were at the very beginning of their creation. Today, it can be stated that the development of products and services, sales, customer service and the development of human resources are key segments of every telecom, but in the eighties of the last century when telecoms were technologically oriented and technologically driven, business level areas were less important.

At the very beginnings of modern telecommunications, there was not so much interest in the environment for that area. Many definitions and regulations that exist today from the regulatory, legal and financial areas as well as the area of sustainable development, were simply not defined. Many items regarding market regulation or competition simply did not exist, and therefore all segments from the Environment Level (EL) could be classified into one area that would include the current legal and regulatory items.

Individual items by area will not be shown here, as this is not necessary for this paper, but only the basic characteristics of the model and individual areas will be summarized. It can be stated that the CTE Model has only five areas (14 segments), which clearly indicates the fact that the telecom market was not significantly developed in this period, nor was special attention paid to certain segments.

Table 2. The assumed appearance of the CTE Model in the eighties of the last century

	CTE Model		
Technical Level	Coverage and Accessibility to Users, Technological Dev. and IT Development: Technology (and IT) development and accessibility to the customer will be based on fixed network: copper pair and coax network. There were no advanced ICT services yet.		
Business Level	Products Development and Services Development: Fixed tariffs without special modern services.	Sales and Customer care: no special features	Human Resources (HR): this segment was not yet significantly developed
Environmental Level	Political, Financial, Regulatory and Law environment and Quality of Brand and Presence in public: no special features		

While the theoretical foundations of modern mobile telecommunications were laid in the 1980s, the first concrete practical steps were taken in the 1990s - the first mobile GSM network was launched, the first GSM mobile call was made, the first SMS message was sent, the first commercial GSM roaming contract was established between telecoms in different countries, etc. The most important events that characterized this decade are:

- 1991: The first GSM call made with the mobile operator Radiolinja in Finland.
- 1992: The first international roaming agreement was concluded between Telekom Finland and Vodafone from Great Britain.
- 1992: The first SMS message was sent.
- 1993: Telstra Australia becomes the first non-European operator to sign the GSM MoU, which was previously signed by 32 network operators in 18 countries.
- 1994: GSM phase 2 – start of commercialization of data transmission and fax services.
- 1994: The number of one million users of GSM services in the world has been reached.
- 1995: The number of GSM users reached 10 million.
- 1995: More mass use of fax, data and SMS services began.
- 1995: The first video call via the GSM system was demonstrated.
- 1995: The first mobile network in the USA that worked in the PCS 1900 spectrum (today GSM 1900) was put into commercial operation.
- 1996: The first mobile networks in China and Russia were put into operation commercially.
- 1996: Commercialization of the first pre-paid GSM service (in Portugal).
- 1996: The number of mobile networks in the world is 167 in 94 countries.
- 1996: The number of GSM users is 50 million.
- 1997: In operation (commercial use) 15 GSM mobile networks in the USA in the 1900 MHz frequency range.
- 1997: There is at least one mobile network in 100 countries in the world.
- 1997: Presented the first mobile device that works on all three GSM spectrums (900/1800/1900).
- 1998: The number of GSM users exceeded 100 million.
- 1999: First test Wireless Application Protocol (WAP) services in France and Italy.
- 1999: The first contracts for the delivery of the General Packet Radio Service (GPRS) system were signed. GPRS stands for 2.5 G mobile GSM systems.

Through this short presentation of mobile communications in the nineties of the last century, it is clear that the market and segment of telecommunications has changed significantly in this decade. This can also be shown through the reset appearance of the CTE model at the end of the nineties of the last century.

At the end of this decade, the CTE Model has a slightly different appearance in the structure of areas and differently defined items by area. According to the analyzes of the available literature from that era, the optimal appearance of the CTE Model is with 7 areas in the form of 2-3-2. In this period, telecoms were still more technologically oriented and managed, which is why this distribution of areas is understandable. In Table 3, items by area will not be given, as this is not even essential for the analysis, but the focus on individual areas will be clarified in order to observe the differences and progress of the telecommunications sector in this decade.

The technical level changes shape in the nineties and two areas are defined. Analysis of all found and available works, documents, regulations and the like, clearly shows the need to define the area of availability and the area of IT and technological development. It is important to emphasize that at the end of nineties of the last century, there would be about 8 items defining the quality of fixed network accessibility to users and a maximum of 2 items describing accessibility to users via the mobile network. A significant shift in the development of telecommunications

in the direction of moving towards mobile accessibility to users is noticeable, although fixed accessibility to users still prevails in the telecommunications segment. These fixed items brought significantly higher revenues than the mobile segment of telecommunications.

Table 3 also shows how significantly the telecommunications segment is changing. By comparing Table 2 (view of the CTE Model at the end of the eighties of the last century) with Table 3 (view of the CTE Model at the end of the nineties of the last century) can clearly notice all the changes by areas. There is the change in the structure of the model itself - the technical level is divided into two areas. All the changes will not be further analyzed here, but this part will be used later in the paper (together with the analyses that follow), for a complete presentation of the changes in the telecommunications sector from the beginning of the eighties of the last century until today.

Table 3. The assumed appearance of the CTE Model at the end of nineties of the last century

	CTE Model		
Technical Level	T.1. Coverage and Acc. to Users: Mobile coverage and access to the customers. Mobile connection was based on GSM and GPRS technologies. Fixed access based on copper pairs and coax copper network. One to two items were based on optical network systems: connections among settlements. Appx. 8 fixed items and 2 mobile items in this area.	T.2. Technological Development and IT Development Quality analysis of mobile switching systems Analysis of the quality of fixed switching systems Analysis of transmission quality at different levels Analysis of local access network quality Analysis of the quality of optical transmission systems at the international, national and other levels (if they exist) Analysis of the quality of the IT system within the company to support better business operations (if any) By items, the technological segment prevails (8 items), while the IT segment is still in its early stages of development (2 items).	
Business Level	B.1. Products Development and Services Development: Products and services development: one area. Tariffs in fixed networks. Different tariffs in mobile networks based mostly on voice and SMS. Services were based on VAS, SMS/MMS and similar.< By items, product development items predominate (approx. 7 items), while service development is represented by approx. 3 items.	B.2. Sales and Customer care Sales activities include analysis of the distribution and quality of sales points, the quality of the sales staff there, and the quality of B2B sales through authorized sales representatives The customer service is based mainly on the analysis of the quality of the Call Center (speed of response, quality of the answer...) and the training of the staff from the customer service. There is still no online sales or customer care.	B.3 Human Resources (HR) Already in the mid-1990s, the strengthening of HR segments (sector / department) within telecom operators was noticeable, and the importance of this segment for the development of telecoms was recognized. In the coming years, this segment within telecoms will gain more and more importance.

Environmental Level	E.1 Political, Financial, Regulatory and Law environment	E.2 Quality of Brand and Presence in public
	With the development and growth of the mobile telecommunications market, segments in this area began to recognize the importance of telecommunications. This especially applies to the part related to regulatory affairs. Other segments have also begun to adapt to the business area of telecommunications.	This area is experiencing significant changes in the nineties. The quality of the brand is becoming one of the key indicators for the recognition of telecom operators. Positioning of telecoms in the public and recognition of telecoms and its products and services by users is becoming one of the most important areas in a competitive environment. Individual items will not be defined here, because it is not important for the article itself or for the analysis in it, but only important. It is descriptively shown how much this area is changing compared to the eighties of the last century.

In the first decade of this century, significant changes began in the telecommunications segment, with special emphasis on changes in the mobile segment. Some of these changes that are important for analysis are:

- 2000 year
 - First commercial GPRS network launched
 - The tender for the first 3G licenses has been announced
- 2001 year
 - The world's first WCDMA (3GSM) network launched commercially
 - The number of GSM users in the world has exceeded 500 million
- 2002 year
 - The 800 MHz band for GSM is also being introduced
 - First MMS (Multimedia Messaging Services) message sent
 - About 95% of countries around the world have GSM networks
- 2003 year
 - The first commercial EDGE (Enhanced Data Rate for GSM Evolution) network launched
 - Mobile operators from over 200 countries in the world are members of the GSM association
- 2004 year
 - There are 1 billion mobile users in the world
 - There are more than 50 WCDMA networks in commercial operation worldwide
- 2005 year
 - Over 1.5 billion GSM users
 - The first commercial HSDPA (High-Speed Downlink Packet Access) network launched
 - Over 100 WCDMA (Wideband Code Division Multiple Access) networks in commercial operation
- 2006 year
 - 2 billion GSM users in the world
 - Over 120 WCDMA networks in commercial operation in over 50 countries - almost 100 million users
 - Approximately 85 HSDPA networks in commercial operation (at the end of 2006)

- 2007 year
 - Continued commercialization of HSDPA networks and presented HSUPA (High-Speed Uplink Packet Access)
- 2008 year
 - Three billion mobile users in the world.
 - HSPA (common name for HSDPA and HSUPA) has about 50 million users.
 - Completed LTE standards.
 - There are over 4 billion mobile users in the world.
- 2009 year
 - The first commercial HSPA+ (or E-HSPA = Evolved HSPA) network put into commercial operation
 - The first commercial LTE (4G) network launched

In the first decade of this century, changes also occurred in the fixed segment of telecommunications, but much faster and more significantly in the mobile segment, which is why these changes are mentioned. Table 4 will show the changes by areas and in the structure of the CTE Model itself, because these changes in the fixed part (IP telephony, IPTV technology, xDSL technology, FTTH access and the like) must not be ignored.

The technical level didn't change shape in the in this decade and there are still two areas. Individual items within these areas have changed significantly and this indicates continuous changes in the field of telecommunications as a whole. The comparison of the appearance of the CTE Model at the end of the nineties of the last century and at the end of the first decade of this century is clearly manifested and shown in the items in these two areas. Comparing the Technical Level (TL) of CTE Model, it is clear that the telecommunications market is turning towards the mobile segment and towards the IT segment. In other words, the field of telecommunications is becoming increasingly mobile and oriented towards IT technologies. The end of this decade is characterized by the commercialization of the first LTE networks, which confirms these previously mentioned facts.

Table 4. The assumed appearance of the CTE Model at the end of the first decade of this century

Technical Level	CTE Model	
	Coverage and Accessibility to Users:	Technological Dev. and IT Development
	Mobile Coverage: 4G started in 2009 Emphasis on mobile accessibility in urban areas (indoors and outdoors), on roads of all levels and as much as possible in rural areas Fixed services based on copper pairs, coax and FTTH and FTTBus Massive connections among settlements by fiber optic cables Appx. 6 fixed and 4 mobile items.	Web 2.0 started in 2005. Year Services related to Internet access are becoming increasingly important Social networks are gaining importance in the second half of this decade VAS services The first OTT services are appearing, which are both a threat and an opportunity for operators. Appx. 6 Technology and 4 IT items

Business Level	Products Development New approach in mobile tariff models. Convergent fixed-mobile tariffs Tariffs based on mobile Internet access IPTV Appx. 5 fixed and 5 mobile product development items.	Services Development Convergent fixed-mobile services Services based on (mobile) Internet approach SMS/MMS VAS services IP services Video services More mobile than fixed items in this area.	Sales and Customer care The capabilities of the call center are significantly enhanced Sales points gain importance. B2B sales are becoming a must have. The first web applications for customer support also appeared.	Human Resources (HR) HR is gaining importance because the importance of the quality of personnel in all segments is widely understood HR specialized teams are formed Training of employees through professional and scientific training.
Environmental Level	Political, Financial, Regulatory and Law environment Regulatory items are significantly gaining importance. The emphasis is on the legal (claims collection) but also the financial (fraud) area The environment that affects operators is becoming an increasingly important area because the importance of telecom operators in society and the environment is being recognized.		Quality of Brand and Presence in public: Brand quality and recognition in the public are measured Digital marketing is becoming an indispensable part of the marketing mix Beginning of advertising on social networks A quality Marketing mix (TV, radio, newspapers, online, outdoor...) becomes crucial for the success of recognition Brand quality becomes more important as recognition becomes key in a large number of advertisements in all media.	

Significant changes are observed at the Business Level (BL). There are now four areas at this level as the “Product and Service Development” area has been split into two areas, namely “Product Development” and “Service Development”. In this decade, increasing emphasis is being placed on the quality of tariffs, tariff options and tariff groups (products), as well as on services such as mobile VAS SMS/MMS services and the beginnings of the development of various Over the Top (OTT) services. The business level and the change in it clearly indicate that telecoms are becoming more and more business-oriented and fruit-driven, and that new diverse services and products and a flexible approach to users are becoming crucial as competition in this market grows.

Significant changes are also noticeable at the Environment Level (EL). Significant changes and shifts are occurring in both areas, and this can especially be noted for area E.2 “Area of brand quality and presence in the public”. Precisely because of the increase in the number of operators, the increase in the number of new services and products, and the raising of the level of quality of access to users, the quality and recognition of the brand and presence in the public become crucially important for every telecom. These changes will be specifically summarized at the end of this analysis where the changes will be clearly shown and how the CTE Model would react to them.

In the second decade of this century (2010 – 2019), significant changes continued in all areas of the telecommunications market. The changes that are important for analysis are:

- 2010
 - Over 5 billion mobile users in the world
 - Over 162 HSPA networks and 52 HSPA+ networks put into commercial operation.
 - There are 17 LTE commercial networks in operation.

- 2011
 - Over 6,000,000,000 users of mobile services
 - Over 2,000,000,000 mobile Internet users
 - “Downloaded” over 35,000,000,000 mobile applications
 - About 1,400,000,000 users of social networks in the world
- 2012
 - The number of users of GSM technology in the world is over 6.5 billion.
 - The most mobile users are in China (about 1.1 billion), followed by India (about 900 million), the USA (320 million), Indonesia (260 million), Brazil (260 million), Russia (227 million), Japan (128 million)...
 - Germany has the most mobile users in Europe (about 115 millions)
- 2013
 - At the end of 2013, there were around 6.9 billion mobile users in the world
 - In the last few years, with an emphasis on the period from 2015, it is much more important to observe the guidelines for the development of mobile systems.
- 2014 - 2019
 - Vision 2020 includes preparations for the introduction of 5G mobile networks, IoT (Internet of Things), IIoT (Industrial Internet of Things), Over the Top (OTT) applications, cloud services and the like.
 - The emphasis is no longer on the mass and number of users of mobile devices, but on the number of devices connected to the Internet (IoT and IIoT)
 - In the future, users will not only be people but also devices/things connected to the Internet.

The CTE Model that was current at the transition from the second to the third decade of this century (roughly in the period 2018 - 2023) is shown in Table 5. All items are listed by area, but due to the complexity of the description, forward-backward links are not listed here. The entire model with all descriptions can be found in the attached literature.

When the current appearance of the CTE Model is analyzed and compared with previous representations from 1980 to the present, it is clear how much the telecommunications market has changed (and accordingly the CTE Model) and in which direction these changes are going. According to these inputs, in the further part of the text, an attempt will be made to obtain guidelines for the development of the telecommunications market in the next 25 years, which can significantly help telecom operators in planning their guidelines and long-term development strategies.

Table 5. The appearance of the CTE Model in the period around 2020

CTE Model			
T.1. Signal coverage and accessibility to users (T1) T.1.1. Quality of mobile data access in outdoor urban environments T.1.2. Quality of access to mobile data in special parts of urban environments - areas of mass gatherings T.1.3. Quality of access to mobile data in rural areas T.1.4. Quality of access to mobile data on highways and main national roads T.1.5. Quality of access to mobile data on regional and local roads T.1.6. Quality of distribution and number of portable optical cables (fibers) at the state level T.1.7. Percentage of fiber optic connections to homes (houses, apartments, cottages,...) - FTTH (Fiber to the Home) T.1.8. Percentage of fiber optic connections to factories, business facilities, incubators, etc. – FTTB (Fiber to the Business) T.1.9. Local loop shortening T.1.10. Quality of protection of the primary transmission system and all transmission systems up to the endpoints in case of failure of the entire system or part of it		T.2. Technological and IT development (T2) T.2.1. Quality of the switching system T.2.2. Quality of the billing system T.2.3. Quality of obtaining reports from databases T.2.4. Quality of Self-service customer portal(s). T.2.5. Quality of transmission system technologies T.2.6. The quality of technical support for the IoT offering of mass services T.2.7. The quality of technical support for IoT offers B2C services for private users T.2.8. Quality of technical support for IIoT service offering T.2.9. Quality of technical support for the quality of OTT services T.2.10. Quality of Cloud Service Center	
B.3. Product development (B3) B.3.1. Quality of post-paid private mobile tariff models B.3.2. The quality of post-paid business mobile tariff packages B.3.3. Quality of pre-paid mobile tariff packages B.3.4. Quality of post-paid private mobile tariff groups B.3.5. Quality of post-paid business mobile tariff groups B.3.6. Quality of tariffs for fixed Internet access and TV service for private users B.3.7. Quality of tariffs for fixed Internet access and TV service for business users B.3.8. Quality of tariff packages and options for IoT/IIoT services B.3.9. Quality of tariff packages and options for Over The Top (OTT) services B.3.10. Quality of tariff packages and options for IaaS, PaaS and SaaS services	B.4. Service development (B4) B.4.1. Quality of Service of the Internet of Things (IoT) Mass Market B.4.2. Quality of specialized Internet of Things (IoT) services for private users B.4.3. Quality of Internet of Things (IIoT) business services B.4.4. Quality of Over The Top (OTT) video services B.4.5. Quality of Over The Top (OTT) services for calls, video calls and messages B.4.6. Software as a Service (SaaS) quality B.4.7. Quality of "Platform as a Service" service (PaaS) B.4.8. Quality of "Infrastructure as a Service" service (IaaS) B.4.9. Quality of "Anything (Other) as a Service" (XaaS) B.4.10. "Combined advanced services" quality	B.5. Sales activities and customer care (B5) B.5.1. The quality of distribution of sales centers in the country B.5.2. Quality distribution of sales representatives and partners B.5.3. Quality of sales and customer staff B.5.4. Quality of "B2C online" sales B.5.5. Quality of "B2C online" support and customer care B.5.6. The quality of "B2B online" sales B.5.7. Quality of "B2B online" care for business customers B.5.8. Quality of pre-sale analyses B.5.9. Quality of after-sales analysis B.5.10. Quality of Call center	B.6. Human Resources (HR) (B6) B.6.1. Quality (potential) of telecom managers B.6.2. Quality (potential) of telecom employees B.6.3. Quality of independence in hiring managers and employees B.6.4. Quality of investment in training and education B.6.5. Quality investment in specialized courses and training B.6.6. Quality of compensation – salaries, bonuses and others B.6.7. Quality of work environment B.6.8. Quality and expertise of the staff in the HR segment B.6.9. Quality of information systems (database) about employees B.6.10. Quality of the positioning of the company in the environment - as desirable for the employee
E.7. Political, financial, regulatory and legal environment (E7) E.7.1. Resistance to the political situation in the country E.7.2. Resistance to political changes in the region and the wider area of potential influence on the state of the analyzed telecom E.7.3. The potential of the average purchasing power of individuals in the country for telecom operations E.7.4. The potential of the average purchasing power of the family E.7.5. The potential (quality) of users who are employed in production or service activities E.7.6. The potential of international visitors for telecom business - private users - individuals and families E.7.7. Potential of international visitors for telecom business - business users E.7.8. Quality and speed of resolution of legal cases in the courts of the country E.7.9. Regulatory stability in the telecommunications sector in the country E.7.10. Percentage of consumed energy of the telecom that was produced from renewable energy sources.		E.8. Brand quality and media presence (E8) E.8.1. Quality of the telecom operator brand in the country E.8.2. Quality of sub-brands of telecom operators in the country E.8.3. Quality of the brand and sub-brands recognized by visitors from other countries E.8.4. Relative amount of money invested in telecom campaigns, taking into account marketing spending at the country level in all business segments E.8.5. Quality of the digital environment - assessment of the potential of your website E.8.6. Quality of digital advertising - web advertising E.8.7. Quality of digital advertising - use of LinkedIn social network E.8.8. Quality of digital advertising - use of the social network Facebook E.8.9. Quality of digital advertising - use of the Instagram social network E.8.10. Quality of digital advertising – e-mail advertising	

3.2. Assessment of the development of the telecommunications based on the CTE Model

CTE Model was created for the need to assess the potential of individual telecom operators and their mutual comparison as a whole as well as by item. Through research that has been conducted for many years, it has been concluded that this model, with certain assumptions, can also be used for forecasting and evaluating the development of telecommunications markets in the future. This very possibility, which was recognized through research on the model, will be used in the next part of the work, and an assessment of the development of the telecommunications market will be presented, as well as assumptions in which direction telecom operators should develop and position themselves.

The prediction of the development of the telecommunications market, that is, the development guidelines for telecom operators, will be processed by area through the model. These changes and predictions will be presented and summarized in following tables and graphs. Considering the work in which the emphasis is on technical changes, changes will be presented with an emphasis on areas T.1 and T.2, i.e. changes at the Technical Level (TL).

Table 6. Development of T.1 area of CTE model from 1990 – 2040 year

T.1.	1990	2000	2010	2020	2030	2040
Fix	5-6	8	6	5	2	0
Mob	0	2	4	5	8	10

Graph 1. Development of T.1 area of CTE model from 1990 – 2040 year

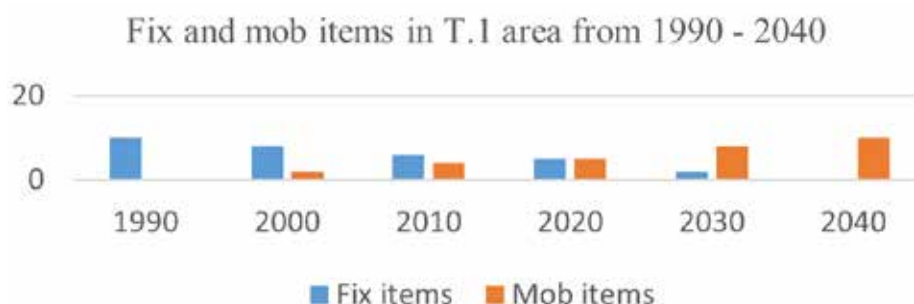


Table 7. Development of T.2 area of CTE model from 1990 – 2040 year

T.2.	1990	2000	2010	2020	2030	2040
Tech.	4-5*	8	6	4	2	0
IT	0	2	4	6	8	10

*) - In the eighties of the last century, whose presentation is given in 1990, there was only one area at the TL level.

Graph 2. Development of T.2 area of CTE model from 1990 – 2040 year



Although the CTE Model was not originally intended as a model for forecasting the development of the telecommunications market, but only for the analysis of telecom potential and their comparison, in this paper it was used precisely for forecasting the development of the telecommunications segment (with certain assumptions). With the assumption of a certain linear development of the Technical Level (TL), an assumption was made of the distribution of items in T.1 and T.2 areas, which suggests the direction in which the development of telecommunications is going. This was done until 2040 with a note that the fifth decade of this century (2040 - 2050) will be analyzed separately at the end of the work because it is not possible to guarantee the linearity of development in the next 25 years. Tables 6 and 7 clearly show the even development of areas T.1 and T.2, which is logical because any disturbance in this development can lead to the investment of funds in some segment, which would not lead to an adequate return of the invested funds.

Table 8. The vision view of the CTE model in 2030 based on the assumptions of the development of the ICT segment in the future period

	CTE Model			
Technical Level AI will have significant impact	Coverage and Accessibility to Users: 6G mobile networks Li-Fi technology Satellite communications Mobile coverage everywhere FTTO and connections among settlements. Eight items from mobile segment and two from fixed segment.		Technological Dev. and IT Development Technological part: Quality of transmission systems and Quality of switching systems. All other items will be from IT Development: IoT, IIoT, OTT platforms, Cloud systems and servers, XaaS servers and supports, Billing servers and support. Technological Dev. = 2 items; IT Dev. = 8 items.	
Business Level AI will have significant impact	Products Development Post-paid and pre-paid tariffs based on mobile Internet. The focus will be on tariffs with download/upload speed and latency and with an unlimited amount of traffic consumption (with a fair consumption clause) and not on tariffs with included talk minutes, SMS messages and data traffic. Tariff models for IoT, IIoT, Cloud, OTT (voice and video) and the like will be integrated into post-paid tariff packages or offered as options for pre-paid and post-paid tariff packages.	Services Development Services based on mobile Internet. Services will be based on existing and new technologies that will be offered to users as integrated or as separate (special purchase options). The services that will dominate are services based on IoT, IIoT, OTT, Cloud services, XaaS and new ones that will be developed in the Web3 / metaverse environment.	Sales and Customer care Sales and customer care will increasingly function online, and Artificial Intelligence will take over a significant part of the work due to the speed of action and the provision of quality and quick answers. Although there are still separate sales activities and customer care activities, the border between sales activities and customer care is slowly disappearing and this area is taking the form of Activities aimed at satisfying all customer needs.	Human Resources (HR) Artificial Intelligence will take over a significant part of the jobs in HR. This segment becomes particularly important because a lot of work will be ordered from external partners and consultants.

Environmental Level AI will have significant impact	Political, Financial, Regulatory, Law and Web3 environment This area is experiencing certain changes because the Web3 environment is included in the overall analysis.	Quality of Brand and Presence in public Emphasis is placed on digital marketing, digital branding and the general Web3 and metaverse environment.
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In Table 8, items are not given by individual areas, but the names of certain technologies and services that will be key for defining the items and areas are described. Emphasis, as previously written, was placed on areas T.1 and T.2. The number of items 2 in the fixed segment of the area T.1 does not mean that the fixed infrastructure is not important. On the contrary, the fixed infrastructure is placed in a subordinate position for the reason that it becomes the basis for the development of mobile networks. Thus, in the prediction of CTE Mode for the fourth decade of this century (Table 9), the number of fixed items in the T.1 area is zero for the reason that a fixed infrastructure based on fiber optic cables becomes mandatory always and everywhere. This is precisely why fixed infrastructure is not analyzed here - it is mandatory, and its lack will be reflected in lower ratings of items in the mobile segment. A similar explanation can be given for area T.2. The number of items from the technological segment is decreasing and the number of items from the IT segment is increasing. Technological items become the basis for the development of IT items. The number of technological items in the T.2 area at the end of the fourth decade of this century will be zero, because they will be the basis for the development of modern and newer IT items.

Table 9. The vision view of the CTE model in 2040 based on the assumptions of the development of the ICT segment in the future period

	CTE Model			
Technical Level AI will have significantly huge impact	Coverage and Accessibility to Users: 7G mobile networks Li-Fi technology 2.0 or higher Satellite communications 2.0 or higher New access technology(ies)? Mobile coverage everywhere and AI on the edge Ten items from mobile segment and zero from fixed segment.		Technological Dev. and IT Development All other items will be from IT Development: IoT, IIoT, OTT platforms, Cloud systems and servers, XaaS servers and supports, Billing servers and support. AI implemented in applications. New types of services and applications? Technological Dev. = zero items; IT Dev. = ten items.	
Business Level AI will have significantly huge impact	Products Development Products will be based for metaverse and Web3 environment. All activities will be based on mobile Internet with very high download and upload speeds and a delay of 0 ms (theoretically). Artificial intelligence will make some of the key decisions.	Services Development Services based on IoT, IIoT, OOT, Cloud Services... but also services in the Web 3 and metaverse environment based on holograms and many new services with low latency, that do not exist for now. AR/VR	Activities aimed at satisfying all customer needs This area will experience significant changes because access to users will also change significantly due to the development and changes in areas T.1, T.2, but also areas B.1 and B.2.	Human Resources (HR) It's hard to predict, but AI will have a huge role and significance in this area. To what extent is difficult to define, but it will certainly increase the objectivity in decision-making in HR.

Environmental Level AI will have significantly huge impact	Political, Financial, Regulatory, Law environment The area E.1 is divided into two areas and this indicates the importance of changes in the environment, which will no longer be only physical but also virtual.	Web3/metaverse environment The area E.1 is divided into two areas and this indicates the importance of changes in the environment, which will no longer be only physical but also virtual.	Quality of Brand in metaverse environment The assumption is that the quality of the brand will be measured in the metaverse environment and that this will be the most important for users when choosing a provider of products and services.
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There are noticeable changes in the structure of the model, which now has a 2-4-3 shape. The change in the environment will also affect other parts of the model in the coming decade, as telecoms will have to adapt to the new Web3 environment in both technical and business terms. When looking at Table 9, it is clear how big the changes are. Emphasis is placed on areas T.1 and T.2. When you look at the comparison of the CTE Model from 1990 and 2040, it is clear by the items in these areas how much the telecommunications market has changed in 50 years. And when you look at the structure of the CTE Model from 1990 (max. value $1+3+1 = 5$) and from 2040 (max. value of the model $2+4+3 = 9$), it is clear that the value potential of telecoms has increased and will be increased even more in following years.

In the fifth decade of this century, there will be additional changes in the telecommunications market, and this can be read in a certain way from the CTE Model. It is hard to forecast 25+ years ahead, some guidance can be given. Table 10 will show the assumed appearance of the CTE Model with an emphasis on areas T.1 and T.2.

Table 10. The vision view of the CTE model in 2050 based on the assumptions of the development of the ICT segment in the future period

	CTE Model	
Technical Level New generation of AI?	Coverage and Accessibility to Users: 8G mobile networks Li-Fi technology 3.0 or higher Satellite communications based on LEO New access technology(ies)? Mobile coverage everywhere and New gen of AI on the edge Possibility of separating the C&A area into two areas - fixed and mobile, where ten items will be analyzed in each of the areas considering the development of telecommunications.	Technological Dev. and IT Development All other items will be from IT Development: IoT, IIoT, OTT platforms, Cloud systems and servers, XaaS servers and supports, Billing servers and support. AI implemented in applications. New types of services and applications? There is a possibility of separating the Tech&IT area into two areas - Technological and IT area. Ten items in each area will be analyzed: development of telecommunications + technological support for new and improved existing IT services.

Business Level New generation of AI?	Products Development Considering the development of ICT and other technologies, it is quite possible that Industry 5.0 will start at the beginning or middle of this decade, and it is impossible to precisely define what telecom products will be based on. But it is possible to assume that global service providers will be able to offer their products and/or services worldwide - it will significantly threaten local telecoms.	Services Development It is the same as for area B.1.*	Activities aimed at satisfying all customer needs All activities are moved to the virtual world. AI assumes a huge role in the field of customer care. Will there even be a need for physical store locations? Maybe for a main point of sale in the biggest cities, without emphasis on them.	Human Resources (HR) It's hard to predict, but New gen of AI will have a huge role and significance in this area. To what extent is difficult to define, but it will certainly increase the objectivity in decision-making in HR.
Environmental Level New generation of AI?	Political, Financial, Regulatory, Law environment The area E.1 is divided into two areas and this indicates the importance of changes in the environment, which will no longer be only physical but also virtual.	Web3/ metaverse environment The area E.1 is divided into two areas and this indicates the importance of changes in the environment, which will no longer be only physical but also virtual.	Quality of Brand in metaverse environment The vast majority (or perhaps all) of the activity is being moved to the virtual world in Web3 or possibly some new Web4 environment..	

*) - note: it is not possible to predict all the new services that will appear, as well as the progress of AI and other technologies.

As stated, it is possible to expect the beginning of the Industry 5.0 era in this decade, which means new significant changes in the telecom market. These changes will be reflected in the CTE Model, which at the end of this decade could take the form of 4-4-3 (max. value 11 without of positive feedback links) and perhaps some other structure whose sum will be greater than 11. This clearly indicates that telecommunications will change significantly, and if we compare the telecommunications segment from the fifth decade of this century (an assumption with approximations) to the eighties of the last century, their importance is more than doubled for people and all business segments.

4. Conclusion

The CTE Model was created as a model for a quick but also reliable assessment of the potential of telecom operators and their mutual comparison. His basic concept and idea was not to predict the future. However, during the research for the model, the idea came up to try to make an assumption of the model from the beginning of the eighties of the last century until the middle of this century. In the literature, it was possible to find a lot of high-quality works

from the past, as well as works dealing with the future and development of telecommunications. That's how this paper came about, which involves predicting changes in the telecommunications market in the future over the next 25+ years with certain assumptions.

According to the analyses and research carried out and presented in this paper, the telecommunications market is continuously and rapidly changing, with the fact that in periods of industrial revolutions these changes are faster and more significant. In essence, it can be pointed out that from decade to decade the changes are more pronounced and for this very reason it is difficult to make certain predictions beyond the year 2050 because all these predictions would be reduced to guesses and big assumptions.

Key managers of telecom operators must understand that the time of changes in the telecommunications market has already begun and that changes are taking place very quickly. Many telecoms are not yet aware of the changes that are happening and there is a real possibility that many of them will not be able to monetize the 5G network and the services that go with it, and the first commercial 6G networks will already appear. This problem will lead to stratification in many markets and to uneven development of the telecommunications market in certain regions and countries. Precisely because of this, this paper offers certain guidelines for telecoms in which direction they must accelerate change processes and in which direction they should invest money in order to catch up with other telecoms from more advanced countries and markets and how to join these advanced markets.

In the next few years, telecoms must carry out a complete digital transformation of their entire business in all areas of the CTE Model, in order to be ready for the next decade and all the changes that follow in the telecommunications market. Also, they must already be aware that the changes after 2040 will probably be even faster and more significant, and that global providers will take over a significant part of the market worldwide, while local and smaller telecoms need to find their niche in cooperation with them through partnership relations. This is precisely why it is necessary to immediately start the necessary changes in business (if they have not already been started so far) in order to find their segment of activity in the coming decades.

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REDDIT WORLD WAR II QUESTION SIMILARITY CORPUS CREATION

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Abstract. The paper outlines the creation of a small-scale corpus intended for use in question pair similarity tasks. The dataset consists of World War II-themed sentences gathered from Reddit. The BERT language representation model was used to obtain the sentence vectors and narrow down the initial question pair pool. This was done by comparing the cosine distance between the sentences and selecting the pairs with a distance below an empirically chosen threshold. The selected sentence pairs were then subjected to a round of manual tagging to separate them into positive and negative examples by tagging them as either 1 (similar) or 0 (dissimilar). Additional sentence pairs were found by means of automatic keyword matching. This part of the process was based on relevant World War II-themed keywords (e.g. *Germany, Churchill, atomic bomb*) extracted from the manually tagged sentence pairs. The tagger also leveraged the NLTK framework for word synonym generation. The assumption was that semantically similar sentences would have multiple significant keywords in common, so sentences were tagged as similar if they shared at least one keyword pertaining to the relevant countries, nationalities and/or leaders (e.g. *USSR*), and at least one contextual keyword that was not a stopword (e.g. *attack*). The question pairs selected by means of automatic tagging were then subjected to a round of manual tagging, and positive matches were combined with the positive and negative pairs gathered in the previous steps to obtain the final corpus. The finished corpus comprises approximately 5600 positive and negative question pairs.

Key words: *BERT, corpus creation, machine learning, NLP, question similarity*

1. Introduction

The purpose of this paper is to outline the creation of a World War II-themed sentence corpus that is intended for use in question pair similarity tasks. Questions related to World War II were selected to narrow down the pool of key terms in the target domain. This makes it suitable for question similarity tasks because superficial similarity based on shared words is not sufficient for accurate predictions; true understanding of the underlying meaning is required for the question pairs to be evaluated correctly.

In more general terms, the purpose of corpora such as this one is testing natural language processing (NLP) approaches in understanding the semantics of texts written in natural languages. Although World War II was chosen as the theme for this corpus, the process outlined in this paper can be applied to any other domain.

The corpus creation process consists of three main parts: data gathering, sentence extraction and processing, and finished corpus assembly.

The sentences were gathered from Reddit and processed programmatically. We then selected a pool of positive and negative sentence pairs using a combination of automatic

and manual tagging. The finished corpus consists of 5652 question pairs in CSV (*comma-separated values*) format.

The first part of the paper presents a brief summary of key terms and machine learning frameworks and libraries relevant to the process, and the second part of the paper outlines the practical steps taken to obtain the finished corpus.

1.1. Question similarity

Question similarity is a type of NLP task that aims to find semantic equivalents of a question in an existing corpus. This type of NLP lends itself well to community-based question answering forums because it allows users to find out if their question has already been posted (Kunneman et al. 2019: 593).

The question similarity (or question relevance) task typically consists of two ranking steps:

1. retrieving relevant questions for the target question input using a general information retrieval technique
2. re-ranking the candidates with a more fine-grained approach (and optionally determining if a candidate question is a duplicate of the target question)

(Kunneman et al. 2019: 593)

1.2. Reddit

Reddit is a news aggregation and discussion website that covers a broad range of topics grouped into subforums that are referred to as *subreddits*. The website allows users to join communities organized around their interests, ask questions, participate in discussions, and rate other members' posts (<https://www.redditinc.com>). Boasting millions of active daily users, Reddit is a popular source of web-scraped corpora and data analytics.

We retrieved the sentences for our corpus from *r/AskHistorians* (<https://www.reddit.com/r/AskHistorians>), a subreddit dedicated to history-related discussions. *AskHistorians* is one of the largest public history forums on the internet, with hundreds of panellists – professionals and amateurs alike – and over 1.5 million monthly visitors¹.

1.3. Pushshift Reddit dataset

Pushshift is a platform dedicated to social media data collection, analysis, and archiving. The platform's Reddit dataset comprises historical data from the moment of Reddit's inception and allows social media researchers to easily access content that would otherwise be difficult and time consuming to collect (Baumgartner et al. 2020: 1).

The dataset contains billions of Reddit comments from 2005 to the present day, and is available through an API that allows users to search post archives, create data aggregations, and check for correlations in the data (Baumgartner et al. 2020: 7).

We used the Pushshift Reddit API to retrieve post content from the chosen subreddit.

1.4. PyTorch

PyTorch is an open-source machine learning framework that offers various tools and libraries for data experimentation, analysis, and processing (<https://pytorch.org>). We used HuggingFace's

¹ <https://www.askhistorians.com>

BERT Transformer (<https://github.com/huggingface/transformers>) available via PyTorch to perform the sentence vector tokenization in the preparation of our corpus.

The HuggingFace *Transformers* library is dedicated to supporting Transformer-based architectures. The Transformer is the dominant architecture for natural language processing, and it is particularly well suited to pretraining on large text corpora (Wolf et al. 2020: 38).

Each model in the *Transformers* library consists of a Tokenizer, Transformer, and Head. The model is pretrained with a fixed head, but other heads can be applied to fine-tune the model and improve its performance in various NLP tasks. Each model uses a specific Tokenizer that corresponds to its pretraining. There are various Transformer architectures that are specialized for different tasks or use cases, such as the BERT masked transformer (Wolf et al. 2020: 40).

1.5. BERT

BERT (**B**idirectional **E**ncoder **R**epresentations from **T**ransformers) is a language representation model designed by a group of Google researchers. At the time of its release, it achieved state-of-the-art results on various language processing tasks (Devlin et al. 2019: 1).

The BERT model architecture is based on the original implementation in Vaswani et al. (2017).

BERT employs the existing strategy of fine-tuning pre-trained language representations from unlabeled text, and improves upon it by leveraging a bidirectional approach. Both left and right context are taken into account in the learning process – a novel feature representing a major improvement over the standard (unidirectional) language models, due to the latter's limitation of only being able to attend to previous tokens in the Transformer's self-attention layers (Devlin et al. 2019: 1-2).

In the pre-training stage, the model is trained in pre-training tasks on an unlabeled corpus using the random word masking strategy. The fine-tuning stage entails initializing the model with the pre-trained parameters from the previous step and fine-tuning it with labeled data (dependent on the downstream task to be performed) (Devlin et al. 2019: 5).

In order to make BERT suitable for various down-stream tasks, a single input representation token sequence can represent both one sentence and a pair of sentences (the special [SEP] token is used as the delimiter between the two). Every sequence token is also given a learned embedding that indicates which of the sentences it belongs to. The first token of every sequence is the special [CLS] token, and its final hidden state serves as the aggregate representation of the sequence in classification tasks. An individual token's input representation is obtained as the sum of the corresponding token, segmentation, and position embeddings (Devlin et al. 2019: 4-5).

Devlin et al. report their results on two models: $BERT_{BASE}$ and $BERT_{LARGE}$. $BERT_{BASE}$ contains 12 layers (Transformer blocks), 768 hidden layers, 12 self-attention heads, and 110M parameters, whereas $BERT_{LARGE}$ has 24 layers, 1024 hidden layers, 16 attention heads, and 340M parameters in total. The authors demonstrate that BERT can be used effectively not only for fine-tuning approaches, but also for feature-based ones (Devlin et al. 2019: 9).

1.6. Scikit Learn and NLTK

Scikit-learn is a Python module that integrates a wide range of machine learning algorithms for supervised and unsupervised problems. It is primarily intended for data analysis by non-specialists in academic and commercial settings (Pedregosa et al. 2011: 2826).

We used *Scikit-learn* helper functions at various points of the process.

NLTK (Natural *Language Toolkit*) is a suite of Python modules, datasets, and tutorials intended for NLP research and development. *NLTK*'s text processing libraries can be used for various tasks, such as tokenization, parsing, and semantic reasoning, and it also provides interfaces to popular datasets and other corpus-related resources (<https://www.nltk.org>).

We used *NLTK* for lemma generation and comparison in the automatic corpus tagging stage, as well as for locating word synonyms via the *WordNet* interface.

2. Related work

Online question answering communities were facing question similarity challenges long before the advent of modern language representation models, as most of the websites wanted to show related questions in response to a user's query (Paranjpe 2007: 1-2).

Question pairs exhibit different levels of similarity and relatedness:

- lexical and semantic similarity (there is a very high degree of overlap in both the words and the meanings)
- lexical similarity only (there is an overlap in words, but the meanings are different)
- semantic similarity only (different words are used, but the meanings are similar)
- somewhat relatedness (there is a partial overlap in both the words and the meanings, and the questions could be considered similar in certain contexts)

(Paranjpe 2007: 3-4).

Measuring semantic similarity between questions becomes challenging when the word overlap is not significant. Since large-scale corpora comprised of semantically similar but lexically dissimilar question pairs can be difficult to assemble from real data, researchers would often resort to generating an artificial corpus by paraphrasing the base collection of sentences somehow (e.g. via translation and back-translation) (Jeon et al. 2005: 1-2).

Other approaches favoured in the past include using bilingual corpora or nonparallel monolingual corpora, but such strategies do not perform as well in question paraphrasing (Zhao et al. 2007: 2). The fact that questions tend to be short means that even small lexical differences can mask semantic similarity (Jeon et al. 2005: 3). Some examples of strategies to circumvent that limitation include relying on comparing the similarity between the corresponding answers (Jeon et al. 2005: 3) and classifying questions by type (Zhao et al. 2007: 2).

In more recent times, a wealth of question-answer data can be obtained from popular question-and-answer websites and networks such as Stack Exchange² and Quora³. Whereas advanced neural networks and language models facilitate the use of unsupervised methods, preprocessing the input and combining multiple methods both contribute to the end result (Kunneman et al. 2019: 599). A few examples of successful novel approaches can be seen in the works of Shirani et al. (2019), Sakata et al. (2019), and Mass et al. (2020).

Shirani et al. assembled a large-scale question relatedness corpus from Stack Overflow, a development discussion platform. The corpus creation steps entailed extracting knowledge units from Stack Overflow and using different types of neural networks and traditional models to identify and extract knowledge unit pairs and to predict relatedness between them (Shirani et al. 2019: 3-5).

Sakata et al. used BERT for determining the relevance between question-answer pairs as part of their FAQ retrieval method, tested on a self-constructed dataset and a Stack Exchange

² <https://stackexchange.com/>

³ <https://www.quora.com/>

dataset (Sakata et al. 2019: 2). The approach to FAQ retrieval tasks proposed by Mass et al. relies on distant supervision and multiple fine-tuned BERT models (Mass et al. 2020: 2).

Inspired by existing research but operating at a much smaller scale, our approach incorporates BERT use with manual and programmatic tagging strategies.

3. Corpus creation

This part of the paper outlines the process of corpus creation and testing, from data collection and preparation to sentence pair validation and BERT model fine-tuning. The steps of the process are outlined in the following flowchart:

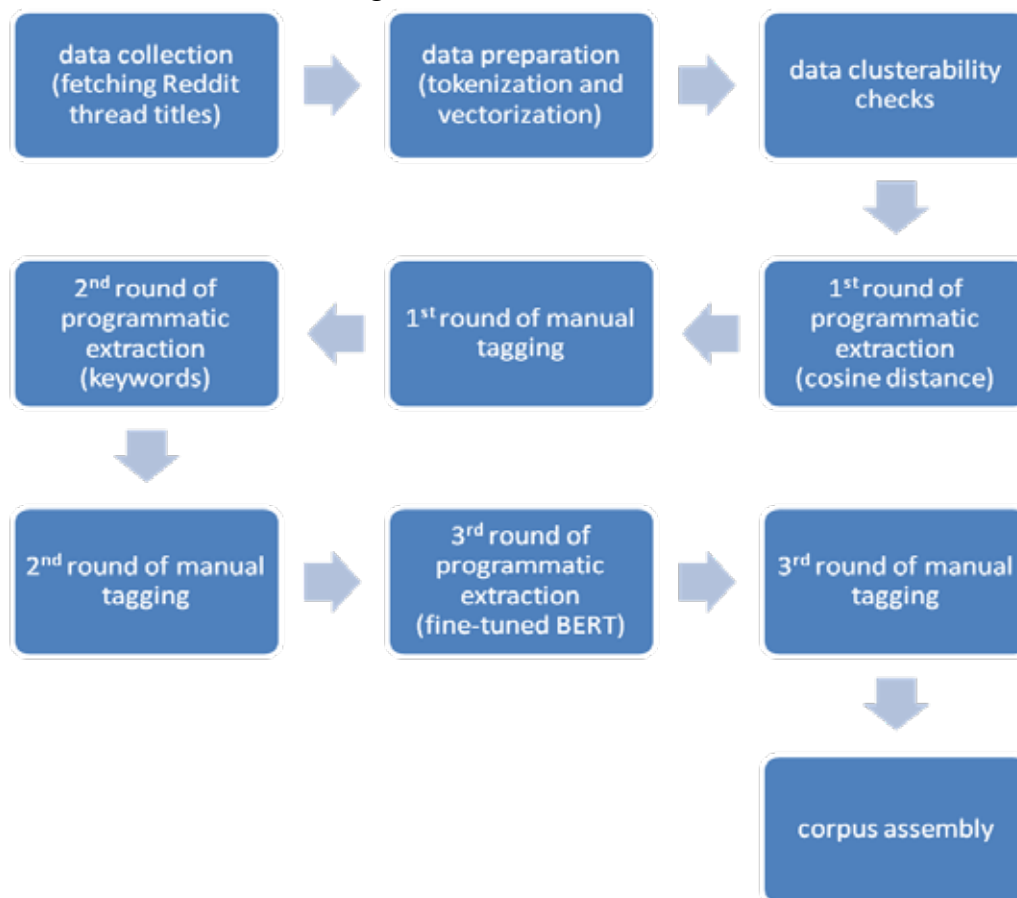


Figure 1 Corpus creation process flowchart

The process begins with data collection, and continues with data preparation and clusterability checks. Those steps are followed by three rounds of programmatic question pair extraction, complemented by three rounds of manual tagging. The finished corpus is assembled from the positive and negative question pairs gathered in the previous steps.

3.1. Data collection

Sentence gathering was the initial point in the corpus construction. We retrieved thread titles from the *r/AskHistorians* subreddit, disregarding the comment content. We used the following criteria to locate suitable sentences:

1. the sentence may only contain English characters ([a-z][A-Z]), apostrophes (‘), commas (,), and question marks (?)

2. the sentence must end with a question mark
3. the sentence must contain a reference to World War II or III ('World War II', 'WWII', 'World War III' and/or 'WWIII'; the latter two were included because of sentences hypothesizing about the future after WWII)

The search yielded 3875 eligible sentences for the time range between January 1st 2011 and January 1st 2020.

We performed no additional data processing because the sentences were already sufficiently simplified due to the restrictive nature of our data gathering criteria. Our next step entailed obtaining token vector representations of the sentences in order to check for clusterability in the sentence pool.

3.2. Data preparation

We used the *BERT-Large Uncased*⁴ model to convert the corpus sentences into token vectors.

To match the required format, they were first wrapped in [CLS] and [SEP] tags. We then used the *pytorch-pretrained-bert* tokenizer to generate the tokenized representations of corpus sentences, wherein every word was replaced by a corresponding index from the tokenizer's model.

The maximum sentence length in the corpus was 54 words, so we settled on 64 (the nearest power of 2) as the standard. The tokenized sentences were all padded to a length of 64 tokens using the placeholder token index 0.

We then fed the tokenized sentences to the model to obtain the word vectors. Each BERT-encoded item was represented by a tensor with the following shape:

12 (hidden layers) x 1 (sentence) x 64 (tokens) x 768 (hidden units)

Since sentence vectors were required for the following step, we obtained those by computing the means of the 11th hidden layer unit values for each of the word vector tokens. We opted for the 11th hidden layer because higher hidden layers tend to have more context-specific representations (Ethayarajh 2019: 5).

3.3. Data clusterability checks

Prior to proceeding to the sentence tagging stage, we tested the clustering tendency of our sentence vectors using several methods.

We first conducted the test using the Hopkins statistic, which relies on the comparison of the distances between sampled data points and pseudo data samples. The underlying assumption is that uniformly distributed data points will not yield meaningful clusters. Therefore, if both sets of distances are similar on average, then the original data points have a low or non-existent clusterability tendency (Adolfsson et al. 2018: 9).

The Hopkins statistic for our Reddit question dataset was very close to 0, indicating a low clustering tendency. There are various possible reasons for such an outcome, one being an insufficient number of sentences that can be paired up. It is also possible that BERT's tokenized sentence representations are not suitable for this type of clustering check, especially because the Hopkins statistic is predominantly used in non-linguistic data checks.

4 <https://github.com/google-research/bert>

We also checked for clusterability using K-means clustering⁵ (with Euclidean and cosine distance, as well as the Elbow method), but the approach produced values indicating a low clusterability and a uniform item distribution.

On the one hand, the results could be taken as an affirmation of the assumption about the majority of the corpus being novel (non-duplicate) questions. On the other, it could mean that the given approaches were ineffective at direct comparison of raw sentence vectors, at least in this particular case.

Due to the nature of forums and the users' tendency towards not repeating questions that have already been asked, we assumed that the number of semantically similar sentences in the dataset would not be high. We opted for a simplified approach of locating semantic pair candidates by comparing the distances between every question and every other question, and determining how many of the top 30 neighbours for each question shared semantic similarity with that question.

3.4. Programmatic candidate question pair extraction

Given that the number of possible sentence pair combinations in our data surpassed 15 million, it first was necessary to narrow down the initial question pair pool in order to enable manual tagging.

We started by ordering the sentence vector pairs (excluding same-sentence pairs) by cosine distance using the Scikit-learn pairwise_distances⁶ metrics method. Cosine distance was selected because it provided slightly better results than Euclidean distance in a test conducted using a smaller part of the corpus.

We decided to extract the pairs with a distance less than 0.0035 for manual tagging. The distance cut-off value was selected empirically; values below it yielded only several hundred to several thousand rows, which seemed too small a sample in a pool of over 7 million rows. Conversely, values above it yielded hundreds of thousands of rows, which would require a great amount of time and effort to tag manually. The selected distance of 0.0035 resulted in a sample size of roughly 20000 rows, both sufficiently small to be suitable for manual tagging and sufficiently large to provide enough positive sentence pair examples.

3.5. Manual question similarity tagging

The selected sentence pairs were manually tagged as 1 (similar) or 0 (dissimilar), with the questions being considered similar if the same (or similar) reply could be used to answer both. Some examples of acceptable pair sentence relations, as per the selected similarity criterion:

1. semantic equivalence (the sentences have different phrasing, but the meaning is unambiguously the same):

Did the populace at large see WWII coming?

Did people see WWII coming?

2. synonymous elements (some words or phrases are not identical, but can be considered synonymous in context):

*At what point during the Cold War was the world closest to **WWIII**?*

*At what point during the Cold War were we closest to a **nuclear WWII**?*

⁵ <https://scikit-learn.org/stable/modules/generated/sklearn.cluster.KMeans.html>

⁶ https://scikit-learn.org/stable/modules/generated/sklearn.metrics.pairwise_distances.html

3. scope overlap (the answer to one question is a subset of the answer to the other question):

*How did countries such as **Switzerland and Spain** remain neutral in WWII?*

*How did **Switzerland** manage to remain neutral in WWII?*

Although the second sentence only refers to Switzerland, it is considered to be semantically similar to the first in this context.

4. ambiguity interpretation (at least one reading of ambiguous expressions is possible in which the meanings line up):

What happened to the German veterans of WWII after the war?

What happened to the German military after WWII?

The word *military* broadly refers to a country's armed forces, but is taken to signify soldiers here to match the meaning of the first sentence.

5. scope similarity (the sentences refer to slightly different concepts that can be considered similar in context):

What happened with Nazi propaganda promoters in WWII?

What happened to the Nazi party after WWII?

Not all Nazi propaganda promoters were members of the Nazi party (and vice versa), but there is some overlap between the two, so the sentences are regarded as similar for the purpose of this paper.

We used a Python application that we created ourselves⁷ to perform manual sentence tagging.

The application works by displaying the main (first) sentence in a pair alongside all its candidate (second in the pair) sentences, and allowing the user to mark one or more candidate sentences as semantic matches of the main sentence. The application also enables the user to tag one or more words in the main sentence as significant, thereby filtering the candidate sentences by instantly removing those that do not contain the selected keywords.

The significant keywords selected during this stage were all recorded and analyzed for the purpose of automatic question pair extraction in the next stage of the process.

Manual tagging produced 250 positive sentence pairs, making up roughly 1% of the sentence pairs that had been selected for manual tagging. As stated previously, same-sentence pairs were excluded from the process.

3.6. Automatic question similarity tagging

Prior to assembling a program to automatically find additional positive question pairs in the data pool, we analyzed the significant keywords selected during the manual tagging stage.

Many keywords were related to countries, locations, and nationalities, such as *Germany*, *Jewish*, *Japan*, *Berlin*, *USA*, *Italy*, *England*, and *Soviet Union*. Country leaders and army generals were also prominent, e.g. *Adolf Hitler*, *Mussolini*, *Churchill*, *Hirohito*, *Eisenhower*. Other keywords were war-related words referring to weapons, vehicles, and the like (*guns*, *atomic bomb*, *tanks*).

Based on these findings, we created a custom script⁸ to go over all the remaining question pairs (excluding same-sentence pairs) and tag them as either similar (1) or dissimilar (0) according to a simple set of rules. The program employs the *NLTK* library to locate and match keyword lemmas in the sentences being compared.

⁷ The source code is available at github.com/tkarabatic/manual-sentence-pair-tagger.

⁸ Available at github.com/tkarabatic/automatic-sentence-pair-tagger.

We separated the sentence keywords into two categories:

1. country/nationality/leader (e.g. *US*, *Russian*, *Winston Churchill*) – hard-coded
2. other – inferred from the context

The keywords in category 1 were derived from the manual tagging keyword analysis. The selected keywords were added to the program as a set of constants, which also included synonyms, e.g. *FDR*, *Roosevelt*, *Franklin Delano Roosevelt*. We also added *Hilter* as a synonym for *Hitler* because it was present in some of the sentences.

The keywords in category 2 were not hard-coded, but were determined on a per-sentence basis. These were defined as any non-stopwords that were not part of the first category, and we also made use of the *NLTK* WordNet reader's *synset*⁹ function to generate synonyms to compare against.

The terms *WWII* and *World War II* were also treated as stopwords, considering the fact that all the sentences contained one or the other, as per our criteria outlined in section 2.1.

Question pairs were automatically rated as similar if they had at least one 1st-category match (e.g. *UK* and *Churchill*) and at least one 2nd-category match (e.g. *weapon* and *gun*).

The automatic tagging process marked 760720 sentence pairs as similar, many of which were false positives. Examples of such sentence pairs:

1. *By the end of WWII how did the **US** UK German and Soviet main battle **tanks** stack up against one another?*
*Was the **US** right to use nuclear **weapons** in WWII?*
2. *Did **Hitler** think that the Russians were superior for **winning** World War II? Japan **Germany** and USA as the true **victors** of World War II?*
3. *Why was the **French** population so divided during the **lead** up to World War II? What were **Europeans** saying about Judaism in the **lead** up to WWII?*

Although all of the sentence pairs satisfy the automatic tagging conditions outlined above (the triggers are outlined in bold in the examples), it is evident that there is no semantic overlap within those pairs.

A more in-depth procedure of semantic parsing via a neural net would have yielded much better accuracy. However, the purpose of our rudimentary automatic tagging process was the separation between sentence pairs that share at least some common keywords from those that share none, and the process was successful to that effect.

The automatically tagged pairs were further subjected to a round of manual tagging, resulting in 1131 positive question pairs. We combined them with the pairs located in the first round of manual tagging, for a total of 1381 positive entries. We manually selected 1381 negative (non-matching) pairs from the remaining automatically rated pairs, and added those to the positive entries for a total of 2762 entries. We also included the inverse versions of all the pairs to obtain a corpus consisting of 5524 question pairs.

3.7. Finding additional question pairs with a fine-tuned BERT model

For this part, we repeated the data preparation steps outlined in 2.2, with the distinction of combining sentences into pairs: *[CLS] sentence one [SEP] sentence two [SEP]*.

We fine-tuned a BERT model on the tokenized corpus using a 20:80 test-train split over 2 training epochs. The resulting validation accuracy was 97%.

We then used the fine-tuned model on a small sample of the full dataset with the intention of locating more positive question pairs. The sample included 50 main sentences and their

⁹ <https://www.nltk.org/howto/wordnet.html>

combinations with all other available sentences, excluding same-sentence pairs and the question pairs already present in the finished corpus.

The fine-tuned model tagged 4867 question pairs as positive, 32 of which were found to be true positives in a round of manual tagging. The tagging process being resource-intensive, we decided not to proceed with the fine-tuned search due to the low cost-benefit ratio at a true positive rate of only 0.6 per cent.

The 32 new positive pairs were added to the existing corpus, along with 32 negative pairs and the inverses of both sets, resulting in a finished corpus of 5652 entries.

4. Conclusion

In this paper, we have outlined the basic steps of the creation of a small proof-of-concept corpus based on data gathered from a popular discussion website. Several conclusions can be drawn from the process.

Firstly, the outcome of our attempt at using a fine-tuned BERT model illustrates the importance of using an extensive dataset in training NLP models. A training corpus of roughly 4400 question pairs was insufficient in training a model that would adequately locate true positives in a new dataset without also yielding numerous false positives.

Considering that our corpus would benefit from a greater number of rows, additional content could be gathered from the Reddit dataset using a less stringent set of rules.

Furthermore, we should note that the abundance of free and open-source frameworks and content platforms facilitates experimentation and the creation of novel corpora. The tools and libraries can also be complemented with custom code and resources to provide additional functionality.

It is worth noting that the corpus creation process we have outlined is not restricted to World War II questions, but can also be applied to other domains of knowledge. The general steps taken to collect, prepare, and tag the data can easily be adapted to any other topic for the purpose of question pair similarity tasks.

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Analysis of Thin-walled Curved Beams with a Doubly Symmetric I- and H- Shaped Cross-sections Loaded with Uniformly Distributed In-plane Line Loads

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Abstract. This paper presents a simplified approach for the in-plane linear static analysis of long isotropic thin-walled curved beams with doubly symmetric I- and H- shaped cross-sections, whose undeformed centroid line is the circular arc of small or moderate curvature. In this approach, only the uniformly distributed in-plane centroid line loads (radial and circumferential) are considered, while the presented closed-form solutions are obtained using the initial parameters method. This approach is based on Vlasov's assumptions with the addition that the terms defining the curvature effect are consistently linearized using the Maclaurin series expansion. The analytical solutions are compared with the results of the shell finite element analysis.

Key words: *thin-walled curved beam, doubly symmetric cross-sections, in-plane linear static analysis, distributed line loads, closed-form solutions*

1. Introduction

The thin-walled curved beams with an open cross-section are structural elements whose analysis is complex due to the coupling effects of displacements and internal forces. For doubly symmetric cross-sections, the axial force and the bending moment about the principal axis perpendicular to the plane of curvature (in-plane moment) are coupled, as are the torsional moment and the bending moment about the principal axis in the plane of curvature (out-of-plane moment). For the other cross-section types, all internal forces and displacements are coupled in most cases (Tong & Xu, 2002). Vlasov (1961) presented the first successful model of the kinematics of straight thin-walled beams (Yanze et al., 2021), assuming that there is no cross-section distortion and that the shear strain in the middle-surface can be neglected. Vlasov (1961) also analysed thin-walled curved beams whose cross-section is arbitrarily shaped and whose undeformed centroid line is a circular arc. In order to obtain the internal force-displacement relations of curved thin-walled beams, Vlasov replaced the curvatures of the deformed straight beams with the curvatures of the deformed curved beams in the internal force-displacement relations used for the straight beams. The equilibrium equations of this

approach were established using the free-body method, in which the position of the shear centre with respect to centroid is neglected. Timoshenko & Gere (1961) used a similar approach, but additionally neglected warping and assumed that the centroid line is inextensible, while Yoo et al. (1982) used a similar assumptions in the total potential energy expression.

Alternative approaches to the analysis of thin-walled curved beams are based on the elasticity equations expressed either in the polar (Tong & Xu, 2002) or cylindrical coordinate system. As far as the authors are aware, Tong and Xu (2002) were the first to correctly extend Vlasov's straight beam approach to curved thin-walled beams with arbitrary open cross-sectional shape by using the elasticity equations for shells of revolution. A detailed comparison between Vlasov's approach and approaches based on elasticity equations in the cylindrical coordinate system, where the governing equations were obtained using Vlasov's assumptions, was also presented by Tong & Xu (2002). Among these approaches, only Yang & Kuo (1986) presented the expressions for the longitudinal displacements of thin-walled curved beams with a doubly symmetric I- and H-shaped cross-sections that would fulfil Vlasov's assumptions (Tong & Xu, 2002). According to Kang & Yoo (1994), Yang & Kuo (1986) neglected the membrane component of shear stress in their analysis.

It should be noted that most papers dealing with thin-walled curved beams are concerned with buckling and vibration problems, with numerical methods being investigated to a greater extent than analytical methods (Kustura et al., 2023). Kustura et al. (2022) proposed an analytical approach for the linear static analysis of thin-walled curved beams based on Yang and Kuo's approach but taking into account the membrane component of shear stress. In addition, Kustura et al. presented closed-form solutions required for the in-plane (2022) and out-of-plane (2023) static analysis of thin-walled curved beams with doubly symmetric I- and H-shaped cross-sections. In contrast to the approach presented by the authors of this paper in Kustura et al. (2022), where the effect of distributed line loads is neglected, this study now considers distributed line loads acting in the plane of curvature.

2. Theoretical Development

2.1. Displacements and Normal Stress

The middle-surfaces of a thin-walled curved beam with a doubly symmetric I- and H-shaped cross-section are shown in Fig. 1 and Fig. 2, respectively, where R is the radius of the undeformed curved centroid line. The cylindrical coordinate system $I\rho\phi Y$ and the curvilinear coordinate system $Cxyz$ are used in this analysis, where: $\rho = R + z$ and $\phi = x / R$. The origin C is located at the cross-section centroid and the origin I is located at the centre of the undeformed curved centroid line. The positive direction of the x -axis corresponds to the increase of the angle ϕ , while the y - and z -axes are the principal axes of the cross-section; u , v and w are the displacements of any point P on the middle-surface and u_c , v_c and w_c are the displacements of the cross-section centroid C in the direction of the x -, y - and z -axes, α is the angle of torsion (twist angle), ω is the sectorial coordinate and $(\cdot)' = d(\cdot) / dx$.

As in Kustura et al. (2022), the following assumptions are also used in this study:

- the displacements and strains are small,
- the cross-section middle line is rigid in its own plane,
- the shear strain in the middle-surface is neglected and
- the material is linearly elastic.

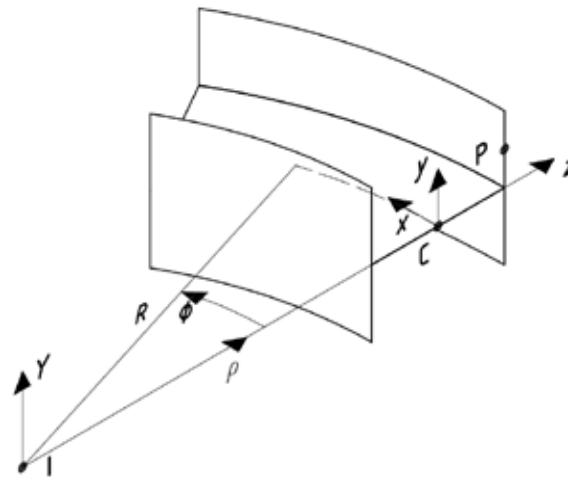


Figure 1 Coordinate systems and middle-surface of a thin-walled curved beam with a doubly symmetric I-shaped cross-section (Kustura et al., 2022)

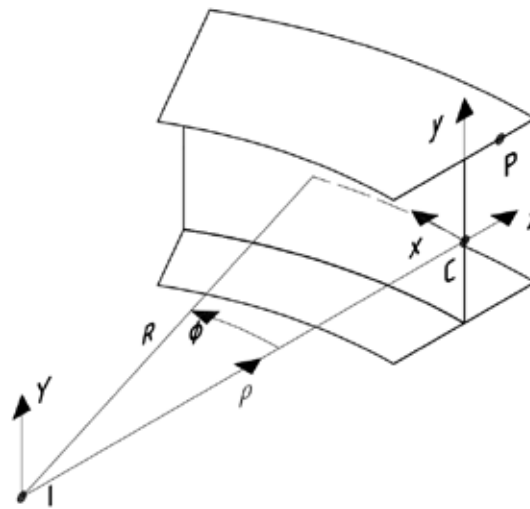


Figure 2 Coordinate systems and middle-surface of a thin-walled curved beam with a doubly symmetric H-shaped cross-section (Kustura et al., 2022)

To obtain the approximate closed form solutions, the following constraints are used in this study:

- as in Kustura et al. (2023), the initial curvature of the beam is small or moderate ($R/d^* \geq 7$, where d^* is the largest dimension of the cross-section),
- only doubly symmetric I- or H- shaped cross-sections are considered,
- thin-walled curved beams are only loaded with the in-plane loading and
- only the uniformly distributed centroid line loads are considered.

In this study, the exponents I and H are used to differentiate the expressions for the beams with a doubly symmetric I- and H- shaped cross-sections respectively, while the expressions without the exponent apply to both cross-sections. If the doubly symmetric cross-section is rigid in its own plane, the transverse displacements of any point P are defined as in Vlasov (1961), i.e.

$$v = v_C - z\alpha \quad (1.a)$$

$$w = w_C + y\alpha \quad (1.b)$$

Based on the strain-displacement relations presented in Yang in Kuo (1986) and following the approach presented in Kustura et al. (2022), the longitudinal displacements of the arbitrary point P are defined as follows:

$$u^I = u_c - yv'_c - z\left(w'_c - \frac{u_c}{R}\right) - \omega^I\left(\frac{v'_c}{R} + \alpha'\right) \quad (2.a)$$

$$u^H = u_c - yv'_c - z\left(w'_c - \frac{u_c}{R}\right) - \omega^H\frac{R}{R+z}\left(\frac{v'_c}{R} + \alpha'\right) \quad (2.b)$$

where $\omega^I = yz$ and $\omega^H = -yz$.

In this case, the longitudinal strains ε_x are defined as follows (Kustura et al., 2022; Yang & Kuo, 1986, Tong & Xu, 2002):

$$\varepsilon_x^I = \left[\left(u'_c + \frac{w_c}{R} \right) - y \left(v''_c - \frac{\alpha}{R} \right) - z \left(w''_c - \frac{u'_c}{R} \right) - \omega^I \left(\alpha'' + \frac{v''_c}{R} \right) \right] \frac{R}{R+z} \quad (3.a)$$

$$\varepsilon_x^H = \left[\left(u'_c + \frac{w_c}{R} \right) - y \left(v''_c - \frac{\alpha}{R} \right) - z \left(w''_c - \frac{u'_c}{R} \right) - \frac{\omega^H R}{R+z} \left(\alpha'' + \frac{v''_c}{R} \right) \right] \frac{R}{R+z} \quad (3.b)$$

If the material is linearly elastic, the normal stress σ_x is defined by Hooke's law as:

$$\sigma_x = E\varepsilon_x = v_c - z\alpha \quad (4)$$

where E is the modulus of elasticity.

2.2. Internal Force-Displacement Relations

For a doubly symmetric I- and H- shaped cross-sections, the cross-section shear centre coincides with the cross-section centroid. In this case, all internal forces and distributed line loads are defined with respect to the curved centroid line (Vlasov, 1961). For these cross-sections, the in-plane and the out-of-plane internal forces are decoupled (Tong & Xu, 2002), and the internal forces acting in the plane of curvature are defined as follows:

$$N = \int_A \sigma_x dA = v_c - z\alpha \quad (5.a)$$

$$M_y = \int_A \sigma_x z dA = v_c - z\alpha \quad (5.b)$$

where N is the axial (circumferential) force and M_y is the in-plane bending moment. The in-plane shear force Q_z can be obtained using Eq. (5) and the equilibrium equations.

Keeping only the linear terms of the Maclaurin series expansion of the term $R/(R+z)$:

$$\frac{R}{R+z} = 1 - \frac{z}{R} + \left(\frac{z}{R}\right)^2 - \left(\frac{z}{R}\right)^3 + \left(\frac{z}{R}\right)^4 - \dots \cong 1 - \frac{z}{R} = v_c - z\alpha \quad (6)$$

and combining Eqs. (3)-(6), the internal force-displacement relations for both cross-sections can be expressed as follows (Kustura et al. 2022):

$$N = AE \left(u'_C + \frac{w_C}{R} \right) + \frac{EI_y}{R} \left(w''_C - \frac{u'_C}{R} \right) \quad (7.a)$$

$$M_y = -EI_y \left(w''_C + \frac{w_C}{R^2} \right) \quad (7.b)$$

where $A = \int dA$ is the cross-sectional area and $I_y = \int_A z^2 dA$ is the moment of inertia about the y -axis. Due to Eq. (6) and the simplicity of the solutions presented, the cross-sectional properties of the curved beams used in this study are the same as those of straight thin-walled beams.

2.3. Equilibrium and Governing Equations

The infinitesimal segment dx of the curved centroid line with in-plane internal forces and distributed line loads is shown in Fig. 3, where q_x and q_z are the distributed line loads in the direction of the x - and z -axis, respectively.

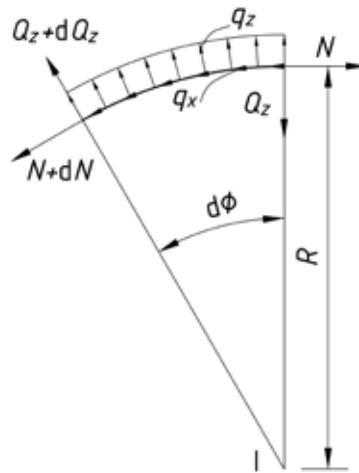


Figure 3 Infinitesimal segment of a curved centroid line with internal forces and distributed loads

The differential equilibrium equations, determined using the free-body approach (Tong & Xu, 2002), for the in-plane analysis are defined as follows:

$$N' + \frac{Q_z}{R} + q_x = 0 \quad (8.a)$$

$$Q'_z - \frac{N}{R} + q_z = 0 \quad (8.b)$$

$$M'_y - Q_z = 0 \quad (8.c)$$

where higher order terms are neglected.

Eliminating the shear force Q_z and the axial force N from Eq. (8), we obtain:

$$M_y''' + \frac{M_y'}{R^2} + q_z' + \frac{q_x}{R} = 0 \quad (9)$$

The governing equation for the in-plane static analysis of thin-walled curved beams with a doubly symmetric I- and H- shaped cross-sections is derived using Eqs. (7.b) and (10), i.e.

$$EI_y \left(w_C'' + 2 \frac{w_C'''}{R^2} + \frac{w_C'}{R^4} \right) - q_z' - \frac{q_x}{R} = 0 \quad (10)$$

2.4. Initial Parameters Method and Boundary Conditions

Equation (10) is a non-homogeneous partial differential equation with constant coefficients and its solution, for the case of constant distributed line loads q_x and q_z , can be expressed as follows:

$$w_C = d_1 + \left(d_2 + d_3 - \frac{d_4}{R} x \right) \cos\left(\frac{x}{R}\right) + \left(d_4 + d_5 - \frac{d_2}{R} x \right) \sin\left(\frac{x}{R}\right) + \frac{q_x R^3 x}{EI_y} \quad (11)$$

where d_1, \dots, d_5 are integration constants. The longitudinal displacement of the cross-section centroid u_C follows from Eqs. (7), (8.a), (8.c) and (11):

$$u_C = \int \frac{N - \frac{AE}{R} w_C - \frac{EI_y}{R} w_C''}{AE - \frac{EI_y}{R^2}} dx + d_6 \quad (12)$$

where d_6 is another integration constant.

In this study, the integration constants are determined on the basis of the initial parameters, which are arranged into an initial state vector:

$$\mathbf{v}|_{x=0} = \mathbf{v}_0 = \left[Q_{z0} \quad M_{y0} \quad \beta_0 \quad w_{C0} \quad N_0 \quad u_{C0} \right]^T \quad (13)$$

where the shear force Q_z is obtained using Eqs. (7.b), (8.c) and (11). The bending moment M_y is obtained using Eqs. (11) and (7.b), the axial force N is obtained using Eqs. (7.a), (11) and (12), while β is the slope of the deflection line in the $I\rho\phi$ plane and is defined as follows:

$$\beta = -\left(w_C' - u_C / R \right) \quad (14)$$

The expressions for the linear static analysis of isotropic thin-walled curved beams with doubly symmetric I- and H- shaped cross-sections, and in-plane loads only, are obtained and expressed by the method of initial parameters as:

$$\mathbf{v} = \mathbf{K}\mathbf{v}_0 + \mathbf{I} \quad (15)$$

where \mathbf{K} is the field matrix defined as in Kustura et al. (2022) and \mathbf{I} is the load vector introduced in this paper in Appendix A. It should be noted that the internal force-displacements relations, the governing equations, and the obtained solutions are only approximately valid due to the simplification introduced in Eq. (6). The expressions for the boundary conditions required for the problem under consideration result from the partial integration of the principle of virtual work and are given in Table 1 (Kustura et al., 2022).

Table 1 The boundary conditions for the in-plane analysis (Kustura et al., 2022)

Clamped end	$u_C = 0$	$w_C = 0$	$\beta - u_C / R = 0$
Simply supported	$u_C = 0$	$w_C = 0$	$M_y = 0$
Symmetry	$u_C = 0$	$\beta - u_C / R = 0$	$Q_z = 0$

3. Results

The analysis of a thin-walled curved beam with an I- shaped cross-section is intentionally omitted in this study since its stiffness-to-mass ratio is smaller compared to H-shaped cross-section for this type of loading. The arc length of the beam is L while b , h and t are the height, width, and thickness of the cross-section, respectively, as shown in Fig. 4.

The elastic modulus and Poisson's ratio are $E = 73$ GPa and $\nu = 0.3$, respectively. The examples used in this study refer to the in-plane analysis of a beam with small and moderate initial curvature clamped at both ends and loaded with a radially distributed centroid line load ($q_z = 100$ N/mm) as shown in Fig. 5. The obtained results are compared with the finite shell model calculated by ADINA (2017), where the local coordinate system of the cross-section is used to define the boundary conditions and to read the results. Due to symmetry at the beam midspan section ($x = L/2$), only half of the beam is analysed.

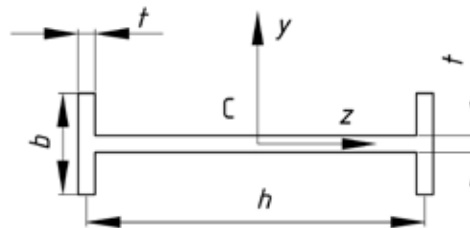


Figure 4 Dimensions of the analysed H- shaped cross-section

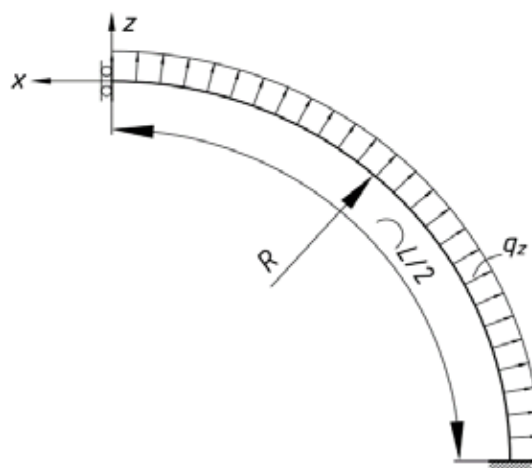


Figure 5 Boundary conditions of the analysed thin-walled curved beam

The boundary conditions as well as the undeformed and deformed configurations of the finite shell model of the beam with moderate curvature are shown in Fig. 6 and Fig. 7, respectively. The values of the radial displacements w_C and the normal stresses σ_x at the web-flange junctions ($y = 0$, $z = \pm h/2$) at the beam midspan ($x = L/2$), i.e. the circumferential displacement u_C at the quarter point of the beam ($x = L/4$), are shown in Table 2 for the moderately curved beam

($t = 5 \text{ mm}$, $b/t = 10$, $h/t = 20$, $R/h = 7$, $L/R = 5\pi/6$) and in Table 3 for the beam with small curvature ($t = 5 \text{ mm}$, $b/t = 6$, $h/t = 20$, $L/h = 30$, $L/R = \pi/2$).

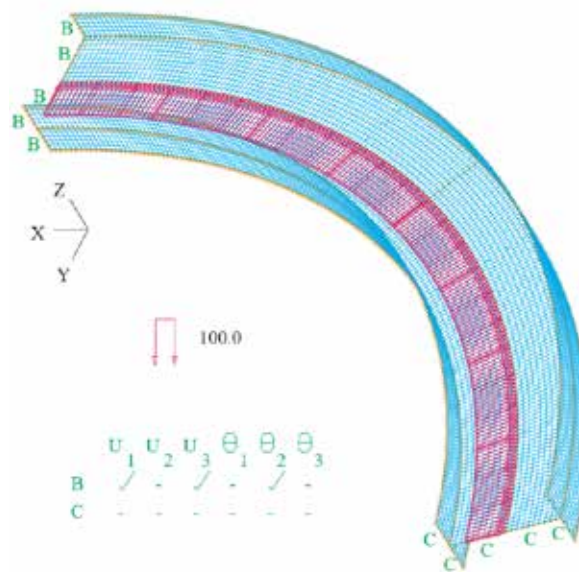


Figure 6 Boundary conditions of the finite shell model of a curved beam with moderate curvature



Figure 7 Deformed and undeformed (dashed line) configuration of the finite shell model of a curved beam with moderate curvature

Table 2 Centroid and normal stress values for the beam with moderate curvature

	w_c / [mm], ($L/2, 0, 0$)	u_c / [mm], ($L/4, 0, 0$)	σ_x / [MPa], ($L/2, 0, h/2$)	σ_x / [MPa], ($L/2, 0, -h/2$)
This paper	1.2341	0.2538	80.1265	53.0299
ADINA (2017)	1.2211	0.2449	77.7763	57.9837

Table 3 Centroid and normal stress values for the beam with small curvature

	$w_c / [\text{mm}],$ $(L/2, 0, 0)$	$u_c / [\text{mm}],$ $(L/4, 0, 0)$	$\sigma_x / [\text{MPa}],$ $(L/2, 0, h/2)$	$\sigma_x / [\text{MPa}],$ $(L/2, 0, -h/2)$
This paper	11.3062	1.3903	291.0726	163.8751
ADINA (2017)	11.2338	1.3687	286.733	168.997

Regarding the displacements, Tables 2 and 3 show a good agreement between the results presented in this paper and those obtained with the finite shell model. There is a slightly larger discrepancy between the analytical and numerical results for the normal stresses, especially for the normal stresses at the inner web-flange junction point ($y=0, z=-h/2$). It can be seen from these results that the discrepancies between the results increase with decreasing radius of curvature. This effect is more pronounced for the normal stress at the inner web-flange junction. The main source of this discrepancy is Eq. (6) where the effect of curvature is simplified. From Tables 2 and 3, it can be also observed that the normal stresses at the inner flanges are significantly reduced compared to the normal stresses at the outer flanges ($y=0, z=h/2$).

4. Conclusions

The closed-form solutions for the linear static analysis of a thin-walled curved beam with a doubly symmetric I- and H- shaped cross-section loaded with uniformly distributed in-plane line loads were presented in this paper. The assumptions used in this study are the same as those of Vlasov. It was shown that there is a good agreement between the results of the proposed approach and those of the finite shell model, both for moderate and small curvature beams. It should be noted that the discrepancy between these results increases for short and relatively short beams, especially for beams with moderate curvature. The authors consider that the shear strain in the middle-surface must be taken into account when analysing these types of beams and that a further parametric study of this problem is required. Furthermore, in the subsequent studies, the governing expressions should be extended to analyse beams with monosymmetric and asymmetric cross-sections and the term $R/(R+z)$ should be fully considered to analyse the curvature effect.

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Appendix A. Field Matrix and Load Vector

The field matrix **K**, introduced in Eq. (15), is:

$$\mathbf{K} = \begin{bmatrix} \cos\left(\frac{x}{R}\right) & 0 & 0 & 0 & \sin\left(\frac{x}{R}\right) & 0 \\ R\sin\left(\frac{x}{R}\right) & 1 & 0 & 0 & R\left(1 - \cos\left(\frac{x}{R}\right)\right) & 0 \\ \frac{R^2\left(1 - \cos\left(\frac{x}{R}\right)\right)}{EI_y} & \frac{AR^2x}{EI_y(AR^2 - I_y)} & 1 & 0 & K_1 & 0 \\ \frac{R^2\left(x\cos\left(\frac{x}{R}\right) - R\sin\left(\frac{x}{R}\right)\right)}{2EI_y} & \frac{R^2\left(\cos\left(\frac{x}{R}\right) - 1\right)}{EI_y} & -R\sin\left(\frac{x}{R}\right) & \cos\left(\frac{x}{R}\right) & K_2 & \sin\left(\frac{x}{R}\right) \\ -\sin\left(\frac{x}{R}\right) & 0 & 0 & 0 & \cos\left(\frac{x}{R}\right) & 0 \\ -K_2 & K_1 & R\left(1 - \cos\left(\frac{x}{R}\right)\right) & -\sin\left(\frac{x}{R}\right) & K_3 & \cos\left(\frac{x}{R}\right) \end{bmatrix}$$

where:

$$K_1 = -\frac{R^2}{EI_y} \left[\sin\left(\frac{x}{R}\right) + \frac{ARx}{I_y - AR^2} \right]$$

$$K_2 = \frac{R^3}{2EI_y} \left\{ 2 \left[\cos\left(\frac{x}{R}\right) - 1 \right] + \frac{x}{R} \sin\left(\frac{x}{R}\right) \right\}$$

$$K_3 = \frac{R^2 \left[x \cos\left(\frac{x}{R}\right) - 3R \sin\left(\frac{x}{R}\right) \right]}{2EI_y} - \frac{AR^4x}{EI_y(I_y - AR^2)}$$

The load vector \mathbf{I} due to the distributed line loads, also introduced in Eq. (15), is:

$$\mathbf{I} = -Rq_x \left\{ \begin{array}{c} 1 - \cos\left(\frac{x}{R}\right) \\ x - R \sin\left(\frac{x}{R}\right) \\ \frac{R^2}{2EI_y} \left\{ \frac{x^2}{R^2 - \frac{I_y}{A}} - 2 \left[1 - \cos\left(\frac{x}{R}\right) \right] \right\} \\ \frac{R^3}{2EI_y} \left\{ 3 \sin\left(\frac{x}{R}\right) - \frac{x}{R} \left[2 + \cos\left(\frac{x}{R}\right) \right] \right\} \\ \sin\left(\frac{x}{R}\right) \\ \frac{R^3}{2EI_y} \left\{ 4 \left[\cos\left(\frac{x}{R}\right) - 1 \right] + \frac{x}{R} \sin\left(\frac{x}{R}\right) + \frac{x^2}{R^2 - \frac{I_y}{A}} \right\} \end{array} \right\} - Rq_z \left\{ \begin{array}{c} \sin\left(\frac{x}{R}\right) \\ R \left[1 - \cos\left(\frac{x}{R}\right) \right] \\ R \left[x - R \sin\left(\frac{x}{R}\right) \right] \\ \frac{EI_y}{EI_y} \\ \frac{R^3}{2EI_y} \left\{ 2 \left[\cos\left(\frac{x}{R}\right) - 1 \right] + \frac{x}{R} \sin\left(\frac{x}{R}\right) \right\} \\ \cos\left(\frac{x}{R}\right) - 1 \\ \frac{R^3}{2EI_y} \left\{ \frac{x}{R} \left[2 + \cos\left(\frac{x}{R}\right) \right] - 3 \sin\left(\frac{x}{R}\right) \right\} \end{array} \right\}$$

A FAST ALGORITHM FOR SOLVING 2D AND 3D ELASTOPLASTIC PROBLEMS WITH MATLAB USING THE CELL-ARRAY APPROACH

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Abstract. The purpose of this study is to propose a fast and efficient MATLAB implementation for solving elastoplastic problems using the finite element method. To accelerate the process of assembling finite element matrices in MATLAB, it is crucial to avoid the use of large ‘for’ loops, as this approach can result in slow and impractical code. By implementing a more efficient method, this study aims to improve the speed of elastoplastic problem-solving with the finite element method.

In the context of finite element analysis with a large number of nodes and elements, vectorized assembling of the required matrices is fundamental to achieve high performance. This paper proposes the use of cell-array data types for assembling strain-displacement and tangent operator matrices. The cell-arrays are constructed as 2D matrices filled with vectors that contain the necessary values for each integration point. This approach can significantly improve the efficiency of the finite element analysis process.

The presented problem is expressed in terms of displacements and then subsequently discretized through the implicit Euler method in time and the finite element method in space. The resulting discretized problem is then solved using the semismooth Newton method.

To facilitate the comprehension of the algorithm, elastic perfectly plastic material obeying von Mises yield criteria, has been assumed. However, it should be noted that the code can be easily adjusted to solve problems that involve hardening.

Given the materially nonlinear nature of the problem, the strain-displacement cell-array can be computed once and remain constant throughout all iterations. To update the tangent operator during each Newton iteration, only integration points exhibiting trial stress greater than yield stress require attention. This approach accelerates the construction of the tangent stiffness matrix, as well as the entire iteration process.

The study has compared the algorithm presented with an existing vectorized MATLAB code. The results indicate that the proposed approach leads to faster convergence times, which speeds up the overall process. These findings demonstrate that this approach is efficient and reliable, making it suitable for various industrial and academic applications.

Key words: *Elastoplasticity, Finite element method, MATLAB vectorization, MATLAB cell-array*

1. Introduction

In modern engineering, as well as educational, research, and industrial environments, Finite Element Analysis (FEA) is the primary method used to solve structural analysis problems. Developing finite element codes can be achieved using different programming languages.

However, high-level computational platforms like MATLAB are often more advantageous due to their simplicity, requiring fewer lines of code and less programming effort overall. However, if MATLAB is not used properly for Finite Element Analysis (FEA), it can result in inefficient code that may be impractical to use. One particular challenge in generating high-performance code on modern hardware is vectorization [1]. Although MATLAB is slow at executing ‘for’ loops over large arrays, it excels in efficiently handling vectorized array and matrix operations. To leverage this strength, vectorization techniques have been applied to various finite element formulations [2,4,5]. Additionally, MATLAB introduced paged matrix functions in version R2020b, which can be used for finite element analysis vectorization [6].

This paper extends the cell-array approach proposed in [3,14] to nonlinear elastoplastic analysis. Using the technique for assembling the tangent stiffness matrix described in [11] together with the cell-array approach, it is possible to construct a fast and efficient algorithm for solving elastoplastic problems.

This approach is based on an elastoplastic solution scheme that incorporates several key techniques. Spatial discretization is achieved through the finite element method, while time discretization is handled via the implicit Euler method. A return-mapping algorithm updates the stress and strain states within each element according to the constitutive model, ensuring the yield conditions are satisfied. Nonlinear equation systems are resolved using the Newton method. The code implementation for the elastic-perfectly plastic model is shown to illustrate the efficiency of the presented approach.

2. Solution of Elastoplastic Problems

The formulation of time-discretized elastoplastic problems using the virtual work principle is essential in the finite element analysis of materials that exhibit both elastic and plastic responses under load. The virtual work principle states that the work done by the actual stress on the virtual displacements is equal to the work done by external forces. For an elastoplastic material, the virtual work equation at time step k is given by:

$$\int_{\Omega} \sigma_k : \delta \varepsilon dV = \int_{\Omega} f_{B,k} \cdot \delta u dV + \int_{\Gamma_t} f_{\Gamma,k} \cdot \delta u dA \quad (1)$$

where Ω is body domain, $\sigma_k = \sigma_k(\varepsilon(u_k))$ is stress tensor which is nonlinear function of strain:

$$\varepsilon_k = \varepsilon(u_k) = \frac{1}{2}(\nabla u_k + (\nabla u_k)^T) \quad (2)$$

u_k is vector of displacements, $f_{B,k}$ is the vector of body forces. $f_{\Gamma,k}$ is the tractions vector applied on the boundary Γ_t , $\delta \varepsilon$ is the virtual strain tensor and δu is the virtual displacements vector. Therefore, the displacements vector u_k that satisfies equation (1) and prescribed boundary displacement must be found. Equation (1) after spatial discretization through the finite element method represents a system of nonlinear equations which can be written as

$$F_k(u_k) = f_k \quad (3)$$

where F is a nonlinear function representing internal forces and f is the vector of external forces. Due to the non-smooth nature of F it is necessary to use the semismooth Newton method for solving equation (3). For each Newton iteration l , a linear system of equations

$$\mathbf{K}_{k,tangent}^l \Delta u_k^l = f_k - F_k(u_k^l) \quad (4)$$

should be solved. In equation (4) Δu_k^l denote unknown incremental vector, u_k^l is previous iteration of the displacement vector and $\mathbf{K}_{k,tangent}^l$ is the tangential stiffness matrix representing generalized derivative of F with respect to u at the current point u_k^l . When Δu_k^l is found then next iteration of displacement vector is simply $u_k^{l+1} = u_k^l + \Delta u_k^l$. Once equation (4) is solved and Δu_k^l is found, it is necessary to update internal forces vector and tangential stiffness matrix for the next Newton iteration

$$\mathbf{K}_{k,tangent}^{l+1} \Delta u_k^{l+1} = f_k - F_k(u_k^{l+1}) \quad (5)$$

as well as internal forces vector and tangential stiffness matrix $\mathbf{K}_{k+1,tangent}$ for next time step $k+1$ when convergence for time step k is reached.

To update the internal forces vector and the tangential stiffness matrix, a constitutive model for elastoplastic material should be used. By applying a backward time discretized constitutive model for elastic perfectly plastic material and the von Mises yield criterion, the expressions for updating the internal forces vector and the tangential stiffness matrix can be written as follows [11]:

$$\sigma_k = \sigma_k^{tr}, \quad \Psi = |s_k^{tr}| - \sqrt{\frac{2}{3}}\sigma_Y \leq 0 \quad (6)$$

$$\sigma_k = \sigma_k^{tr} - (|s_k^{tr}| - \sqrt{\frac{2}{3}}\sigma_Y)n_k^{tr}, \quad \Psi = |s_k^{tr}| - \sqrt{\frac{2}{3}}\sigma_Y > 0$$

$$\mathbf{C}^{alg} = \mathbf{C}, \quad \Psi = |s_k^{tr}| - \sqrt{\frac{2}{3}}\sigma_Y \leq 0 \quad (7)$$

$$\mathbf{C}^{alg} = \mathbf{C} - 2\mu \mathbf{I}_D + 2\mu \frac{\sqrt{\frac{2}{3}}\sigma_Y}{|s_k^{tr}|} (\mathbf{I}_D - n_k^{tr} \otimes n_k^{tr}), \quad \Psi = |s_k^{tr}| - \sqrt{\frac{2}{3}}\sigma_Y > 0 \quad (8)$$

$$\sigma_k^{tr} = \mathbf{C} \epsilon_k - \epsilon_k^p, \quad s_k^{tr} = \mathbf{I}_D \sigma_k^{tr}, \quad n_k^{tr} = \frac{s_k^{tr}}{|s_k^{tr}|}$$

In above expressions Ψ is yield function, σ_Y is a yield stress, s_k^{tr} deviatoric part of trial stress, n_k^{tr} normal unit deviatoric vector, $\mathbf{I}_D = \mathbf{I} - \frac{1}{3}\mathbf{I} \otimes \mathbf{I}$ fourth order deviatoric tensor where $\mathbf{I} \otimes \mathbf{I}$ denotes the tensor product of unit (second order) tensors and \mathbf{I} is the fourth-order unit symmetric tensor. In equations (7) \mathbf{C}^{alg} is so-called consistent (or algorithmic) tangent operator [8,9] and \mathbf{C} is fourth order elasticity tensor defined in terms of bulk modulus K and shear modulus μ with expression

$$\mathbf{C} = KI \otimes \mathbf{I} + 2\mu \mathbf{I}_D \quad (9)$$

To get expressions (6) and (7) elastic predictor, plastic corrector method is applied [7,8]. Initially, a trial stress σ_k^{tr} is computed to determine if it resides within the elastic domain. If the trial stress is within the elastic domain ($\Psi \leq 0$) then $\sigma_k = \sigma_k^{tr}$. Otherwise, a plastic correction, also known as return mapping, must be applied to the trial stress. Similarly, if the trial stress falls within the elastic regime, consistent tangent operator remains unchanged $\mathbf{C}^{alg} = \mathbf{C}$, if not a correction is required. Furthermore, the plastic strain has to be updated as follows:

$$\epsilon_k^p = \epsilon_{k-1}^p, \quad \Psi = |s_k^{tr}| - \sqrt{\frac{2}{3}}\sigma_Y \leq 0 \quad (10)$$

$$\epsilon_k^p = \epsilon_{k-1}^p + \frac{1}{2\mu} (|s_k^{tr}| - \sqrt{\frac{2}{3}}\sigma_Y)n_k^{tr}, \quad \Psi = |s_k^{tr}| - \sqrt{\frac{2}{3}}\sigma_Y > 0$$

3. Assembly of Stiffness Matrices Using MATLAB Cell-arrays

For an effective MATLAB implementation of Finite Element Analysis, especially in analyzing elastoplastic nonlinear problems, the crucial concept is vectorization. Vectorization involves storing all data describing parts of the Finite Element space discretization in vectors or arrays of vectors, for the entire system simultaneously. This approach helps avoid lengthy 'for' loops, which can significantly slow down MATLAB code and sometimes render it entirely inefficient.

In this paper, we use cell arrays, a data type comprised of indexed data containers called cells. Each cell can hold any type of data. Specifically, we employ cell arrays as 3D array, which can be conceptualized as 2D matrix where each element is a vector of length n . It can also be conceptualized as a data container consisting of n layers where every layer is a 2D matrix (Figure 1). For example, consider a cell array \mathbf{A} structured as a 2×2 matrix where each element is a $n \times 1$ vector. Also, we can say that has n layers where every layer is a 2×2 matrix.

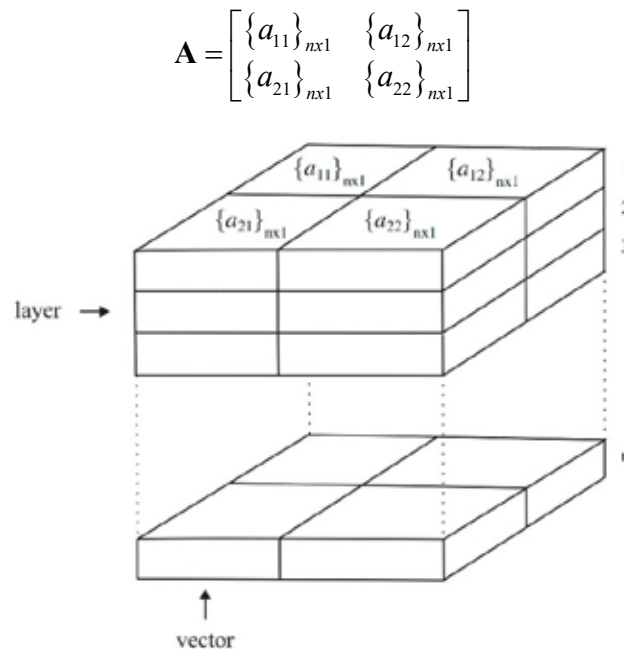


Figure 1 Cell-array with layers and vectors

If another cell array \mathbf{S} of layer size 2×3 and vector size $n \times 1$ is constructed

$$\mathbf{S} = \begin{bmatrix} \{s_{11}\}_{n \times 1} & \{s_{12}\}_{n \times 1} & \{s_{13}\}_{n \times 1} \\ \{s_{21}\}_{n \times 1} & \{s_{22}\}_{n \times 1} & \{s_{23}\}_{n \times 1} \end{bmatrix}$$

product of cell-arrays \mathbf{A} and \mathbf{S} is given by:

$$\{(as)_{ij}\}_{n \times 1} = \sum_{k=1}^2 \{a_{ik}\}_{n \times 1} \square \{s_{kj}\}_{n \times 1}, i=1,2, j=1,2,3 \quad (11)$$

Where symbol \square denotes Hadamard product which multiplies vectors stored in \mathbf{A} and \mathbf{S} by multiplying corresponding elements and resulting in a vector of the same size. This product can be executed very fast in MATLAB for very large vectors and is highly important for the concept of vectorization.

Stiffness matrices in the finite element method are typically assembled element by element, utilizing local stiffness matrices. For instance, this process can be represented as follows:

$$\mathbf{K}_{elast} = \sum_{e=1}^{n_e} T_1(\mathbf{k}_e) \quad (12)$$

The total count of finite elements is represented by n_e . The index transformation function T_1 maps local indices to global indices based on the connectivity data of elements. Assuming space discretization of (1) by the finite element method with isoparametric elements [10,14] connection between strain and displacement for element is given by:

$$\boldsymbol{\varepsilon} = \mathbf{B}_e \mathbf{u} \quad (13)$$

where \mathbf{B}_e is a strain-displacement matrix and the local stiffness matrix can be expressed as

$$\mathbf{k}_e = \int_{\Omega_e} \mathbf{B}^T \mathbf{C} \mathbf{B} d\Omega_e \approx \sum_{g=1}^{n_g} w_g \mathbf{B}_{e,g}^T \mathbf{C}_{e,g} \mathbf{B}_{e,g} \quad (14)$$

where Ω_e is element domain, n_g is a number of integration points for element, w_g are integration weights, \mathbf{B} is a strain-displacement matrix and \mathbf{C} is the elastic constitutive matrix derived from Hooke's law.

As it was noted before assembly of stiffness matrices using element by element approach in MATLAB leads to very long 'for' loops and consequently very slow code. So, it is much more efficient if we construct strain-displacement cell-array \mathbf{B}_G where every layer is matrix $\mathbf{B}_{e,g}$ which belongs to element e and integration point g . In cell-array \mathbf{B}_G constructed in this way length of the vectors is $n_e \times n_g$. Because only material nonlinearity is considered, cell-array \mathbf{B}_G can be precomputed and stored for use in iteration process. In the same way we can construct elastic constitutive cell-array $\mathbf{C}_{G,elast}$ with layers $\mathbf{C}_{e,g}$. So, because it is elastic constitutive cell-array and for homogeneous materials every layer is the same, $\mathbf{C}_{G,elast}$ also can be precomputed and stored for later use. With this cell-arrays equation (12) can be rewritten as

$$\mathbf{K}_{elast} = T_2(w \mathbf{B}_G^T \mathbf{C}_{G,elast} \mathbf{B}_G) \quad (15)$$

Here, w is a vector of integration weights and T_2 index transformation operator. This method eliminates lengthy 'for' loops over all elements and replaces them with shorter loops over the layer sizes of cell-arrays \mathbf{B}_G and $\mathbf{C}_{G,elast}$. Size of \mathbf{B}_G layer depends on element type (as shown in Table 1) and size of $\mathbf{C}_{G,elast}$ layer is 3x3 in 2D and 6x6 in 3D configuration. Since both \mathbf{B}_G and $\mathbf{C}_{G,elast}$ can be precomputed, the same applies to \mathbf{K}_{elast} .

Table 1 Sizes of layers for different types of finite elements

Element type	Size of matrix B (layer of cell-array)
2D quadrilateral with four nodes	3x8
2D quadrilateral with eight nodes	3x16
3D hexahedral with eight nodes	6x24
3D hexahedral with twenty nodes	6x60

Similarly, one can assemble the tangent stiffness matrix for an elastoplastic problem:

$$\mathbf{K}_{tangent} = T_2(w\mathbf{B}_G^T \mathbf{C}_{G,tangent} \mathbf{B}_G) \quad (16)$$

For each integration point layer of cell-array $\mathbf{C}_{G,tangent}$ can be obtained from equations (7). Cell-array $\mathbf{C}_{G,tangent}$ has the same size and structure as $\mathbf{C}_{G,elast}$. According to (15) equation (16) can be written as

$$\mathbf{K}_{tangent} = \mathbf{K}_{elast} + T_2(w\mathbf{B}_G^T (\mathbf{C}_{G,tangent} - \mathbf{C}_{G,elast}) \mathbf{B}_G) \quad (17)$$

Equations (16) and (17) are algebraically identical. However, form of equation (17) is more suitable for MATLAB implementation as it typically contains many more null layers. This situation arises when the majority of integration points remain within the elastic domain, meaning that the length of the vectors in the cell-array product will be reduced to those points that have moved out of the elastic domain. Consequently, for problems where the plastic regions are smaller, assembling the tangential stiffness matrix can be expedited compared to problems with larger plastic regions. Furthermore, \mathbf{B}_G , $\mathbf{C}_{G,elast}$ and \mathbf{K}_{elast} can be precomputed, while only the cell-array $\mathbf{C}_{G,tangent}$ varies based on the specific plasticity model and must be partially reassembled during each Newton iteration.

4. Algorithm for MATLAB Implementation of Elastoplastic Finite Element Analysis

Elastoplastic problems can be efficiently solved in MATLAB using this algorithm.

Algorithm for solving elastoplastic problem with Finite Element Method using MATLAB

- 1: Define the mesh with **COORD** and **ELEM** array
- 2: Extract the node coordinates of each element in the appropriate composition of vectors **X**, **Y**, **Z**
- 3: Extract the node coordinates for every integration point
- 4: Compose the linear constitutive matrix for all integration points as a cell-array **CG_elast**
- 5: Calculate the strain-displacement matrix for all integration points as a cell-array **BG**
- 6: Calculate the global elastic stiffness matrix **KG_elast** by multiplying and contracting **CG** and **BG**
- 7: Assemble the vector of external forces **F_ext** and set **KG_tangent** = **KG_elast**
- 8: Initialize variables that will be updated during the iteration process
 - vector of total displacements **U**
 - vector of total displacements in previous step **U_old**
 - vector of displacements increments **dU**
 - strain tensor at integration points **E**
 - plastic strain tensor at integration points **Ep_old**
- 9: Define the number of load steps and values of load multiplier
- 10: **for** each load step **do**
- 11: Define the load vector for current step **F_step_i**
- 12: Assign initial displacements **U_it** = **U**
- 13: **while** convergence is not reached **do** (Newton's solver start)

- 14: Calculate the strains for all integration points
 - 15: Solve the constitutive problem, update the stress, the consistent tangent operator and the logical array of plastic integration points
 - 16: **if** number of plastic points > 0
 - 17: Update the **KG_tangent** only with layers that belong to plastic integration points
 - 18: **end if**
 - 19: Calculate the vector of internal forces **F_int**
 - 20: Calculate the displacements increment from $dU = KG_tangent^{-1} * (F_ext - F_int)$
 - 21: Update displacements $U_new = U_it + dU$, $U_it = U_new$
 - 22: Check convergence
 - 23: **end while**
 - 24: Update displacements $U_old = U$, $U = U_it$
 - 25: Calculate the strains for all integration points
 - 26: Update the plastic strains at all integration points
 - 27: **end for**
-

5. Computational example and comparisons

To illustrate the efficiency of the proposed MATLAB implementation and compare speeds of computation, the example from [11] will be used. The body, with an L-shaped geometry shown in Figure 3, is considered. It is assumed to be elastic-perfectly plastic with a Young's modulus of 206900 Mpa, a Poisson's ratio of 0.29 and a yield stress of 450 MPa. A constant traction with a density of $q=200 \text{ N/mm}^2$ is acting on the upper side in the normal direction. Boundary conditions are applied as shown in Figure 2

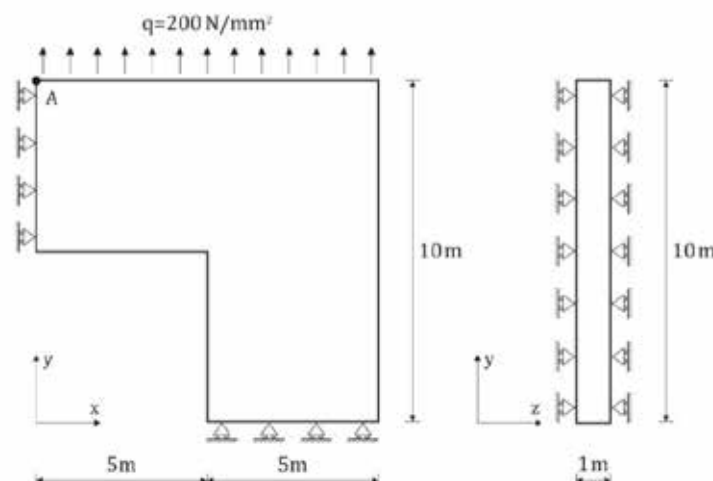


Figure 2 Geometry and boundary conditions of the numerical example

Numerical implementations were conducted for both 2D (plane strain) and 3D problems. Sample meshes are displayed in Figures 3 and 4. The external force was incrementally divided into 10 steps, beginning with a minimum value of 20 in the first step and escalating to a maximum value of 200 in the last step. The total integration time was recorded to evaluate the code's speed.

The performance of the code was tested with MATLAB R2023b on a computer with Intel(R) Core(R) i7-8700 CPU 3.20GHz processor, 16 GB RAM, and 256 GB SSD hard disk memory. A comparison is provided regarding the method proposed in paper [11] by Cermak, Sysala and Valdman using the code from GitHub repository [12].

Results were obtained for 2D quadrilateral elements with four and eight nodes, as well as for 3D hexahedral elements with eight and twenty nodes and are presented in Tables 2 to 5. Each table contains the number of elements, the number of nodes, the number of unknowns, integration points, plastic integration points, and the time required for ten steps of integration using the code from [12] and the code from this paper.

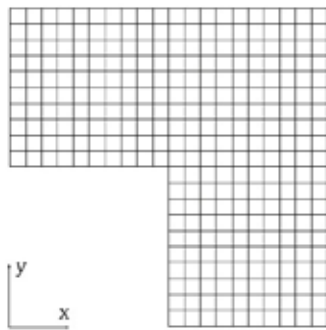


Figure 3 Example of a 2D mesh

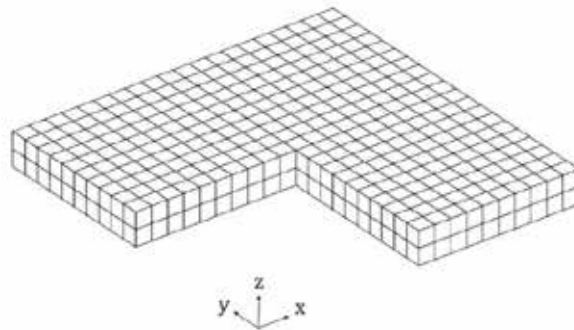


Figure 4 Example of a 3D mesh

Table 2 Numerical results for 2D quadrilateral element with four nodes

Number of nodes	Number of elements	Number of unknowns	Number of integration points	Number of plastic integration points at last step	Time required for integration using the code form [6] (in seconds)	Time required for integration using the method from this paper (in seconds)
1281	1200	2520	4800	2862	1.03	0.62
4961	4800	9840	19200	11831	4.26	2.54
19521	19200	38880	76800	48037	21.23	11.73
77441	76800	154560	307200	193859	103.17	59.49

Table 3 Numerical results for 2D quadrilateral element with eight nodes

Number of nodes	Number of elements	Number of unknowns	Number of integration points	Number of plastic integration points at last step	Time required for integration using the code form [6] (in seconds)	Time required for integration using the method from this paper (in seconds)
3761	1200	7440	10800	6847	3.73	2.47
14721	4800	29280	43200	27500	17.69	10.92
58241	19200	116160	172800	110264	95.27	54.76
231681	76800	462720	691200	441862	524.77	279.41

Table 4 Numerical results for 3D hexahedral element with eight nodes

Number of nodes	Number of elements	Number of unknowns	Number of integration points	Number of plastic integration points at last step	Time required for integration using the code form [6] (in seconds)	Time required for integration using the method from this paper (in seconds)
1023	600	2321	4800	2664	1.66	1.96
6405	4800	16443	38400	22896	23.51	18.01
44649	38400	123287	307200	189296	755.77	314.62

Table 5 Numerical results for 3D hexahedral element with twenty nodes

Number of nodes	Number of elements	Number of unknowns	Number of integration points	Number of plastic integration points at last step	Time required for integration using the code form [6] (in seconds)	Time required for integration using the method from this paper (in seconds)
3625	600	8743	16200	10170	13.91	18.78
23929	4800	63687	129600	82164	340.05	196.16
44097	9600	123695	259200	164328	2482.02	788.09

The data presented in the tables indicate that the method proposed in this paper outperforms the code referenced in [12]. As shown in Figure 5, for 2D elements, the proposed method's code is approximately 34% to 47% faster than the referenced code. Additionally, Figure 6 demonstrates that for 3D elements, while this method is slower for a smaller number of unknowns, it becomes up to 65% faster as the number of unknowns increases.

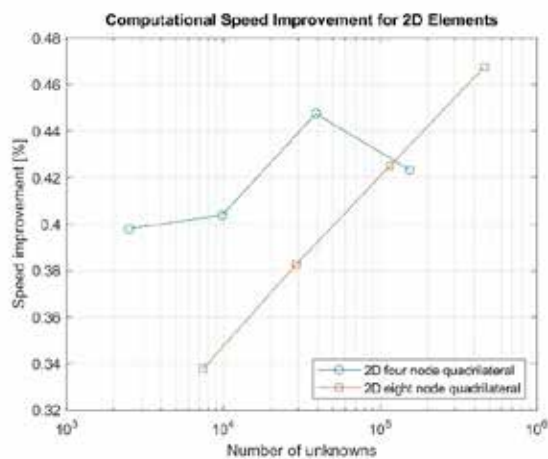


Figure 5 Speed improvent for 2D elements

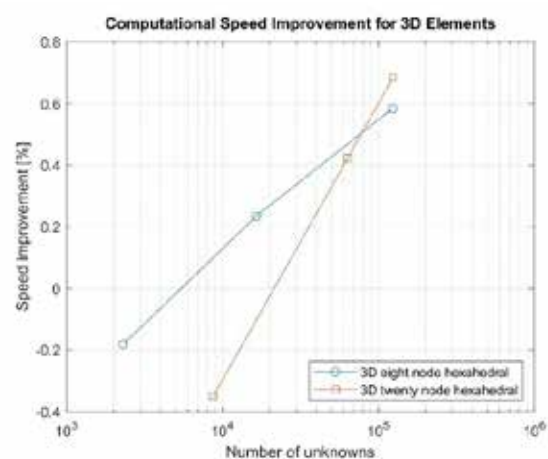


Figure 6 Speed improvent for 3D elements

Fully vectorized code for assembling stiffness matrices often loses the original FEM structure, which leads to reduced code readability [6] or large global strain-displacement and constitutive matrices [11]. The assembling procedure proposed in this paper uses matrix and vector operations on cell arrays with small for-loops, resulting in an implementation that closely resembles the standard form. This approach also leverages the symmetry of stiffness matrices, ultimately leading to faster assembly times.

From the load-displacement diagram of point A for 1200 quadrilateral elements (Figure 7), we can observe that higher-order elements achieve more accurate results near the limit load. This justifies the need for efficient and fast finite element computation for a dense mesh of

higher-order elements. This is further demonstrated in Figure 8, which shows the displacement of point A for different numbers of elements.

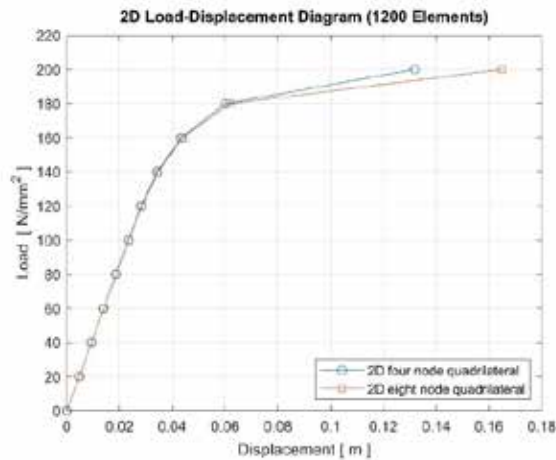


Figure 7 Load-Displacement diagram for point A

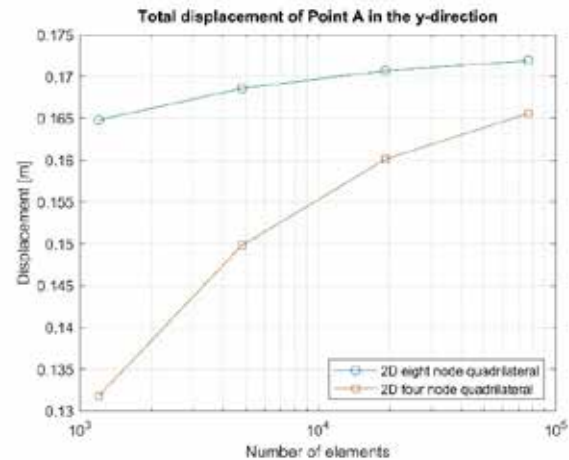


Figure 8 Total displacement of point A

The MATLAB code used for this comparison is available in the repository [15].

6. Conclusion

This paper presents a fast and adaptable approach for solving elastoplastic problems. It introduces an efficient technique for assembling elastoplastic FEM stiffness matrices using a cell-array approach. To accelerate the calculation process, vectorization is employed. The efficiency of the assembly process increases with fewer plastic integration points. Numerical results confirm that this method is highly effective and demonstrates significant speed gains. This implementation closely resembles standard FEM practices, making it easily adaptable to other types of elements. Additionally, it can be easily adjusted to solve problems involving hardening, making it suitable for solving elastoplastic problems with a large number of elements.

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DEFLECTION ANALYSIS OF THE SHAFT SLEEVE IN THE STERN TUBE SLIDE BEARING

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Abstract. Stern tube slide bearing of the shaft line of the ship's propulsion system causes losses during operation. Friction and material wear of the bearing tribosystem occur. Leakage of lubricant with particles of bearing material outside the boundaries of the tribosystem directly affects the ecosystem of the sea and ocean. Namely, liquid friction can easily change to mixed friction due to a certain disturbance of the stern tube slide bearing. The disturbance can be a change in load, an increase in temperature, a decrease in viscosity and speed, and a change in the geometry of the bearing sleeve. By changing the load due to the different navigating regimes of the ship, the curvature of the elastic line of the shaft sleeve inside the stern tube bearing is changed. The elastic line of the sleeve has an influence on the slide bearing working area. Therefore, it is necessary to ensure a sufficient thickness of the lubricant layer for lubrication in relation to these changes. This is the initial criterion for the selection of materials and lubricants of the stern tube bearing. For this reason, this paper analyzes the deflection of the shaft sleeve inside the stern tube bearing using the Mohr's integral. The analyzed general models of shaft lines of ship propulsion systems, which are analytically closest to the real models, are loaded with their self-weight, the weight of the propeller, buoyancy and the moment of the eccentric thrust force. The deflection analysis of the bearing sleeve elastic line was performed for different lengths and numbers of the intermediate shafts of the shaft line. The lengths are determined according to the rules of the Croatian Register of Shipping. The general models of shaft lines given are with a single (aft) stern tube bearing. Considering that the length between the propeller and the stern tube bearing is relatively short, the analysis with the influence of shear on the propeller shaft deflection and on the shaft sleeve deflection inside the stern tube bearing is also presented in the paper. The deflection results obtained were compared and can be useful in the selection of materials and lubricants for the stern tube bearing tribosystem.

Key words: *stern tube bearing tribosystem, elastic line of the bearing sleeve, models of shaft lines, moment of the eccentric thrust force, influence of shear*

1. Introduction

Slide bearings are a fundamental part of the ship's propulsion system. They enable the shaft line to transmit power from the prime mover to the ship's propeller and to take and transmit radial and axial loads. Stern tube slide bearings are specific for the actual ship [1].

The correct selection of the aft stern tube slide bearing is the tribological problem. The aim is to ensure proper operation and energy efficiency of the shaft line (minimizing frictional

losses) and environmental acceptability (minimizing lubricant leakage with particles from bearing bush material). The stern tube slide bearing selected this way should ensure optimal performance, long-term reliability and economic justification [2].

In addition to classic bearings with bushes made of white metal and lubricated with oil, bearings with bushes made of various polymer materials that are lubricated with water are increasingly used. The disadvantage of oil-lubricated bearings is the potential danger of an oil leakage and thus a harmful effect on the ecosystem of the sea and ocean. Due to the significantly lower viscosity of water compared to oil, the minimum water lubricating layer thickness is extremely small. The fluid friction in these bearings can turn into mixed friction even with small disturbances of the input parameters of the tribosystem [1].

Various disturbances have a great influence on the correct operation of the stern tube slide bearing, i.e. on the hydrodynamic lubrication. One of them is different navigation regimes. The fluid velocity field on the ship's propeller determines the magnitude of thrust force, but its point of action is even more important. The position of the thrust force on the surface of the propeller is variable and so is the moment of the eccentric thrust force, which usually corresponds to the spatial curvature of the elastic line of the shaft sleeve in the stern tube bearing [2].

In real operating conditions, the influence of the elastic line curvature of the bearing sleeve is greater than the expected minimum water lubricating layer thickness, so liquid friction along the entire length of the bearing can only be expected after running-in. The running-in – wear and tear of materials has a harmful effect on the ecosystem. A special problem is that by changing the navigating speed the intensity of the thrust force also changes, so the elastic line curvature can become different to the extent that the influence of the change in the elastic line is greater than the minimum of the lubricating layer thickness [1].

To confirm the above, the aim of the paper is to find suitable analytical general models of the shaft lines of the ship's propulsion systems, which will enable a reliable analysis of the deflection of the shaft sleeve in the stern tube bearing. For this purpose, the general models have the possibility of changing the dimensional characteristics (diameter and length of the shafts and bearings) and the configurations of the shaft lines (e.g. number of the intermediate shafts, position of the supports, one or two stern tube bearings). The calculation of the shaft sleeve deflection of such models is given for different loads and for different navigation regimes (using the moment of eccentric thrust force M_p), taking into account the influence of bending and shearing. The obtained results of the shaft sleeve deflection compared to the lubricant layer thickness determine the slide bearing working area and therefore they are extremely important for better selection of the stern tube bearing section.

2. Deflection analysis of the shaft sleeve in the stern tube slide bearing

2.1. Diameters and lengths of the shaft line parts

The geometric characteristics required for shaft deflection analysis are the length and diameter of the shafts in the shaft line. By sizing the shafts of the ship's propulsion system, the basic dimensions of the bearing sleeves were determined, that is, the diameters of the slide bearings D . The outer shaft diameter d of the shaft line (according to the unified requirement of IACS UR M68) is given by the expression [3]:

$$d \geq f \cdot k \cdot \sqrt{\frac{P}{n} \cdot \frac{1}{1 - \varphi^4} \cdot \frac{560}{R_m + 160}} \quad (\text{mm}) \quad (1)$$

where: f is the factor of the driving machine in the propulsion system ($f = 100$ for propeller shaft and 95 to 100 for intermediate shafts), k is low-cycle fatigue factor ($k = 1.22$ to 1.26 for propeller shaft and $k = 1.00$ for intermediate shafts), ϕ is ratio of the outer and inner shaft diameter, R_m is tensile strength of the material of the shaft (MPa) within certain limits, P is rated power transmitted by the shaft neglecting losses in gearboxes and bearings (rated power of the main engine) $P = P_B$ (kW), n is rated rotation speed of the shaft (rpm).

The length of the slide bearings L depends on the selection of bearing bush material and on the permissible pressure for that material. The stern tube slide bearing is longer compared to the radial support bearing of the same nominal diameter, because it is exposed to greater static and dynamic loads in operation, which come from the weight and buoyancy of the ship's propeller, the weight of the shaft and from the thrust force. The length of stern tube bearings L shall not be less than 2 times the rule diameter of the shaft in way of the bearing, that is [4]:

$$L \geq 2 \cdot D \quad (\text{mm}). \quad (2)$$

This analysis covers the lengths of shafts of the ship shaft lines (recommended distance between the centres of adjacent bearings where there are no concentrated masses in the span) determined by the expression according to the rules of the Croatian Register of Shipping based upon flexural and whirling vibrations [4]:

$$5.5\sqrt{d} \leq l \leq \lambda\sqrt{d} \quad (\text{m}) \quad (3)$$

where: l is length between the two aftmost bearings (m), d is intermediate shaft diameter (m).

Factor λ is 14 for $n \leq 500$ rpm or $\frac{300}{\sqrt{n}}$ for $n \geq 500$ rpm, where n is rated rotation speed of the propeller shaft (rpm).

2.2. Load of the shaft line

The shaft line of the ship's propulsion system is loaded by the self-weight, the weight of the ship's propeller in water or sea-water and by the moment of the eccentric thrust force (Figure 1) [5].

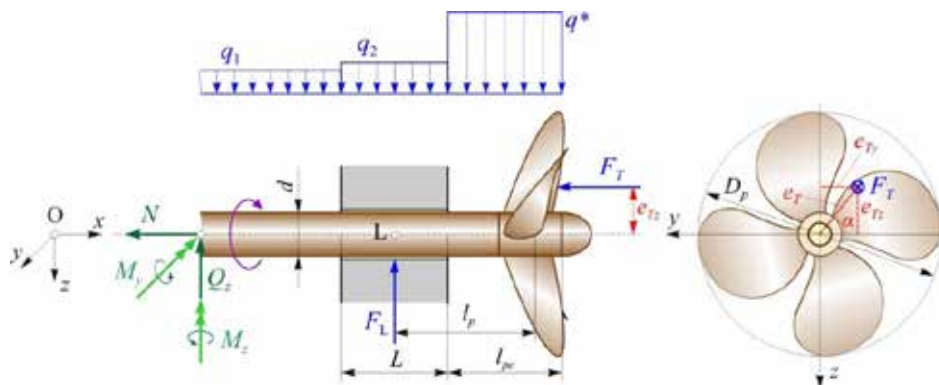


Figure 1 Theoretical load model of the shaft line

The self-weight load q_1 and q_2 of the shafts can be determined from the expression [5]:
- for intermediate shafts q_1 is:

$$q_1 = \rho_{is} \cdot \frac{\pi}{4} d^2 (1 - \phi^2) \cdot g \quad (\text{N/m}) \quad (4)$$

- for propeller shaft q_2 is:

$$q_2 = \rho_{ps} \cdot \frac{\pi}{4} d^2 (1 - \varphi^2) \cdot g \quad (\text{N/m}) \quad (5)$$

where: ρ_{is} is density of intermediate shaft (kg/m^3), ρ_{ps} is density of propeller shaft (kg/m^3), d is outer shaft diameter, φ is ratio of the outer and inner shaft diameter.

In this paper, the load of the shaft line when complete propeller immersion was analyzed, according to the design criteria by applicable DNV GL rules [6]. For the complete immersion propulsion elements, the load by their weights q^* can be determined from the expression [5]:

$$q^* = \left[\rho_{ps}^* \cdot \frac{\pi}{4} d^2 (1 - \varphi^2) + \rho_p^* \cdot \frac{V_p}{l_{pe}} \right] \cdot g \quad (\text{N/m}) \quad (6)$$

where: ρ_{ps}^* and ρ_p^* is equivalent density for complete immersion of the propeller shaft and propeller (kg/m^3), V_p is propeller volume (m^3), l_{pe} is propulsion elements length (m).

Equivalent density for complete immersion of the propeller shaft ρ_{ps}^* and propeller ρ_p^* can be determined from the expression [5]:

$$\rho_{ps}^* = \rho_{ps} - \frac{\rho_w}{1 - \varphi^2} \quad (\text{kg/m}^3) \quad (7)$$

$$\rho_p^* = \rho_p - \rho_w \quad (\text{kg/m}^3) \quad (8)$$

where: ρ_p is density of propeller (kg/m^3), ρ_w is density of sea water (kg/m^3); $\rho_w = 1025 \text{ kg/m}^3$. The propeller volume V_p is:

$$V_p = \frac{m_p}{\rho_p} \quad (\text{m}^3) \quad (9)$$

where: m_p is mass of propeller (kg).

Design margins also cater for some eccentric propeller loading, for instance, due to an inhomogeneous wake field and/or operation with the propeller blade tips in close vicinity of the water surface. Different navigation regimes may induce an excessive eccentric thrust on the propeller and, consequently, a bending moment on the shaft line [6]. Accordingly, the moment of the eccentric thrust force M_p can be determined from the expression [2]:

$$M_p = \pm F_T \cdot e_T \quad (\text{Nm}) \quad (10)$$

where: F_T is thrust force (N), e_T is distance from the propeller centre (m).

The value of the thrust force F_T can be determined using the expression given by the Croatian Register of Shipping [4]:

$$F_T = 57.6 \cdot 10^6 \cdot \frac{P}{H \cdot n} \quad (\text{N}) \quad (11)$$

where: P is rated power $P = P_B$ (kW), H is mean propeller pitch (mm), n is rated rotation speed of the propeller (rpm).

The amount of the distance e_T according to the rule-of-thumb used by the Croatian Register of Shipping is assumed, i.e. [1]:

$$e_T = 4\% D_p \quad (\text{m}) \quad (12)$$

where: D_p is propeller diameter (m).

2.3. General model of the shaft line

The specified loads of the shaft line cause shafts deflection. Considering that the bending and shearing influence on the shaft deflection will be analyzed, the shaft deflection will be calculated using the Mohr's integral. Mohr's integral is suitable for determining the generalized displacement q (linear or angular) of the loaded shaft line. Mohr's integral is as follows [7]:

$$\begin{aligned} q = & \sum_{i=1}^n \frac{1}{A_i \cdot E_i} \cdot \int_0^{l_i} N_i \cdot n_i \cdot dx + \sum_{i=1}^n \frac{1}{A_i \cdot G_i} \cdot \int_0^{l_i} k_z \cdot Q_{zi} \cdot q_{zi} \cdot dx + \\ & + \sum_{i=1}^n \frac{1}{A_i \cdot G_i} \cdot \int_0^{l_i} k_y \cdot Q_{yi} \cdot q_{yi} \cdot dx + \sum_{i=1}^n \frac{1}{I_{yi} \cdot E_i} \cdot \int_0^{l_i} M_{yi} \cdot m_{yi} \cdot dx + \\ & \sum_{i=1}^n \frac{1}{I_{zi} \cdot E_i} \cdot \int_0^{l_i} M_{zi} \cdot m_{zi} \cdot dx + \sum_{i=1}^n \frac{1}{I_{pi} \cdot G_i} \cdot \int_0^{l_i} M_{ti} \cdot m_{ti} \cdot dx \end{aligned} \quad (13)$$

where the internal forces from the external load are indicated in capital letters, and the internal forces from the unit generalized force corresponding to the generalized displacement are indicated in small letters.

The general model of the shaft line for shaft deflection analysis which takes into account the influence of bending and shearing due to loading due to the weights q_1 and q^* is shown in the Figure 2. It is assumed that the self-weight load q_1 and q_2 of the shafts are the same. The influence of the moment of the eccentric thrust force M_p on the shaft deflection will be analyzed in Section 3.

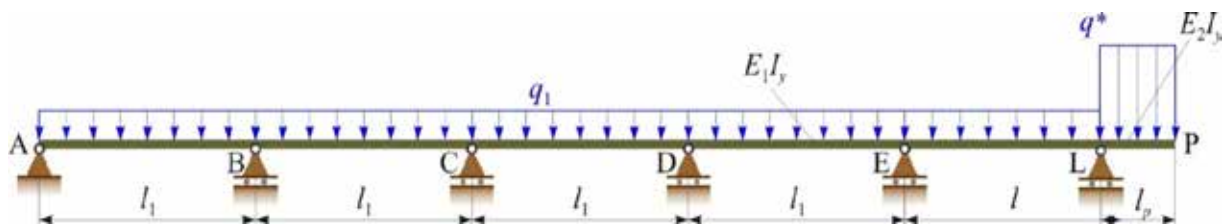


Figure 2 General model of the shaft line loading due to the weights

The general models of shaft lines of ship propulsion systems with five (ABCDELP), four (ABCELP), three (ABELP) and two (AELP) intermediate shafts, loaded due to the weights q_1 and q^* are analytically closest to the real models. The models are with one stern tube slide bearing, i.e. with the aft stern tube bearing [8, 9]. Point P marks the position of the propeller, support L represents the aft stern tube bearing, support A represents the fore bearing of the prime mover (e.g. marine Diesel engine), while the other supports are radial support bearings of the intermediate shaft(s).

Thus, expression for generalized displacement passes into the expression for the deflection which is:

$$q = w = \sum_{i=1}^n \frac{1}{A_i \cdot G_i} \cdot \int_0^{l_i} k_z \cdot Q_{zi} \cdot q_{zi} \cdot dx + \sum_{i=1}^n \frac{1}{I_{yi} \cdot E_i} \cdot \int_0^{l_i} M_{yi} \cdot m_{yi} \cdot dx \quad (14)$$

where: k_z is shear coefficient, which for circular cross-section amounts of 1.1.

If the cross-section is hollow, as in the case of controllable pitch propeller systems, k_z obtains a different value.

2.4. Influence of the shaft line characteristics on the shaft deflection

For the general model (Figure 2), two analyzes of the influence of dimensions and the configurations of the shaft lines on the shaft deflection are given in this subsection. First is the influence of the different length l_1 and number of intermediate shafts and second is the influence of the different propeller distance l_p (length between the propeller and the stern tube bearing) and different diameter d of propeller shaft. The shaft deflection at the location of the propeller w_p was determined using the expression (14). The values from Section 3 were used for this calculation. According to the expression (3) for $n \leq 500$ rpm, the length between the two aftmost bearings E and L is: $3.012 \leq l \leq 7.668$ m. The analysis in the paper is given for equal values of the shafts length $l_1 = l$ of 3, 5 and 7 m. It is assumed that the length between the propeller and the stern tube bearing is $l_p = 0.5$ m.

2.4.1. Length and number of intermediate shafts

Tables 1, 2 and 3 show the results for the bending deflection w_{pb} , shear deflection w_{ps} and total deflection w_p of the shaft at the location of the propeller P. In the same tables, the influence of shear on the total deflection is given.

Table 1 Deflection for the intermediate shaft length of 3 m

$l_1 = l = 3$ m $l_p = 0.5$ m $d = 300$ mm		bending w_{pb} (mm)	shear w_{ps} (mm)	total w_p (mm)	$\frac{w_p - w_{pb}}{w_{pb}}$ (%)
no. intermediate shafts	5 (ABCDELP)	0.137	0.007	0.144	4.83%
	4 (ABCELP)	0.138	0.007	0.145	4.80%
	3 (ABELP)	0.137	0.007	0.144	4.88%
	2 (AELP)	0.142	0.006	0.148	4.56%

Table 2 Deflection for the intermediate shaft length of 5 m

$l_1 = l = 5$ m $l_p = 0.5$ m $d = 300$ mm		bending w_{pb} (mm)	shear w_{ps} (mm)	total w_p (mm)	$\frac{w_p - w_{pb}}{w_{pb}}$ (%)
no. intermediate shafts	5 (ABCDELP)	0.149	0.006	0.155	3.94%
	4 (ABCELP)	0.151	0.006	0.157	3.87%
	3 (ABELP)	0.146	0.006	0.152	4.07%
	2 (AELP)	0.166	0.006	0.172	3.44%

Table 3 Deflection for the intermediate shaft length of 7 m

$l_1 = l = 7 \text{ m}$ $l_p = 0.5 \text{ m}$ $d = 300 \text{ mm}$		bending $w_{pb} \text{ (mm)}$	shear $w_{ps} \text{ (mm)}$	total $w_p \text{ (mm)}$	$\frac{w_p - w_{pb}}{w_{pb}} \text{ (%)}$
no. intermediate shafts	5 (ABCDELP)	0.062	0.005	0.067	8.76%
	4 (ABCELP)	0.067	0.005	0.072	8.21%
	3 (ABELP)	0.052	0.006	0.058	10.60%
	2 (AELP)	0.104	0.005	0.109	5.03%

The largest shaft deflection at the location of the propeller w_p is for the general model of the shaft line with intermediate shaft length of $l_1 = 5 \text{ m}$, while the smallest is for the intermediate shaft length of $l_1 = 7 \text{ m}$. The results in the above tables confirm the more significant influence of bending on deflection w_p compared to shearing. By reducing the number of intermediate shafts of the equal length l_1 , the deflection increases. Favorable deflection can be obtained by combining the number and length l_1 of intermediate shafts (optimal configuration of the shaft line), for example, model with 3 intermediate shafts length of $l_1 = 7 \text{ m}$ have less deflection than model with 4 intermediate shafts length of $l_1 = 5 \text{ m}$. Further analysis was carried out for the case of the largest total deflection w_p , which is for the general model of the shaft line with the intermediate shafts length of $l_1 = l = 5 \text{ m}$.

2.4.2. Propeller distance and diameter of propeller shaft

Tables 4, 5 and 6 show the results for the bending deflection w_{pb} , shear deflection w_{ps} and total deflection w_p of the shaft at the location of the propeller P. In the same table, the influence of shear on the total deflection and the ratio between the propeller distance and propeller shaft diameter l_p/d is given. The general model of the shaft line for this shaft deflection analysis is with 3 intermediate shafts length of $l_1 = l = 5 \text{ m}$. The propeller shaft diameter is within the value of $d = 300 \text{ mm} + 10\%$ for the given input parameters of P and n in Section 3.

Table 4 Deflection for the propeller distance of 0.4 m

$l_1 = l = 5 \text{ m}$ $l_p = 0.4 \text{ m}$ 3 (ABELP)		bending $w_{pb} \text{ (mm)}$	shear $w_{ps} \text{ (mm)}$	total $w_p \text{ (mm)}$	$\frac{w_p - w_{pb}}{w_{pb}} \text{ (%)}$	l_p/d
propeller shaft dia. $d \text{ (mm)}$	300 mm	0.073	0.005	0.078	6.29%	1.333
	310 mm	0.059	0.004	0.063	7.24%	1.290
	320 mm	0.047	0.004	0.051	8.42%	1.250
	330 mm	0.038	0.004	0.042	9.89%	1.212

Table 5 Deflection for the propeller distance of 0.5 m

$l_1 = l = 5$ m $l_p = 0.5$ m 3 (ABELP)		bending w_{pb} (mm)	shear w_{ps} (mm)	total w_p (mm)	$\frac{w_p - w_{pb}}{w_{pb}}$ (%)	l_p/d
propeller shaft dia. d (mm)	300 mm	0.146	0.006	0.152	4.07%	1.667
	310 mm	0.122	0.006	0.128	4.55%	1.613
	320 mm	0.102	0.005	0.107	5.10%	1.562
	330 mm	0.085	0.005	0.090	5.72%	1.515

Table 6 Deflection for the propeller distance of 0.6 m

$l_1 = l = 5$ m $l_p = 0.6$ m 3 (ABELP)		bending w_{pb} (mm)	shear w_{ps} (mm)	total w_p (mm)	$\frac{w_p - w_{pb}}{w_{pb}}$ (%)	l_p/d
propeller shaft dia. d (mm)	300 mm	0.243	0.007	0.250	3.03%	2.000
	310 mm	0.206	0.007	0.213	3.34%	1.935
	320 mm	0.175	0.006	0.181	3.68%	1.875
	330 mm	0.149	0.006	0.155	4.06%	1.818

The results in the above tables confirm that by reducing the l_p/d ratio, the deflection decreases and vice versa. By moving the propeller away from the stern tube bearing, i.e. by increasing the distance l_p , the deflection at the location of the propeller w_p increases. Due to the dimensions of the propulsion elements l_{pe} and stern tube bearing L (Figure 1), this is realistic to expect. For this reason, it is necessary to analyze the deflection of the shaft sleeve in the stern tube bearing and its influence on the working area of that slide bearing. The influence of shearing on deflection becomes negligible and falls below 3%.

2.5. Shaft line models for the deflection analysis of the shaft sleeve in the stern tube bearing

Deflection analysis of the shaft sleeve in the stern tube bearing is important for the slide bearing selection. In addition to the load by the self-weight q_1 and q_2 and the weight of the ship's propeller (complete immersion propulsion elements) q^* , the moment of the eccentric thrust force M_p has a great influence on the curvature of the elastic line of the sleeve inside the stern tube bearing. The change in the moment of the eccentric thrust force M_p due to the different navigating regimes of the ship leads to a spatial change in the elastic line curvature of the shaft sleeve and causes disturbances in the operation of the stern tube bearing, i.e. a transition from fluid to mixed friction. In this case, there is inevitable wear of the material of the slide bearing bush due to the adjustment of the curvature of the shaft sleeve. So, it is important that these changes remain within the actual thickness of the lubricants layer h_0 , that is, there must exist a minimum thickness of the lubricant layer [2].

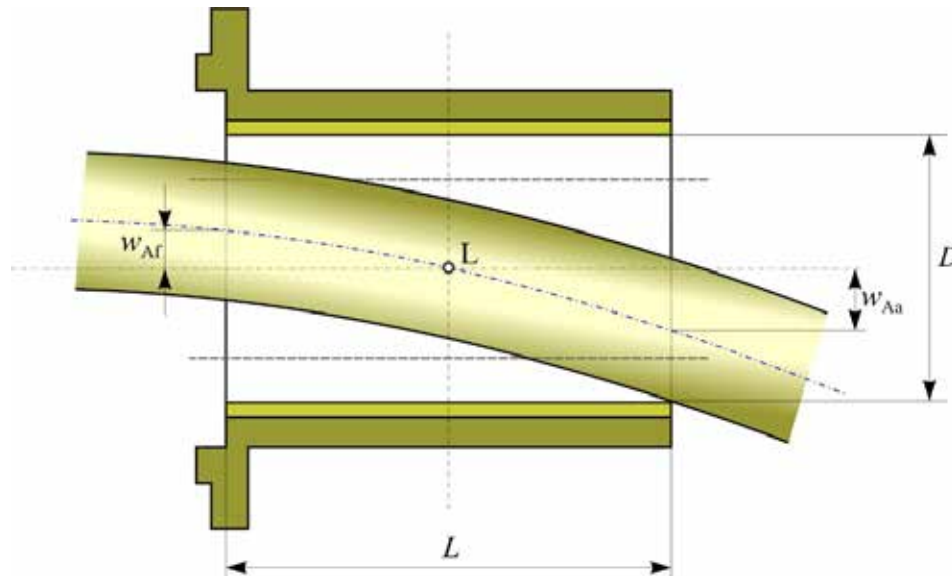


Figure 3 Deflection of the shaft sleeve in the stern tube bearing

An analysis of the deflection of the shaft sleeve in the stern tube bearing can be carried out for different constructive characteristics of the bearing L/D and the length of the intermediate shaft $l_1 = l$. The results of the deflection of the shaft sleeve in the forward w_{Af} and aft w_{Aa} ends of the aft stern tube bearing (Figure 3) for the cases of loading of the shaft line due to the weights q_1 , q_2 and q^* and the moment of the eccentric thrust force M_p can be obtained using the Mohr's integral [7]. The shaft line analytical models suitable for these deflection analysis of the shaft sleeve in the stern tube bearing are shown in Figures 4 and 5.

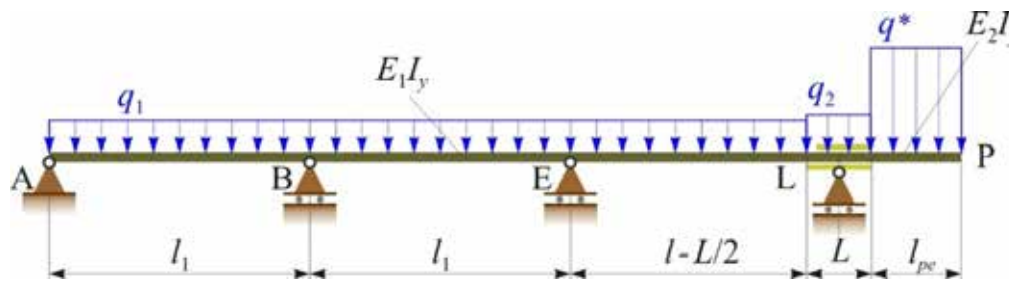


Figure 4 Model of the shaft line loading due to the weights

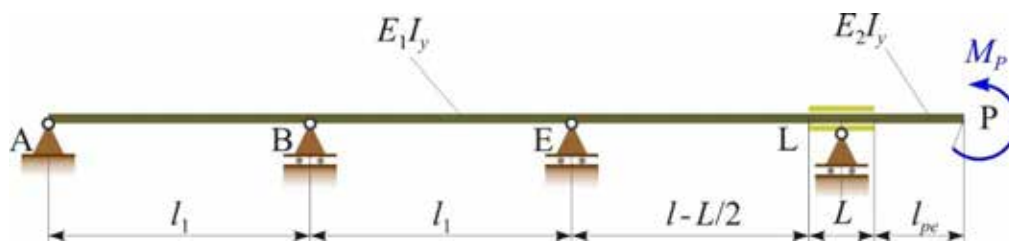


Figure 5 Model of the shaft line loading due to the moment of the eccentric thrust force

The analysis of the deflection values w_{Af} and w_{Aa} obtained using expression (14) and their comparison with the expected minimum lubricant layer thickness h_0 opens the possibility of more convenient selection of the stern tube bearing tribosystem [1].

2.6. Minimum lubricant layer thickness

The minimum lubricant layer thickness h_o can be determined from the expression [1]:

$$h_o = 0.5 \cdot D \cdot \psi \cdot (1 - \varepsilon) \quad (15)$$

where ψ is relative clearance, D is slide bearing diameter (mm), ε is relative eccentricity.

Relative bearing clearance ψ is:

$$\psi = \frac{z_1}{d} \quad (16)$$

where: z_1 is recommended clearance (mm), which is: $0.001d+0.3$ for white metal or $0.0025d+1.9$ for polymer slide bearing.

Relative eccentricity ε can be determined from the diagram $So = f(\varepsilon, L/D, \Omega)$ given for hydrodynamic lubrication regime [1].

The expression that gives the amount of the Sommerfeld number So is [10]:

$$So = \frac{\bar{p} \cdot \psi^2}{\eta \cdot \omega} \quad (17)$$

where: \bar{p} is mean specific pressure (Pa); $\bar{p} = \frac{F}{D \cdot L}$, η is dynamic lubricant viscosity (Pas), ω is hydrodynamic angular velocity (rad/s).

In this paper bearing reaction force is $F = F_L$ [10]. For this analysis, the reaction value was obtained from the analytical model shown in Figure 4.

Table 7 shows the recommended values of output parameters of the classic oil-lubricated and the polymer water-lubricated stern tube slide bearings [1].

Table 7. Recommended values of output parameters of stern tube slide bearings with the contact angle $\Omega = 360^\circ$

Output parameters	Oil-lubricated white metal slide bearings	Water-lubricated polymer slide bearings
Mean specific pressure (bearing load) (MPa)	0.5 – 0.8 $L/D \leq 2$	0.2 – 0.6 $L/D \geq 2$
Operating temperature of the bearing (lubricant) t (°C)	40 °C – 60 °C	20 °C – 22 °C
Dynamic lubricant viscosity η (Pas)	$136 \cdot 10^{-3} - 57 \cdot 10^{-3}$	$1.003 \cdot 10^{-3}$
Sommerfeld number So $So = f(\varepsilon, L/D, \Omega)$	≤ 20	100 – 500 (1000)
Relative eccentricity ε $\varepsilon = f(So, L/D, \Omega)$	0.5 – 0.8	0.998 - 0.99
Minimum lubricant layer thickness h_o (mm)	20 – 300	2 – 5

3. Results and discussion

In this section the real example was used in further analysis. The actual ship is powered by a slow-speed Wärtsilä marine Diesel engine RT-flex35 with the maximal continuous rated power of $P_B = 3475$ kW at the speed of $n_e = 167$ rpm. There is no reduction gearbox, so the rated speed of the propeller shaft (propeller) is $n = 167$ rpm (transmission ratio $i = 1$) [2].

The material of the intermediate shaft is medium carbon steel 1.0503/C45, while the material of the propeller shaft is austenitic stainless steel AISI 304 (S30400) (Table 8) [11].

Table 8. Material properties of intermediate and propeller shaft

Material properties	Tensile strength R_m (MPa)	Yield strength $R_{p0.2}$ (MPa)	Elastic modulus E (GPa)	Shear modulus G (GPa)	Density ρ (kg/m ³)
1.0503/C45	630	310	193	72	7850
S30400	620	350	200	77	7850

For this analysis, the four-blade fixed-pitch propeller type B, series B.4.55. is selected. It is made of copper-nickel-aluminium (CuNiAl), density of $\rho_p = 7650$ kg/m³. The mass of the propeller is $m_p = 11778.5$ kg. The diameter of the propeller is $D_p = 4$ m and the pitch ratio is $H/D_p = 0.95$ (mean propeller pitch is $H = 3800$ mm) [2].

3.1. Geometric and constructive characteristics of the shaft line

The shaft line used for this example is with 3 intermediate shafts length of $l_1 = l = 5$ m (Figure 4 and 5). The propulsion elements length is $l_{pe} = 0.5$ m. The chosen diameter of the propeller shaft and intermediate shafts is equal and according to expression (1) is $d = 300$ mm. The geometric characteristics of the shafts cross-section are: $I_y = 3.97 \cdot 10^8$ mm⁴ and $A = 7.07 \cdot 10^4$ mm². The stern tube bearing is with constructive characteristics $L/D = 2$ [4]. The diameter of the stern tube bearing is $D = 300$ mm, so the length is $L = 600$ mm.

3.2. Load of the shaft line

The load values of the shaft line are given in Table 9.

Table 9. Load of the shaft line

Load	expressions	Value
Intermediate shaft self-weight, q_1	4	$q_1 = 5443$ N/m
Propeller shaft self-weight, q_2	5	$q_2 = 5443$ N/m
Complete immersion propulsion elements, q^*	7, 8, 9, 6	$q^* = 204864$ N/m
Moment of the eccentric thrust force, M_p	11, 12, 10	$M_p = 50000$ Nm

3.3. Minimum lubricant layer thickness

Table 10 shows the data for the minimum lubricant layer thickness h_0 of the classic oil-lubricated and the polymer water-lubricated stern tube slide bearings (expressions 16, 17, 15).

Table 10. Minimum lubricant layer thickness of stern tube slide bearings

Output parameters	Oil-lubricated white metal slide bearings	Water-lubricated polymer slide bearings
Mean specific pressure, (MPa)	0.6	0.6
Relative clearance, ψ	0.002	0.0088
Sommerfeld number, So	2.11	2657
Relative eccentricity, ε	0.52	0.99
Min. lubricant layer thickness, h_o (mm)	144	1.32

3.4. Deflection analysis of the shaft sleeve in the stern tube bearing

The calculation of the shaft sleeve deflection in the aft stern tube bearing was carried out using the analytical models given in the Figures 4 and 5. The results of the deflection were obtained using the expression (14).

Tables 11 and 12 show the results for the bending deflection w_{Afb} and w_{Aab} , shear deflection w_{Afs} and w_{Aas} and total deflection w_{Af} and w_{Aa} of the shaft sleeve in the forward and aft ends of the stern tube bearing for the cases of loading of the shaft line model due to the weights q_1 , q_2 and q^* (Figure 4). In the same tables, the influence of shear on the total deflection is given.

Table 11 Deflection of the shaft sleeve in the forward end for the case of loading due to the weights

bending w_{Afb} (mm)	shear w_{Afs} (mm)	total w_{Af} (mm)	$\frac{w_{Af} - w_{Afb}}{w_{Afb}}$ (%)
-0.215	0.001	-0.214	0.26%

Table 12 Deflection of the shaft sleeve in the aft end for the case of loading due to the weights

bending w_{Aab} (mm)	shear w_{Aas} (mm)	total w_{Aa} (mm)	$\frac{w_{Aa} - w_{Aab}}{w_{Aab}}$ (%)
0.273	0.008	0.281	2.74%

The influence of shearing on shaft sleeve deflection in the stern tube bearing is negligible. In the forward end it is only 0.26%, while in the aft end it is 2.74%.

Table 13 show the results of the shaft sleeve deflection w_{Af} and w_{Aa} in the forward and aft ends of the stern tube bearing for the cases of loading of the shaft line model due to the moment of the eccentric thrust force M_p (Figure 5). For this analytical model the influence on the deflection is only from the bending.

Table 13 Deflection of the shaft sleeve for the case of loading due to the moment of the eccentric thrust force

total w_{Af} (mm)	total w_{Aa} (mm)
± 0.246	∓ 0.304

3.5. Influence of different navigation regimes on the shaft sleeve deflection

For this analysis, the change in position of the thrust force F_T is related to the navigating regime. The value of the thrust force according to expression (11) is $F_T = 315$ kN, while the distance (position of the thrust force) according to expression (12) is $e_T = 0.16$ m. It is assumed that the position of the thrust force F_T is on the negative z -axis for the case of straight ahead and astern navigation, and on the positive y -axis for the case of turning of the ship.

Figures 6, 7 and 8 show the elastic lines of the shaft sleeve for the assumed positions of the thrust force F_T of the navigation regimes mentioned. The values of shaft sleeve deflection at the edges of the stern tube bearing are given for: a) loading due to the weights q_1 , q_2 and q^* (shafts and propeller), b) loading due to the moment of the eccentric thrust force M_p and c) total loading, and they are compared with the values for the minimum lubricant layer thickness h_0 (Tables 10, 11, 12 and 13).

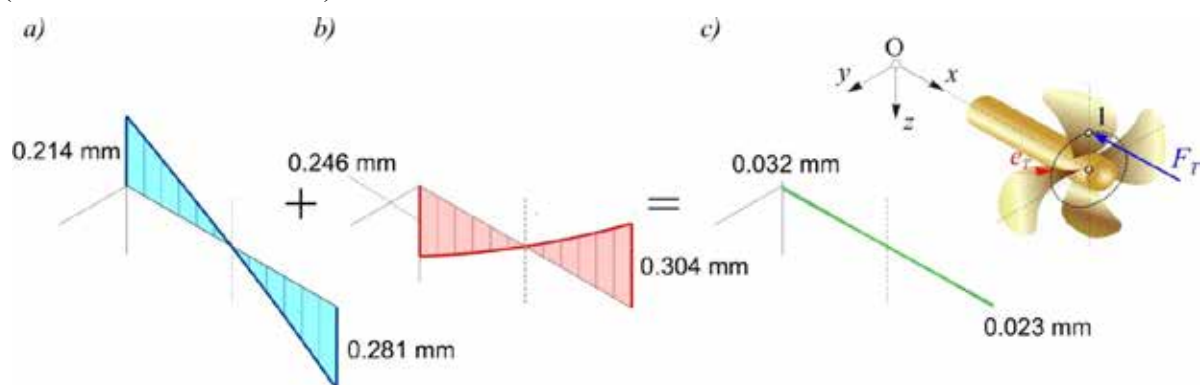


Figure 6 Deflection of the stern tube bearing sleeve for the case of navigating straight ahead

During normal straight-ahead navigation (Figure 6), the moment of eccentric thrust force M_p corrects the elastic line of the shaft sleeve caused due to the loading of the weights q_1 , q_2 and q^* . The ship navigating at her steady-state speed, and fluid friction occurs in the stern tube slide bearing. If such a regime is established and the sea during navigation is deep and calm, the thickness of the stern tube slide bearing lubricant layer is sufficient in relation to the shaft sleeve deflection (Figure 6c). In the case of minor disturbances in the navigation regime, the bearing enters the area of mixed friction. Hydrodynamic lubrication along the entire length of the bearing is achieved by adjusting the surface of the bearing and sleeve by running-in - wear [2].

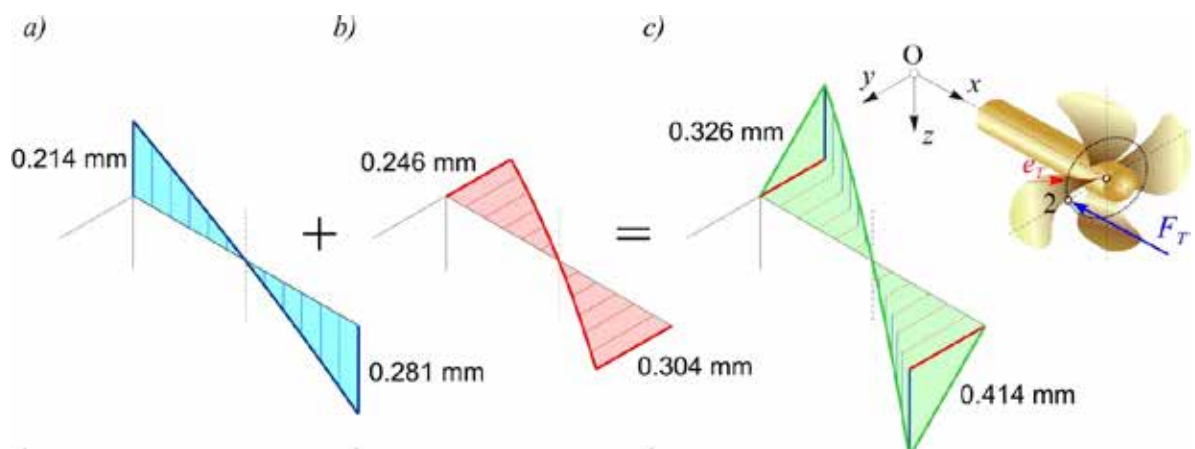


Figure 7 Deflection of the stern tube bearing sleeve for the case of turning

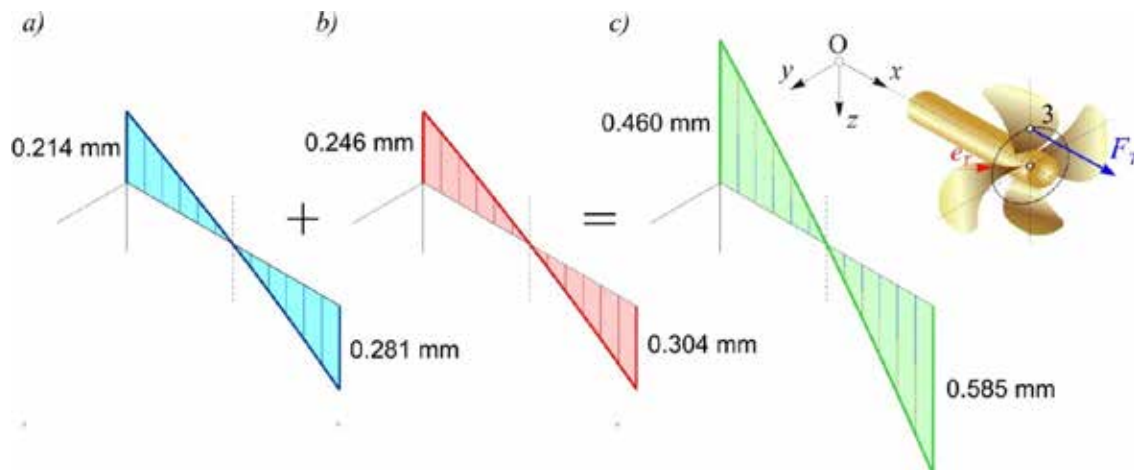


Figure 8 Deflection of the stern tube bearing sleeve for the case of navigating astern

The turning of the ship during straight ahead navigation leads to changes in the curvature of the elastic line of the shaft sleeve inside the stern tube bearing (Figure 7). A greater thickness of lubricating oil is more suitable for these changes in the navigation regime. Here, edge wear occurs on the side surfaces of the aft and forward parts of the slide bearing bush (Figure 7c) and the stern tube slide bearing will enter the area of mixed friction [2].

Strong disturbances in the operation of the stern tube bearing occur when the ship is navigating astern (Figure 8). Due to the greater resistance of the ship and the variable velocity field on the propeller, the equal value of the thrust force $F_T = 315$ kN is assumed for this analysis with the position of action on the negative z -axis. In this case, the aft part of the surface of the slide stern tube bearing bush wears due to elastic deformations and the deflection of the shaft sleeve caused due to the weights q_1 , q_2 and q^* and the moment of the eccentric thrust force M_p (Figure 8c). It is possible that the stern tube slide bearing is in the transition area from mixed to semi-dry friction and vice versa [2].

The given diagrams, show the influence of the shaft sleeve deflection on friction and wear of the material of the slide bearing bush for various cases of external loading. The calculated moment of the eccentric thrust force M_p only for the case $e_T = 4\%D$, already has a great influence on the working area of the stern tube bearing. It is necessary to discuss which stern tube bearing selection is favorable. The harmful impact of lubricating oil or white metal particles to the environment should also be considered.

4. Conclusion

The correct selection of the material of the slide bearing bush and lubricants for the lubrication of the stern tube slide bearing for different navigation regimes is an extremely important topic in the field of maritime traffic and transport. The goal is to achieve the energy efficiency of the shaft line of the ship's propulsion system as well as the environmental sustainability. As a rule, this also provides economic justification.

For this reason, it is important to monitor the changes that occur inside the stern tube bearing during the ship operation. One of the ways to define the state of the bearing for different navigation regimes is the deflection analysis of the shaft sleeve in the stern tube bearing. For these purposes, in this paper, shaft line analytical models were set up, which are analytically closest to the real models.

The installed models enable the analysis of the influence of the dimensional and constructive characteristics of the shafts and bearings, as well as the configurations of the shaft lines on the

deflection. By properly combining the length and number of intermediate shafts, more favorable working parameters of the stern tube bearing can be achieved, i.e. hydrodynamic lubrication (optimal configuration of the shaft line).

Deflection analysis of the shaft sleeve and comparison with the expected lubricant layer thickness for different navigation regimes (navigation straight ahead, astern and turning) can determine within which working area the stern tube bearing is located. The obtained results can be useful for the selection of more convenient materials and lubricants for the stern tube bearing tribosystem.

The paper also analyzed the influence of shearing on the shaft sleeve deflection. It's below 3% showing that it can be neglected in these deflection calculations. The same conclusion can be expected by considering the influence of shear on stress. This may be the subject of future research.

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EXPLORING KEY SUCCESS FACTORS IN TECHNICAL ENGLISH LEARNING: EXPERIENCE AND MOTIVATION

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Abstract. This study investigates the connection between motivation, demographic factors, and student achievement in Technical English learning. The objective of the study is to discern the disparities between successful and less successful students concerning their motivational levels and how these, along with demographic variables such as learning experience, forecast students' academic success. A cohort of 114 first-year undergraduate students enrolled in Technical English I at the University Department of Professional Studies of the University of Split participated in this research. The main tools for data collection utilized a validated Motivational questionnaire tailored for Croatian learners of English (Mihaljevic, 1998), alongside a demographic survey and students' final exam results. Aimed at reaching the research objective the analyses conducted within the study involved the employment of SPSS: descriptive statistics, a two-way analysis of variance (ANOVA), an Independent Samples Test, and hierarchical regressions. Results underscore a notable contrast in motivational levels between successful and less successful students, with demographic variables such as previous learning experience and motivation for learning emerging as positive predictors of academic success. These findings hold significant teaching implications and enhance the efficacy of ESP learning methodologies.

Key words: *experience, motivation, students' achievement, Technical English learning*

1. Introduction

Various theoretical models within the field of foreign language learning (FLL) and second language acquisition (SLA) have identified three key components contributing to foreign language/second language achievement (L2): cognitive factors (such as intelligence, language aptitude, and cognitive learning strategies), affective factors (involving motivation, attitudes, personality traits, language anxiety, and learning strategies referring to some kind of emotional input), and contextual factors (encompassing instructional context as well as social and cultural influences). In light of the prevalent view in the field of applied linguistics underscoring motivation as one of the most important psychological factors within the affective domain of the mere process of FLL, second language (L2) motivation has garnered significant scientific attention over the last three decades prompting a plethora of studies emphasizing its contribution to successful FLL (for reviews see Gardner, 1985; Mihaljević Djigunović, 1998; Ehrman et al., 2003; Dörnyei, 2005).

The abstract concept of motivation—a multifaceted construct that encompasses an array of cognitive, affective, and behavioral dimensions still escapes any single theory and is not provided

with a single theory due to its multi-tier nature. Motivation serves as the valuable impetus driving individuals toward their learning goals, influencing their persistence, engagement, and ultimately, their academic outcomes. Demographic factors, such as prior learning experiences and cultural influences, intricately intertwine with motivation, shaping learners' trajectories in language acquisition. Recognizing the diverse array of learners populating our Technical English classrooms, it becomes imperative to discern how the demographic variables interact with motivation to predict academic success.

Furthermore, due to the rapid development of all branches of technology, particularly AI technology, a dramatic uptick in globalization trends, and the recent solidification of the status of English as the global language of business, English language proficiency (EFL) has become a prerequisite for successful general and professional education. The benefits of mastering English also permeate and shape many aspects of people's personal lives enabling access to more travel opportunities, social media, and larger friendship groups, thus turning proficiency in English into a transformative investment and not merely a business necessity.

ESP, particularly, Technical English, as the language of science, technology, engineering, and mathematics (STEM), serves as a gateway for students aspiring to thrive in various technical disciplines. Mastery of Technical English is not merely about linguistic prowess but also a precursor to professional competence and career advancement. Hence, understanding the determinants of success in this domain holds even more significant implications for educational practitioners and teachers in this area. Therefore, unveiling the vital and nuanced interplay between motivation, demographic variables and academic achievement in Croatian students of Technical English is at the heart of this investigation.

The primary objective of this study is twofold: first, to delineate motivational differences between successful and less successful students of Technical English; and second, to elucidate how these motivational disparities, in conjunction with demographic factors, forecast students' academic achievements. To account for the underlying impetus that prompts our students' interest and their effort investment in Technical English learning and its interaction with our students' prior experience and their language performance, i.e. academic achievement, we have set our small-scale research between the general perspective of the social psychological period by providing a general view of SLA motivation and the situation-specific period by considering the immediate learning context. By taking the situative perspective, we endeavor to explore the types and intensity of Technical English motivation at the tertiary education level in Croatia where Technical English is part of the core curriculum and where EFL is taught at all levels of education within the broader socio-educational context. By dissecting these intricate relationships, this research aims to furnish educators with actionable insights to optimize pedagogical practices and enhance student outcomes in Technical English education.

Through a comprehensive analysis of empirical data and theoretical frameworks, this study endeavors to shed light on the nuanced nexus of motivation, demographics, and academic achievement in the domain of Technical English learning, thereby contributing to the broader discourse on language education and student success.

After a brief review of major L2 motivational theories in Section 2, the participants partaking in our study, the types and intensity of motivation they displayed, the main instruments for collecting the data on our students' linguistic achievement, and the research questions we focused on will be elaborated in Section 3. In Section 4 the results of this research will be analyzed and further expanded upon. Finally, further implications based on our research conclusions will be provided in the last section of the paper.

2. Theoretical background

Understanding student motivation to learn a foreign language is crucial for language educators and researchers alike. Several prominent theories have emerged over the years to understand this complex phenomenon.

Among the very first to discuss is the socio-educational model. Developed by Robert Gardner and Wallace Lambert in 1985, this model focuses on the social and educational factors influencing second language acquisition. It highlights the role of integrative motivation, which refers to learners' desire to integrate into the target language community and culture. Integrative motivation is influenced by attitudes towards the target language community, social integration, and instrumental motivation (the practical benefits of learning the language). Educators can enhance integrative motivation by creating opportunities for meaningful interactions with native speakers, fostering a supportive classroom environment, and highlighting the cultural and personal relevance of language learning.

The second model to examine is the motivation-orientation model. This model, proposed by Zoltán Dörnyei in 1994, emphasizes the dynamic nature of motivation and its impact on language learning outcomes. It distinguishes between two types of motivation: integrative motivation, similar to the socio-educational model, and instrumental motivation, which focuses on the pragmatic benefits of language learning, such as career opportunities or academic requirements. Additionally, the model identifies three language learner orientations: the integrative orientation, the instrumental orientation, and the personal orientation, which emphasizes the intrinsic enjoyment and satisfaction derived from language learning. Educators can promote motivation and engagement by aligning instructional activities with learners' motivational orientations and providing a pedagogical framework ensuring autonomy, competence, and relatedness.

Self-determination theory (SDT) was postulated by Richard Ryan and Edward Deci in 2017. SDT posits that intrinsic motivation is fostered when individuals' basic psychological needs for autonomy, competence, and relatedness are satisfied. In the context of language learning, autonomy involves providing learners with choices and opportunities for self-directed learning, competence entails scaffolding tasks to match learners' skill levels and providing constructive feedback, and relatedness involves creating a supportive and inclusive learning community. SDT underscores the importance of promoting intrinsic motivation to sustain long-term engagement and proficiency in foreign language learning.

Proposed by Mihaly Csikszentmihalyi in 2000, the Flow Theory describes a state of optimal experience characterized by deep concentration, enjoyment, and a sense of timelessness. In language learning, achieving a state of flow often occurs when learners are appropriately challenged by tasks that match their skill level, receive immediate feedback, and experience a sense of progress and mastery. Educators can design learning activities that promote flow by balancing challenge and skill, providing clear goals and feedback, and fostering a supportive and immersive learning environment.

By integrating insights from these theories, language educators can develop holistic approaches to motivate and engage learners, address their diverse needs and motivations, and cultivate a lifelong passion for language learning. Effective language instruction involves not only teaching linguistic skills but also nurturing students' motivation, autonomy, and sense of belonging in the target language community.

After a brief review of major L2 motivational theories in Section 2, we report on the study carried out in Section 3. In Section 4 the results of this research will be analyzed and further expanded upon. Finally, further implications based on our research conclusions will be provided in the last section of the paper.

3. Methodology

The analyses conducted within the study involved the employment of SPSS, specifically descriptive statistics, a two-way analysis of variance (ANOVA), a t-Test, and hierarchical regressions.

3.1. Sample

Table 1 presents the means (M), standard deviations (SD), minimum (Min.), and maximum (Max.) values of the analyzed demographic variables.

Table 1: Descriptive statistics of demographic variables

Demographic variables	N	Min.	Max.	Mean	Std. Deviation
Age	114	18	34	20,54	,257
Prior learning experience	114	5	20	12,74	1,942
Level of State Matura exam, i.e. state secondary school graduation exam	114	0	2	1,48	,568
State Matura exam grade	114	0	5	3,61	1,118
Course grade	114	0	5	3,94	,943

As shown in Table 1, the participants of this study were three cohorts of undergraduate first-year students of technical studies (Mechanical Engineering, Power Engineering and Electronics) studying at the University Department of Professional Studies of the University of Split. All 114 participants were enrolled in the course Technical English I in the academic year 2023/24, taught using the same methods of teaching, provided with the same textbook, and required to take the same tests. There were 93% (N=106) of male participants and 7% (N=8) of female participants in the study. All participants are aged between 18 and 34 (M= 20,54; SD=3,034) and have TE I as an obligatory course. They have all studied English between 5 and 20 years (M=12,74; SD= 1,942). A high percentage of students (89%) attended a vocational secondary school and a low proportion of them (11 %) a grammar school (M= 1,89; SD=,308). Only 17% of all the participants attended additional language classes outside of school. A substantial percentage of all the students (79%) had general English courses in secondary school, while only 21% had Technical English. Less than half of them (45%) took the A-level State Matura exam in English (The State Matura exam in Croatia is a secondary school leaving examination. The exam is managed and organized by the National Centre for External Evaluation of Education. Students who have completed their secondary education from grammar, vocational, or art high schools are required to sit for the State Matura exams.). More than half of the students (52 %) passed the B-level of State Matura (M= 1,48; SD=,568) and merely (3 %) of them did not partake in State Matura exams. Their average grade in the English State Matura exam was (M=3,61; SD= 1,118). The average Technical English I grade they got is (M=3,94; SD=,943). This should be further clarified by pointing out that the grading system in higher education in Croatia is the same as in Croatian secondary schools comprising the range of grades from 1 to 5, where grade 1 is assigned to those students who fail the final exam, whereas grade 5 is given to those students who achieve the highest final exam scores. Furthermore, our students' average grade in Technical English I refers to the number of those who took the exam and their average score, expressed through the statistical mean (MD=3.94). The delineation of successful and less successful students is based on the higher education grading system labeling those students obtaining final exam grades 4 and 5 as successful, whilst those receiving final exam grades ranging from 1 to 3 as less successful students.

3.2. *Aims and Hypotheses*

In this research, we were interested in discerning the disparities between successful and less successful students concerning their motivational levels and how these, along with demographic variables such as learning experience, forecast students' academic achievement in mastering the Technical English I course. Therefore, we formulated the following research problems:

1. What is the relationship between motivational levels and types and the success in the final grades of our students?
2. Which are the most significant predictors of student academic achievement in mastering the English language of the profession?

Drawing upon the findings of previous research, this study is grounded in the following hypotheses:

H1: Motivational levels will differ significantly among successful and less successful students, e.g., successful students will display significantly higher motivational levels than the less successful ones.

H2: Motivational levels and types will prove to be significant predictors of success in mastering the foreign language of the profession.

H3: Demographic variables will provide a statistically relevant contribution to the prediction of our students' achievement.

3.3. *Procedure*

A classroom questionnaire on our students' demographic variables and a Motivational questionnaire (Mihaljević, 1998), written in the participants' native language, were administered during the participants' regular Technical English I classes. The participants were first explained the purpose of the investigation and informed that their participation was voluntary. They were asked to write down their names as well. A set of formative and summative tests assessing our students' learning progress was also distributed periodically throughout the course. They served an educational purpose by gathering quantifiable evidence of students' knowledge and proficiency, while also evaluating the learning outcomes outlined in the curriculum design. The testing comprised a poster presentation, an oral presentation, a short test in mathematical, algebraic, and geometric expressions, a summary of a technical text, and two progress tests.

The factor analysis we conducted on the motivational types displayed by our sample resulted in distinguishing the following three factors: (1) pragmatic-communicative motivation, (2) affective motivation, and (3) integrative motivation, with Cronbach's alphas of .79, .87, and .58, respectively.

Cronbach's alpha for the internal reliability of the questionnaire in this study was .86 which indicates good internal consistency of the scale and homogeneity.

3.4. *Instruments*

The main tools for data collection were the classroom questionnaire on our students' demographic variables, the validated Motivational questionnaire tailored for Croatian learners of English (Mihaljević Djigunović, 1998) *Types and Intensity of Motivation for Learning EFL Questionnaire*, and our students' final grades in Technical English Language I course. A present situation analysis (PSA) was obtained through the classroom questionnaire on our students' demographic variables previously defined in the *Sample* subsection. The motivational

questionnaire used on our students was designed and gauged by Djigunović (in 1998) to measure the types and intensity of motivation for learning EFL in the Croatian socio-cultural context. The types of motivation it covers are: affective, which refers to learners' wish to learn English because of specific aesthetic or emotional reasons, pragmatic-communicative, which involves the instrumental and professional value attached to the knowledge and the status of English as a language of international communication and integrative, which reflects learners' wish to be integrated into an English-speaking linguistic and cultural community. Moreover, it unveils two categories of demotivating factors: one pertaining to the teaching environment and the other to learning challenges. This questionnaire was primarily selected due to its suitability for our context-dependent research as a questionnaire validated in participants' L1 and adapted to the target learning context. Due to the primary emphasis being placed on motivational levels and types displayed by our students and their key role in the predictive value of their academic achievement, the abovementioned demotivators were not considered. The 38 items contained within the questionnaire are followed by a five-point Likert scale: (1) strongly disagree, (2) slightly disagree, (3) neither agree nor disagree, (4) slightly agree, (5) strongly agree. As for the final assessment and evaluation of our students' language performance, students were required to partake in four formative and two summative assessment tests, which accounted for their final course grades.

4. Findings and discussion

The results of our study are categorized into three groups and then further elaborated. The data obtained through the PSA analysis and the Motivational Questionnaire were statistically analyzed using SPSS (Statistical Package for Social Sciences).

4.1. Comparison of motivational levels and types and the success in our students' final grades

To find out whether there are any disparities in the motivational levels between more and less successful TE students we initially employed descriptive statistics to compute the average motivational intensity amongst all the cohorts and to provide a general understanding of the tested motivational variables. Results of the descriptive statistics regarding the intensity of each type of motivation for learning TE for the whole sample (see Table 2) reveal that the most intense motivational dimension of our students is pragmatic-communicative motivation with the highest means recorded ($M=4,077$, $SD=6,786$), followed by affective motivation ($M=3,545$, $SD=4,912$). Integrative motivation seems to be less pronounced in this sample with the lowest means reported ($M=2,105$, $SD=3,459$). These findings are in line with previous research: Croatian learners are distinguished by pragmatic-communicative type of motivation rather than integrative (cf. Mihaljević Djigunović, 1998, 1997; Pavičić Takač & Berka, 2014).

Table 2: Descriptive statistics of Types and Intensity of Motivation for Learning EFL Questionnaire

Types/intensity of motivation	Mean	Variance	N of Items	SD
Pragmatic-communicative motivation	4,077	,429	12	6,786
Affective motivation	3,545	,173	6	4,912
Integrative motivation	2,105	,393	4	3,459

The two-way analysis of Variance (ANOVA) and t-Test that were run to compare the means

of our students' motivational levels and types and academic achievement across all the tested cohorts show statistically significant differences in the intensity of pragmatic-communicative motivation between less successful and more successful participants ($F=3,988$, $p=0.048$). Thus, the figures indicate that participants with higher course grades have statistically significantly higher pragmatic-communicative motivation than participants with lower course grades. The relationship between course grades and the remaining two types of motivation does not appear statistically significant ($F=3,375$, $p=0.069$, $F=526$, $p=4.70$). Furthermore, Tables 3 and 4 below indicate that our H1 regarding the comparison between motivational levels and types and academic achievement of our students was partially confirmed. These findings are compatible with Mihaljević Djigunović's study (1998; 1997) where more successful students were found both to be generally more motivated and to display higher pragmatic-communicative motivation than less successful students. High pragmatic-communicative motivation might be accounted for by the prevalent EFL teaching curriculum in secondary schools. Both students who completed vocational school and those who graduated from grammar schools attended exclusively General English courses and were thus exposed to a wide range of information and communicative content about English-speaking communities. They have perceived English not necessarily as the native language of the British, Canadians, etc., but rather, as a language of international communication and its mastering as beneficial for their future educational and career opportunities. This underpins the original concept of pragmatic-communicative motivation defined by Djigunović (1998) both as an instrumental type of motivation referring to the attainability of present and future goals and an integrative orientation implying students' willingness to integrate into the international community. The obtained results corroborate the findings from the previous research carried out on SLA motivation within the Croatian socio-cultural context. The affective and integrative motivational dimensions of motivation for learning EFL among Croatian learners have been less distinctive and less pronounced than pragmatic-communicative motivation.

Table 3: Two-way analysis of variance (ANOVA) of the comparison between types and intensity of motivation and success

		Sum of Squares	df	Mean Square	F	Sig.
P-CM	Btwn. Groups	178,950	1	178,950	3,988	,048*
	Within Groups	5025,339	112	44,869		
	Total	5204,289	113			
AM	Btwn. Groups	79,764	1	79,764	3,375	,069
	Within Groups	2646,806	112	23,632		
	Total	2726,570	113			
IM	Btwn. Groups	6,324	1	6,324	,526	,470
	Within Groups	1345,465	112	12,013		
	Total	1351,789	113			

Note. * $p < 0.5$

Table 4: t-Test analyzing the types and intensity of motivation and success

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Differ.	Std. Error of Differ.	95% Confidence Interval of the Difference	
								lower	upper
PM	,056	,813	-1,997	112	,048	-2,816	1,410	-5,609	-,022
AM			-1,917	49,885	,061	-2,816	1,469	-5,767	,135
IM	,000	,996	-1,837	112	,069	-1,880	1,023	-3,907	,148
			-1,795	51,523	,079	-1,880	1,047	-3,982	,222
	,036	,850	,726	112	,470	,529	,730	-,916	1,975
			,720	53,093	,475	,529	,735	-,945	2,003

Note. *p< 0.5

4.2. *Demographic variables and motivational variables as predictors of student academic achievement*

Hierarchical regressions were performed on the data in order to assess the predictability of our students' academic achievement by demographic variables and motivational intensity and types. Table 5 presents the standardized β coefficients and t values for multiple regressions.

Table 5: Hierarchical regressions: demographic factors and motivational types and levels as predictors of students' achievement

	St. β	t	Sig.	Model summary
Step 1				
Gender	,169	1,812	,073	Adj. $R^2 = 0.12$ F (2,111)=1,675 R square change (ΔR)= 0.29
Age	,024	,261	,794	
Step 2				
Gender	,076	,839	,403	Adj. $R^2 = 1.37$ F (3,110)=6,987 R square change (ΔR) =1.31
Age	-,114	-1,216	,227	
Level of State Matura exam	-,398	-4,138	,000***	
Step 3				
Gender	,030	,323	,747	Adj. $R^2 = 1.73$ F (6,107)= 4,941 R square change (ΔR) =0.57***
Age	-,111	-1,208	,230	
Level of State Matura exam	-,372	-3,925	,000***	
Pragmatic-communicative mot.	,222	1,974	,051*	
Affective motivation	,081	,731	,466	
Integrative motivation	-,134	-1,366	,175	

Note. N=114; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.0005$

The second and third research questions concerning the relative contribution of demographic and motivational variables to the prediction of students' final course grades were addressed by performing hierarchical regressions with three blocks of predictors. The first block of predictors comprises the following demographic predictors: our students' gender and age, the second one contains their gender, age, and the level of State Matura exam, whereas the third one includes all the tested demographic variables and types of motivation. After the variables in step one (gender and age) have been entered, the overall model explains 2.9% of the variance of our students' achievement in the final grade. After step two (gender, age, and the level of State Matura exam) an additional 13.1% of the model as a whole is accounted for by the level of State Matura exam. Finally, when included in the model in the third block, all types of motivation explained an additional 5.7% of the variance in the model after controlling for gender, age, and the level of State Matura exam. However, a statistically significant contribution is indicated by the Sig. F change value for the level of State Matura taken (.000) and pragmatic-communicative motivation (.051). The results of the model as a whole show statistical significance and are therefore consistent with H2 and H3. As predicted, the level of English State Matura exam and the pragmatic-communicative motivation emerge as the statistically significant variables and

thus predictive of students' achievement. This leads to the conclusion that students who took the A-level of English State Matura exam tend to earn better course grades and demonstrate higher academic achievement than those students who passed the B-level of English State Matura exam. Furthermore, as students having taken the A-level of English State Matura exam mostly attended grammar schools, this finding may well point to the importance of students' prior EFL learning experience gained through their attendance of grammar school English lessons supporting the acquisition of higher levels of EFL linguistic competence. Thus, it may be implied that students' reliance on their previously acquired knowledge of EFL is largely reflected in their academic achievement, i.e. "EFL proficiency measured by course grades" as corroborated by Pavičić Takač & Berka (2014) and Jakovac & Kamenov (2012). The strong predictive value of pragmatic-communicative motivation reported by this finding is corroborated by the aforementioned studies conducted by Mihaljević Djigunović (1997, 1998). As discussed previously, pragmatic-communicative motivation seems to be the most representative type of motivation among EFL learners at all educational levels in Croatia and is therefore found to be a strong predictor of academic achievement.

5. Conclusion

Finally, we can draw several conclusions and list corresponding practical and scientific implications arising from the obtained and interpreted data. First of all, the findings of this study indicate low motivational levels for learning Technical English in all our participants. This overall weak score percentage across all types of motivation could be explained by students' insufficient awareness of the importance of acquiring proficiency in TE for their future career and educational paths and their potential perception of the Technical English I course as being a less important course in comparison to other core courses within their study programs. It might also reflect the fact that the linguistic and educational contents of Technical English course I are generally perceived as easy to learn by our students and thus high levels of motivation and great effort investment as unnecessary for their acquisition. This primarily calls for designing and implementing a comprehensive strategy for raising awareness of the importance of EFL and TE proficiency among our students through various workshops, seminars, and lessons enriched with specifically designed and challenging learning tasks. Another implication it holds for instructional design might be deliberating a thorough modification of the syllabi and curricula of all ESP courses that students would find attainable, but challenging, demanding, but relatable, and willing to engage with.

The pragmatic-communicative motivation being the most representative type of motivation, its statistically confirmed significance concerning success and its strong predictive value of success could be capitalized on by modifying the instructional process, adjusting the teaching materials and syllabus, redesigning learning tasks, as well as time allotted for certain skills, and creating a motivating learning environment. This may well imply considering moving across the TE continuum and readjusting the teaching process in favor of teaching academic skills such as listening, reading, taking notes, understanding common structures of argumentation, and representing abstract concepts using figures and tables. Even periodic resorting to General English instruction might be worth examining at this point of study due to its perceived relatability and a facilitating role in helping students transition from the grammar school General English threshold level to the Technical English university level.

Students' prior learning experience along with the level of English State Matura exam they took emerging as significant predictors of their Technical English I course grades fall into a category of contextual factors affecting the L2 teaching process that teachers cannot directly

affect, but could adapt to and raise awareness of. This also confirms that longer exposure to language raises students' motivation, is likely to be associated with higher final course grades, and is a strong predictor of success in mastering TE.

Notwithstanding teachers' key role in generating and maintaining student's L2 motivation, there will always be limits as to how far teachers can affect it. Therefore, teachers and students should constantly strive to find ways to effectively translate students' high levels of L2 motivation into actual learning behavior. This goal is attainable only if students get actively engaged with various components of the learning environment and if their motivation is realized in action. One may argue that emphasis on active task involvement, i.e. engagement is even stronger in language education than in other subject matters because the automatization of L2 skills requires an extended practice period.

Regarding teachers' contribution to the enhancement of student engagement and the situation-specific perspective of our study, we would like to express our agreement on the importance of engaging with some obvious aspects of the learning process distinguished by Dorneyi (2019): school context (e.g. adopting school norms and developing general academic confidence); syllabus and the teaching materials (e.g. match between the syllabus to the students' needs; ownership and personalization of the materials); learning tasks (e.g. utilizing the principles of task-based language teaching; application of project/problem-based learning; goal-setting and progress checks); one's peers (e.g. group cohesiveness, norms of cooperation and tolerance); teacher (e.g. student-teacher). As shown by our study findings, it could be claimed that some of the aspects, specifically school context, syllabus and teaching materials, and learning tasks contributed to the level of English State Matura exam selected and taken by our students, making for a crucial factor in predicting our students' academic achievement.

Students' boost of their active involvement in the learning process can be generated and maintained through motivational self-regulation and an increased sense of ownership of the learning process through learner autonomy. Motivational self-regulation encompasses an array of self-motivating strategies (Dorney; 2001) ranging from commitment control strategies for helping to preserve or increase the learners' original goal commitment, metacognitive control strategies for monitoring and controlling concentration, and for curtailing unnecessary procrastination, satiation control strategies for eliminating boredom and adding extra attraction or interest to the task, emotion control strategies for managing disruptive emotional states or moods and environmental control strategies for eliminating negative environmental influences and exploiting positive environmental influences by making the environment.

As for learner autonomy, the most common interpretation would be a sense of personal ownership and agency in relation to one's learning, together with a capacity to make one's own choices and decisions. This implies student involvement in making personally relevant choices and decisions about their learning process and promotes a sense of responsibility which applies to students personally organizing the whole learning process, drawing conclusions, setting rules, etc. Both self-motivating strategies and an increased sense of ownership of the learning process through learner autonomy in ESP-Technical English could be perhaps more easily attainable by exposing students to TE contexts in real working settings rather than merely classroom-based ones. This would pave the way for their overall greater active involvement in the learning process as it would play to their pragmatic-communicative motivation driving their interest and effort investment in learning TE.

Although there are more than a few limitations to this study, we hope that it provides valuable insight into the dynamic interplay of motivation, demographic variables, and academic achievement. To capture the full capacity of motivation similar research should be conducted involving students studying other study programs where L2 mastery is regarded as a long-term

benefit, if not a necessity. Further research should also include exploring the dynamic aspect of the interaction between students' motivation and learning strategies and their reflection on their academic achievement. This research involved only quantitative analysis. However, to gain a broader perspective, both quantitative and qualitative research analyses should be employed.

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USING SERIOUS GAMES TO LEARN ABOUT SUSTAINABILITY

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Abstract. The 2030 Agenda for Sustainable Development has set a number of goals that highlight the role of education in training, raising awareness and sensitizing future generations to sustainable development. The university, as a key actor in higher education, must contribute to the design and implementation of educational methodologies that favor quality learning towards sustainability. In this sense, gamification provides an attractive environment for students that enhances their learning experience, stimulates their motivation, strengthens their commitment, and improves their Education for Sustainable Development (ESD). These digital games are mainly implemented in the form of serious games, which provide interactive learning activities that engage users in sustainable behavior through entertainment. In this work, we combine gamification, technology and ESD through the design and production of serious games in the third year of a bachelor's degree. To do so, students developed serious games to create engaging and meaningful educational experiences for users based on the Sustainable Development Goals (SDGs). Specifically, the games developed focus on SDG3: Good health and well-being; SDG6: Clean water and sanitation; SDG7: Affordable and clean energy; SDG12: Responsible consumption and production; and SDG13: Climate action. To assess the effectiveness of the developed games, it is necessary to evaluate their user experience (UX), i.e. the perceptions and reactions of the users resulting from the use of the games. The results obtained in this UX analysis through the Game Experience Questionnaire, show the level of motivation and learning that the user has experienced during the Serious Game. These results may vary depending on each game, but in general the results achieved the objectives set.

Key words: *Education for Sustainable Development, Serious Games, User Experience*

1. Introduction

The 2030 Agenda for Sustainable Development (United Nations, 2015) has set a number of goals that highlight the role of education in training, raising awareness, and sensitizing future generations to sustainable development. Public awareness, education, and training are essential tools for achieving sustainability. The university, as a key role in higher education, must contribute to the design and implementation of educational methodologies that favor quality learning towards sustainability. In this context and considering the incorporation of digital tools in the teaching-learning process, gamification provides an attractive environment for students that enhances their learning experience, stimulates their motivation, strengthens their commitment, and can be used to improve their Education for Sustainable Development (ESD). These digital games are mainly implemented in the form of serious games (Abt, 1970), which refers to games used for training, advertising, simulation, or education. In this work, we aim to analyze an educational experience that combines gamification, technology and ESD through the design and production of serious games to create engaging and meaningful educational

experiences for users (Durkin & Barber, 2002), based on the Sustainable Development Goals (SDGs) (Katila et al., 2019).

This section continues with a review of the literature on serious games and, more specifically, their use to favor the motivation and commitment of users to the principles of sustainability.

1.1. Serious Games

Serious Games are games designed for a primary goal different from pure entertainment. They are based on real-life scenarios in which the user takes a role in the real or virtual world with the goal of developing a specific knowledge or skill. They are aimed at a wide variety of audiences, such as students, professionals, consumers, etc., and can be of any genre, use different technologies, and be developed for different operating systems. Serious games have shown success in medical contexts (Higgins & Hannan, 2013; Pereira et al., 2014), personal education (Johnson, 2010; Simões et al., 2013), and production (Brauner et al., 2016). According to Marcano (2008), serious games have the following important characteristics:

- They are intended for education, training in certain skills, understanding complex processes regardless of the subject, and to advertise products and services.
- They are linked to some aspect of reality. This favors the identification of the player with the area of reality represented in the virtual environment.
- They form a virtual three-dimensional environment in which trainees can safely practice in some areas.

When creating a serious game, it is necessary to think about the experience of the group to which it will be applied and to propose an appropriate activity to achieve a reproduction of this experience in a playful world. Subsequently, it is essential to adapt the norms and rules of the serious game to the specific objectives of the organization where it will be carried out. A fundamental aspect in determining the effectiveness as a reusable learning object lies in the process of game creation.

The process of creating a serious game is divided into three stages: (1) Contextual Analysis, (2) Methodology Development, and (3) Evaluation. The first and last stages require teamwork, while the methodology is developed individually according to the guidelines agreed during the analysis of the training context. The involvement of the users will be closely related to the outcome of this work. The final look of the game is fundamental in determining the success of the student/player's first contact with it. The reusability of the game, in turn, is directly proportional to the motivation, usefulness, and usability developed by its creators. In addition to that, there are certain aspects that should be emphasized in a serious game such as raising awareness (Global Conflicts: Latin America, 2008; Fairweather, 2009), encourage cognitive processes, and ensure healthy, good, and safe gaming habits. Although serious games are games designed for educational purposes rather than entertainment, they combine entertainment with knowledge transfer. Their purpose goes beyond entertainment, such as education, training, advertising, or promoting social change (Winn, 2008). To organize the different types of serious games, Sawyer and Smith (2008) classified serious games into seven categories: health, advertising, education, training, science and research, production, and employment; and related their potential uses to seven application domains: government and NGOs, defense, health systems, marketing and communications, education, business, and industry.

In the next section, we review of the use of serious games as a tool for sustainable development.

1.2. Serious Games and Education for Sustainable Development

In recent years, there have been an increasing number of serious games with the aim of raising awareness of sustainable development. Their main objective is to provide knowledge about the social and environmental impacts of human activities and to encourage the application and decision-making based on economic, environmental, and social criteria. In general, there is a consensus that serious games can provide players with knowledge on general aspects of sustainable development on specific topics in the environmental, economic, or social fields. However, after the adoption of the 2030 Agenda and the 17 Sustainable Development Goals (SDGs), it is recognized that actions in one area might have impact on outcomes in other areas. Therefore, development must balance environmental, economic, and social sustainability. Hence, it is important that the SDGs are considered when describing serious plays for sustainability.

In this work, we combine gamification, technology, and ESD through the design and production of serious games in the third year of a Bachelor's degree in Design and Development of Video Games and Interactive Experiences to raise awareness about sustainability. To do this, students were organized into groups and followed a game development process from the initial concept to the finished product. The developed serious games focused on the following goals: SDG3: Good health and well-being; SDG6: Clean water and sanitation; SDG7: Affordable and clean energy; SDG12: Responsible consumption and production; and SDG13: Climate action. The rest of the paper is organized as follows. First, we present the formal description of our educational experience and how we implemented it. Then, we present the results according to the evaluation of the students' user experience. Finally, we present conclusions and future work.

2. Implementation

Third-year students of the Bachelor's degree in Design and Development of Video Games and Interactive Experiences at Florida Universitária, within the subjects of "Serious Games" and "Project III", apply the knowledge they have acquired throughout their studies to develop a Serious Games around the Sustainable Development Goals framework (United Nations, 2015) over the course of a semester.

The class was divided into groups of 8 to 9 people. The various groups aimed to develop serious games with the learning objective of raising user awareness about the Sustainable Development Goals. They sought to motivate users during the process through gamification, thereby achieving substantial learning about sustainability. To accomplish this, each group analyzed the different SDGs and decided to focus on the following: SDG3: Good health and well-being; SDG6: Clean water and sanitation; SDG7: Affordable and clean energy; SDG12: Responsible consumption and production; and SDG13: Climate action.

Developing a serious game follows a similar process to developing a videogame. The incorporation of new technologies adds complexity, novelty, and diversity to the process of creating a serious video game (Moreau & Conway, 2014). The creation of a serious video game is a multidisciplinary task that involves several stages and processes. Specifically, the stages that the students follow to create a serious game are the following:

1. Pre-production: In this stage is where you define what the game is about, why you want to make it, and what it will take to make it.
2. Production: In this stage is where the game begins to take shape. The story is refined, assets (characters, props, and environments) are created, rules are set, levels and worlds are built, and code is written.

3. Post-production: In this phase, the game is tested in order to fix bugs, to add additional content, etc.

These stages are described in detail below.

2.1. Pre-production

The first phase of development for any serious game is pre-production. In this stage, the topic under consideration is investigated and analyzed to identify the needs to be addressed and to set the learning objectives that will guide the developers in devising and designing the serious game.

All teams had the freedom to organize their work. Based on the guidance provided by the teachers, they established and designed their own pipelines. The pipeline in the creation of a serious video game is used to manage and organize the team's workflow, enabling the project to be carried out and completed in the most efficient way possible.

The primary objective of a pipeline is to manage and streamline the workflow, and to prevent issues during production. Each student team designed their planning and pipeline using digital collaboration and project management platforms, such as Miro or Trello. Figure 1 shows an example of a Miro board from one of our groups.

In this part of the process, project ideation and planning are carried out, providing a clear description of what the team intends to achieve during the gaming experience and the game concepts that will be developed in the next stage of the process. In the Game Design Document (GDD) is where all these key elements that will define the serious game are outlined. These include the main objective of the game, narrative, mechanics, ideation and conceptualization, and overall planning. The GDD serves as a guide for the entire team during the game's development.

In the design of serious video games, *concepts* are the fundamental ideas that define the theme, mechanics, and objectives of the game. Some of the key concepts established include: the type of player (target) who will interact with the game; the narrative or story that will encompass the game; the character with whom the player will interact in the story; the mechanics and gameplay, which are the rules and actions that the user can perform; the visual and sound aesthetics, including the graphics, types of animations, and music that will help immerse the user in the game; and the design of the different levels, among other things (Ansaldi, 2020; Sánchez et al., 2021). Figure 2 shows an example of an island concept used in one of the serious games developed.

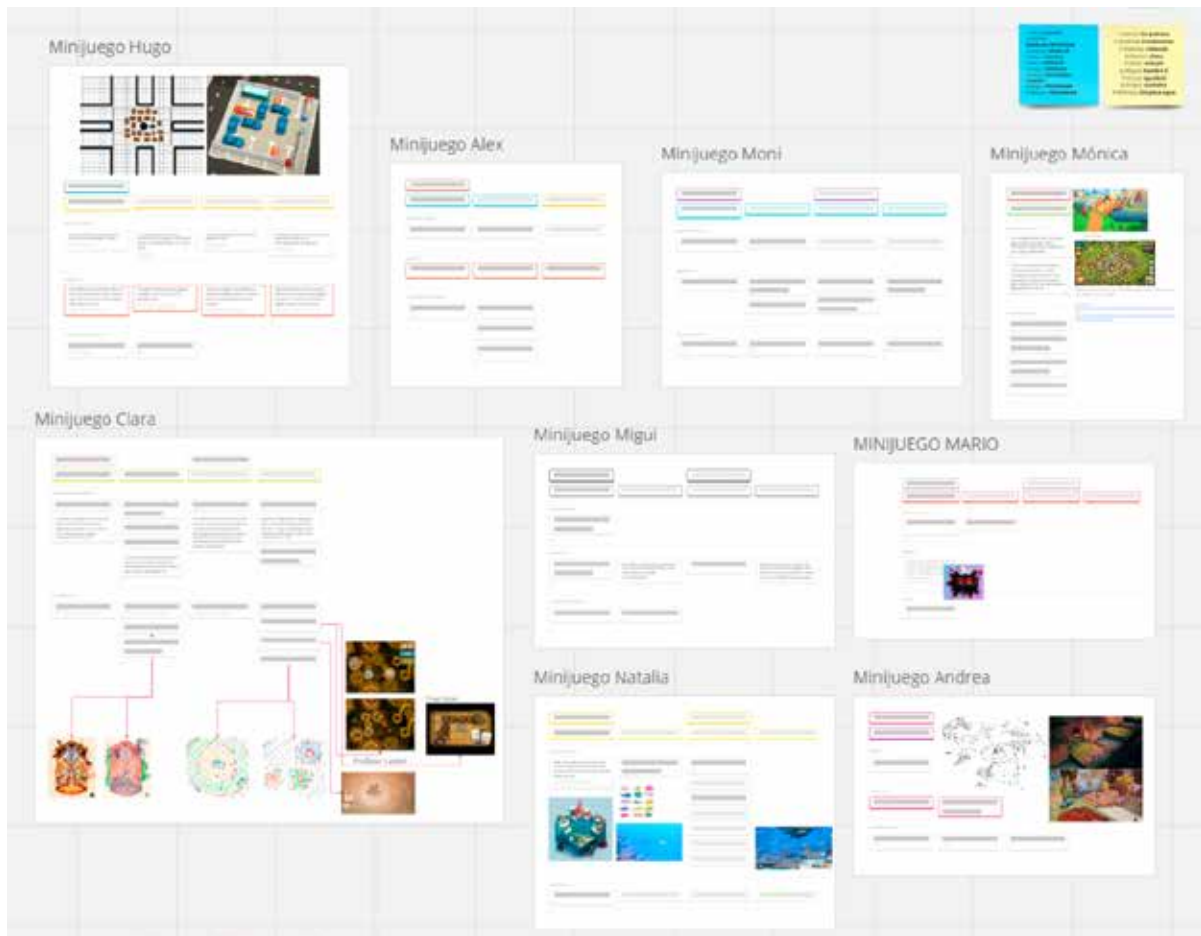


Figure 1. Planning the work of a student team using a digital collaboration and project management platform.



Figure 2. Concept art of one of the serious game scenarios.

Figure 3 shows another concept art of one of the serious game scenarios, but this one includes information about the mechanics and the different characters.



Figure 3. Concept art of the environment for one of the serious games, including information about the mechanics and the character.

In this ideation phase, in addition to establishing the main objectives of the game, the narrative that will guide the user, and the mechanics that will shape the gameplay and learning entertainment, the appearance of the different characters that are part of the game is also designed. This includes the main player, as well as Non-Player Characters (NPCs) or enemies. Factors such as the personality and values that each character must convey, their physiognomy, color range, appeal, etc., are taken into consideration. Figure 4 shows an example of the idea of characters and their characteristics. On the right part of the figure, we can see the initial sketch of a character. On the left part of the figure, we can see the result, including the selected color palette.

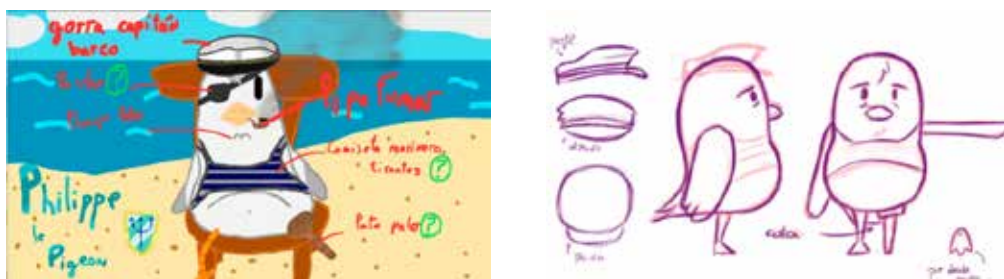


Figure 4. Ideation of a character's physical attributes and personality traits.

Figure 5 shows another example of an appearance study. In this case, the illustration shows the color study conducted by the students for color selection.

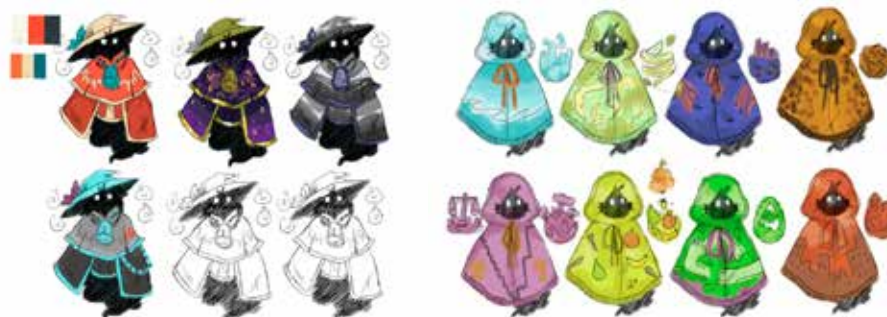


Figure 5. Study of the most suitable color range for each character.

Each one of these aspects plays a fundamental role in shaping the user experience and creating a serious game that meets the minimum requirements for effectiveness. These requirements

include (1) being easy to understand, (2) involving a minimal cognitive load, and (3) having a gradual level of difficulty (Moreau & Conway, 2014). To ensure that the user understands the task and how to perform it, it is necessary to design a tutorial within the game. The feedback that the player receives is not only essential for understanding the game, but also for facilitating a proper learning process. Clear and direct feedback as the player progresses is a fundamental requirement in serious game design. Performance can be quantified and reflected in changes to the user interface, in the HUD, or within the virtual world where the game and narrative unfold. This can be exemplified with badges, leaderboards, scoring, counters, sound effects, visual cues, and even nociceptive feedback (such as the vibration of the game controller, or gamepad, when the player makes a mistake). Figure 6 shows two examples of the feedback design for one of the games.



Figure 6. Planning the feedback that the player will receive during the game.

Sampayo-Vargas et al., emphasized that for serious video games to be intrinsically motivating - an activity that motivates the user - it is essential that they provide an optimal level of challenge. When we are intrinsically motivated to perform an activity or task, when we engage in something purely for the enjoyment of it, we perform better and become more involved (Deci, 1975; Ryan & Deci, 2000). Therefore, learning is favored.

To design an intrinsically motivating experience, one must guide the player to the *flow zone* or the state of flow. Csikszentmihalyi (1975) coined this term to describe the optimal experience that occurs when an individual is fully immersed in and enjoys an activity. The main prerequisites for this experiential state in a game are to have clear objectives, immediate feedback, and a balance between the individual's abilities and the level of challenge presented by the activity being undertaken (Csikszentmihalyi & Csikszentmihalyi, 1992; Engeser & Rheinberg, 2008; Keller & Blomann, 2008; Fong et al., 2015). According to the flow channel model (Csikszentmihalyi, 1975, 1990; Fig.7), whenever the challenge surpasses the player's skill level, the player may become frustrated or anxious. Conversely, when the level of challenge is less than the individual's skill level, they may become bored. Flow has been associated with successful performance and feelings of competence from the user (Engeser & Rheinberg, 2008; Jin, 2012; Rutrecht et al., 2021), as frustration and boredom can lead to decreased concentration and, consequently, result in poor performance (Perone et al., 2019).

As we can see in Figure 7, flow is associated with an immersive experience in which the game causes the user to lose track of time and even themselves (Csikszentmihalyi & Csikszentmihalyi, 1992; Wittmann, 2015, 2018; Rutrecht et al., 2021). To motivate the player, serious game developers must strike a balance between the challenge and the player's skills.

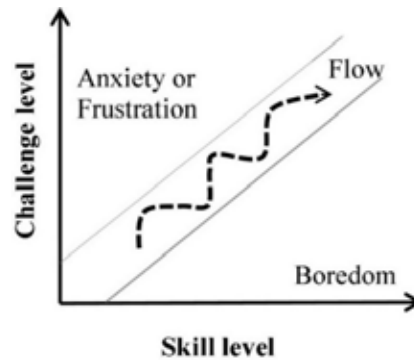


Figure 7. The flow-channel model (Csikszentmihalyi, 1975).

To guide the player into the *flow zone*, it is crucial to have an appropriate approach and design of the game mechanics. Mechanics are *rule-based simulations* that not only facilitate but also encourage the user to explore and understand the properties of their possibility space, all using feedback mechanisms (Koster, 2013).

In a serious video game, the mechanics serve as the primary components through which players acquire strategies and skills. They contribute to the game's playability, enjoyment, and challenge, while fostering learning through meaningful task repetition. The mechanics must be thoughtfully devised and designed to facilitate their subsequent development during the production phase and to ensure the final effectiveness of the game. Figure 8 shows an example of the design and definition of mechanics: in the water (left image), and on the ground (right image).

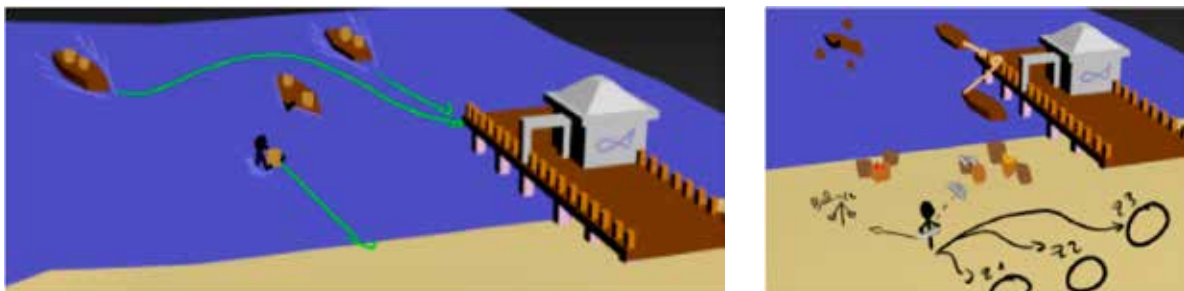


Figure 8. Defining the game mechanics.

All these issues must be appropriately addressed and defined during the pre-production phase before progressing to the next phase. This ensures that the serious game is built on solid and well-established foundations, thereby promoting the learning objectives that have been set. These objectives are achieved once the game's production is completed.

2.2. Production

In this phase, the different teams develop the game prototype based on the components of the serious video game, which were conceptualized in the previous phase to promote engagement, motivation, and learning.

During this stage, tasks include 3D modeling, animating elements and characters, texturing game components (such as assets and characters), lighting scenes and environments, and programming player interactions with the game. This includes mechanics, interface, HUD, and the artificial intelligence of various characters in the game, ranging from NPCs to enemies or traps. Visual effects (VFX) are also developed at this stage. Figure 9 shows an example of a 3D farm model.

The 3D modeling process is conducted using the Blender program. Subsequently, the models are prepared for texturing by displaying the UVs. UVs represent the two-dimensional depiction of a 3D geometry's surface on a flat image. They enable textures and painted details to be projected and accurately applied to the three-dimensional surface of the model. Figure 10 shows an example of the process of modeling and UV mapping of an NPC.

When tasked with designing a serious game focused on education in sustainable development, students were taught the importance of facilitating, through their games, the transfer of acquired knowledge to the user's daily life habits and routines. For this reason, the game mechanics designed and developed by the students proposed learning through gameplay and problem-solving. This was achieved through meaningful, contextualized, and real-world situations. These situations provided the player with resources, guidance, and instructions to promote the assimilation of knowledge and content. This knowledge and content could then be transferred, applied, and understood within the user's daily life. Figure 11 shows the process of adding textures and color to a 3D model.

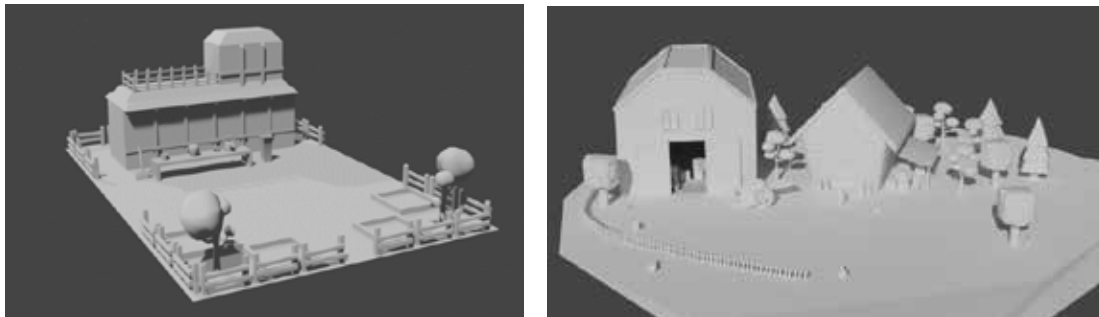


Figure 9. 3D Models of Game Environments.

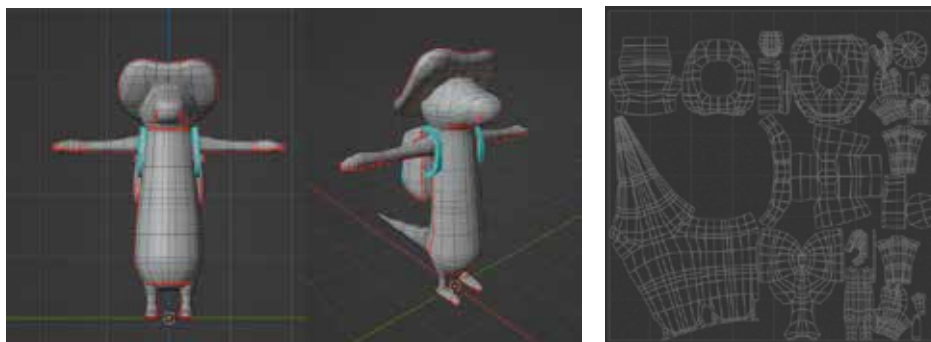


Figure 10. Process of Modeling and UV Mapping for One of the Game Characters.

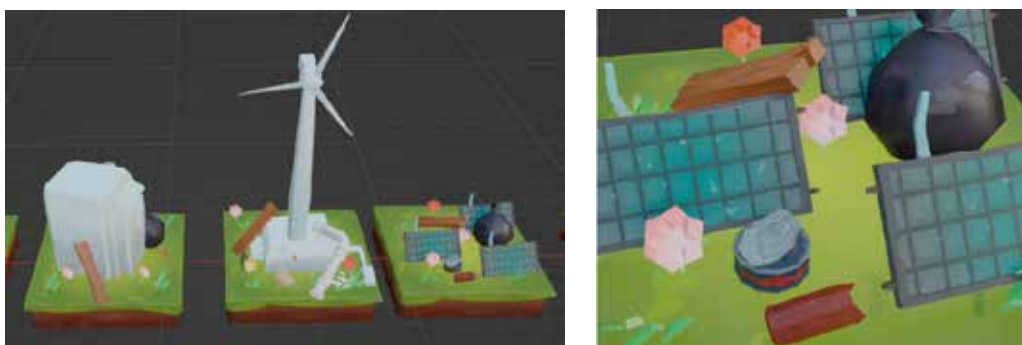


Figure 11. Texturing and painting of 3D models.

In the games developed, the character is controlled by the player from a first-person perspective. Most of these games were designed and programmed so that the player's actions

have an impact on the state of the world, emphasizing the importance of individual behavior in promoting a more sustainable society and world. For example, actions might include purifying polluted water, collecting waste and disposing of it in appropriate containers, and developing proper water canalization and distribution systems. Figure 12 shows a concept of the game mechanics where the scenario is reconstructed based on the player's actions.

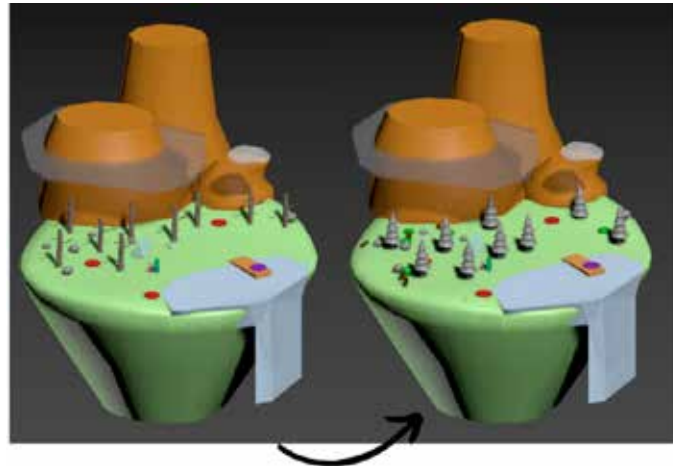


Figure 12. Conceptualization of game mechanics in which the environment is rebuilt through the actions performed by the player.

The assembly and programming of the serious game utilized the 2D and 3D video game and simulation development engine, Unity, which is one of the most popular development tools in the digital entertainment industry. Unity is a platform for creating real-time 3D (RT3D) content, games, and interactive experiences, which can be published across a wide range of devices, including mobile, PC, and consoles. The programming language used in this engine is C#.

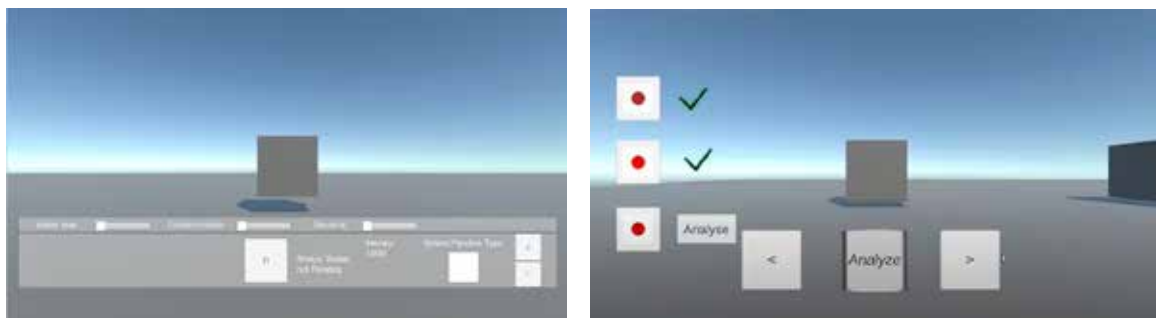


Figure 13. Programming and testing of the interface of the different games.

During the production phase, while the 3D models are being generated, textured, and animated, the programmers are concurrently programming and testing the game mechanics, interface, HUD, VFX effects, etc. Figure 13 shows a testing scenario of the programmed mechanics before the art is assembled. Once all the art is prepared and finalized, everything is assembled to create what will become the final game. The final look of one of the video games is shown in Figure 14.

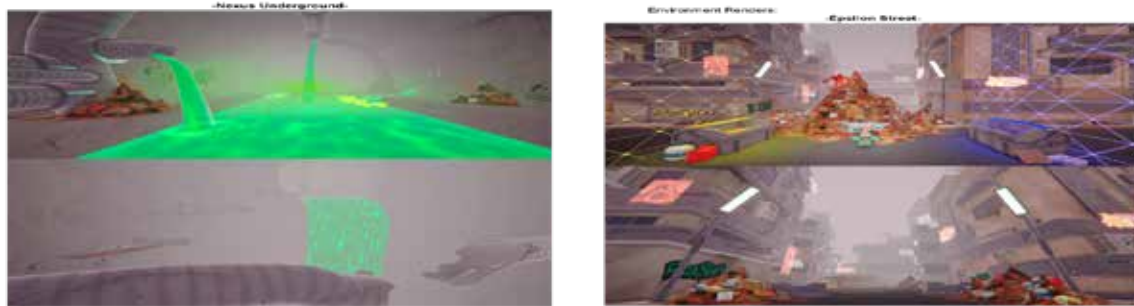


Figure 14. Final look of the serious games created by the students.

2.3. Post-production

Once the production of each project is completed, to ensure that the various serious games developed meet the initially set objectives, the usability, feasibility, and effectiveness of the game are tested. This involves testing and analyzing the user experience (UX) by having players complete a questionnaire after they have tried the game. For this evaluation phase of serious games, we use “the Game Experience Questionnaire” developed by Ijsselsteinjn et al. (2013) as a basis.

This UX analysis and the feedback received indicate to developers whether they need to revisit the design phase and reassess aspects such as objectives, mechanics, playability, and usability, in essence, the overall user experience generated. The evaluation component is crucial in determining the effectiveness of a serious video game (Bul et al., 2015; Khaleghi et al., 2021).

3. Results and discussion

At the end of the semester, when all serious games have been completed, we grade the final project on a scale of 0 to 10. This grade is based on the final serious game, the GDD, the project work process, and a User Experience (UX) analysis of the student’s own game and other students’ games. The final grade is weighted as follows:

- Final Project (50%).
- GDD (20%).
- Work Process (15%).
- UX Analysis (15%).

The UX Analysis is evaluated through a satisfaction survey with several questions. The answers to the questionnaire were organized according to the Likert scale. This is a measurement method used in research to assess a person’s opinions, attitudes, and perceptions about a specific topic. It allows respondents to express their degree of agreement or disagreement on a scale that typically ranges from 1 to 5, with 1 being the least and 5 being the most. The survey was conducted to verify the validity of the serious games that were developed.

Questions 1 to 8 are scored from 1 to 5, and questions 9 to 11 are yes/no questions. Questions from 1 to 4 assessed the level of flow (Csikszentmihalyi, 1975) and the degree of engagement achieved through the serious game, attributable to the level of challenge presented. Figure 15 shows the results of question 1: *Did you feel challenged during the game?*

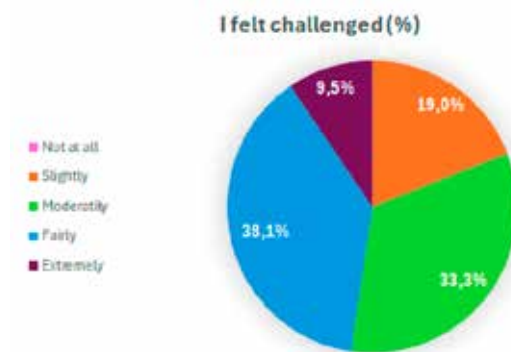


Figure 15. Results for question 1 *Did you feel challenged during the game?*

71.4% of players felt challenged to a degree ranging from ‘fairly’ to ‘extremely’ during the game. This indicates that most of the players experienced a significant level of immersion and interest while playing.

The subsequent questions aimed to analyze the level of motivation that the serious game had instilled in the players, considering how competent and validated it made them feel, and how much they enjoyed the game’s storyline. Figure 16 shows the result of question 2: *Did you feel competent during the game?* The results indicate that 76.2% of the players (from ‘fairly’ to ‘extremely’) felt competent and validated while playing the serious game.

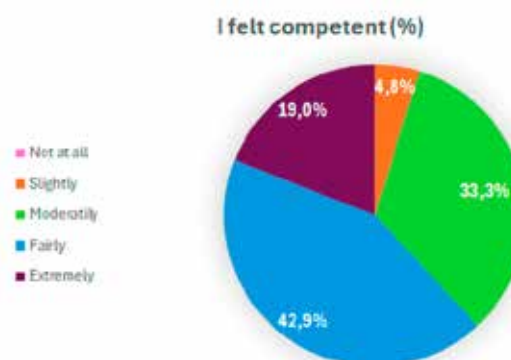


Figure 16. Results for question 2 *Did you feel competent during the game?*

Figure 17 shows the result of question 3: *Did you find the story of the game interesting?* It is important to note that 66.7% of players found the game’s storyline interesting. This factor, along with the feeling of competence, promotes player motivation, which is to say, it fosters an interest in continuing to play and enhances engagement.

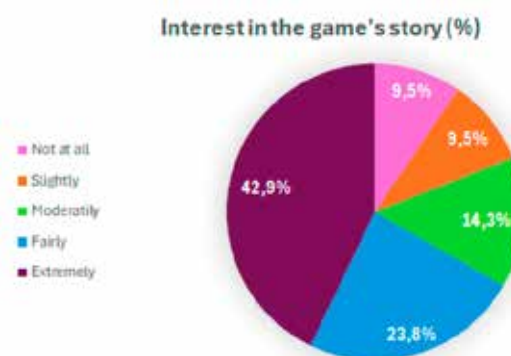


Figure 17. Results for question 3 *Did you find the story of the game interesting?*

The final questions pertained to the objective of the serious game that was developed, which was to raise awareness about sustainability. Firstly, they focused on empathizing with the events in the game, and secondly, they aimed to communicate to the user that all our actions (such as maintaining sustainable habits) have an impact on others and our environment. The results indicate that although a larger percentage of players did connect with and empathize with the game's content, greater awareness could have been achieved in conveying the impact of our actions and those of others.

Figure 18. shows the result of question 4: *Did you empathize with others during the game?*

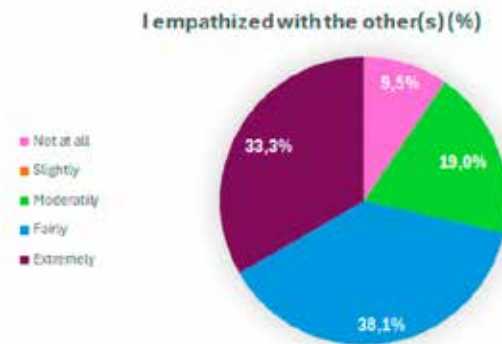


Figure 18. Results for question 4 *Did you empathize with others during the game?*

Finally, Figure 19 shows the result of question 8: *Did you think that your actions can have an impact on the actions of others?*

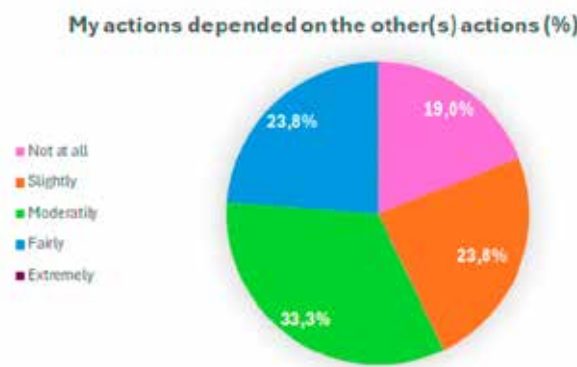


Figure 19. Results for question 8 *Did you think that your actions can have an impact on the actions of others?*

Questions 9 to 11, were answered with yes or no. We asked the following questions:

- Do you think that your serious game has had a positive impact on your learning as a game developer/designer?
- Do you think that your serious game has had a positive impact on your learning about sustainable development?
- Do you think that your serious game will have a positive impact on its users' learning about sustainable development?

More than 80% of the students answered each question very positively (score 5).

Looking towards future work, it will be necessary to analyze the areas of improvement identified from the evaluation and feedback received, mainly improving the game mechanics to help users understand how their decisions and actions impact sustainable development. Pertinent adjustments will need to be made in the serious games developed so that they can more effectively educate users about sustainability. Considering all the above-mentioned points

and the adjustments that need to be made in the serious games developed, we can conclude that serious games are a promising platform for promoting education in sustainable development. They raise awareness about sustainable values and habits among users in an engaging and playful manner.

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EXPLORING QUALITY OF LIFE ACROSS COUNTRIES USING VARIOUS MACHINE LEARNING CLUSTERING METHODS

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Abstract. Many financial decisions are influenced by the subjective measure of happiness known as quality of life. It is an individual's perception of how well they are living their life, considering various factors: financial status, health, social relationships, and many others. It is also possible to observe the quality of life indicators for a particular country and determine which factors have the greatest impact on the general feeling of satisfaction. The basic concepts of artificial intelligence and machine learning are explained through the application of machine learning clustering methods on a database containing some crucial parameters determining the quality of life. The study systematically evaluates the performance of two clustering techniques, namely K-Means and Hierarchical Clustering (HDBSCAN). The results of clustering analysis are significant in understanding how countries are grouped based on common characteristics. By examining the clustering outcomes, we can gain a better understanding of the patterns and similarities among nations, which can help us understand the factors that contribute to their grouping. In conclusion of our study, the results clearly indicate the importance of carefully selecting the machine learning method depending on the characteristics and complexity of the data. The differences in the results obtained using the K-Means and HDBSCAN algorithms confirm that the correct choice of the algorithm can significantly affect the interpretation and usefulness of the final analytical results.

Key words: *Quality of Life, Machine Learning, Clustering*

1. Introduction

The purpose of this paper is not only to identify the similarities among countries by comparing the parameters that define the Quality of Life but also to demonstrate the feasibility of using artificial intelligence for this purpose. Moreover, it aims to emphasize the significance of mathematics, which forms the foundation of the clustering algorithms used in this study.

According to the World Health Organization [1], Quality of Life (QoL) is "an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards, and concerns." Understanding the factors that contribute to QoL in different countries has become increasingly important in today's world. As QoL includes various aspects of welfare, including health, social, economic,

and environmental-related factors, it can be used as a comprehensive measure of the overall satisfaction of individuals within some society. For example, the Expert Group on QoL indicators, organized by the European Commission, recommends the organization of a set of QoL indicators for the EU based on 8+1 dimensions, like it is shown in **Figure 1**. Taking into account all of the above, categorizing countries based on their QoL index gives valuable insights that are important for understanding the differences between countries in terms of how well their populations live.



Figure 1 Base QoL indicators defined by Expert Group organized by the European Commission [2].

Artificial intelligence (AI) has astonished many people with its capabilities upon their first encounter with one of its applications. Technology has come a long way since its early days and is now integrated into various aspects of daily life. While most people are familiar with popular AI applications like Chat GPT and Gemini, AI is used extensively in many areas, including healthcare, finance, transportation, and many others. Although AI is often thought of as a special kind of system, it is a combination of technologies capable of solving a wide range of complex problems. In many of these technologies, mathematical algorithms form the basis that enables further development.

The development of AI has significantly improved research on QoL, enabling a deeper analysis of huge amounts of data from different sources. Through the use of AI algorithms, particularly ML-based clustering methods, it has been possible to identify critical factors that affect QoL, detect hidden patterns, and make more precise forecasts. This has provided valuable insights into various aspects of socio-economic dynamics and has enabled better-informed decisions in politics and development planning.

2. Related work

In 2005., in the paper [3], the authors conducted a thorough analysis of the factors that contribute to the QoL. They explain how the well-being indicators that can be measured are combined and assigned weights to produce composite measures of QoL.

A clustering analysis is applied in various studies dealing with QoL. The author uses it in [4] to identify regions in Latvia with the largest need for stimulating their development. In [5], the authors analyze factors that determine the QoL of the City Councils of Chile. They applied cluster analysis by using different clustering algorithms, and, in all cases, the results were similar for all tested approaches. The study presented in [6] compares the effectiveness of

average linkage and K-Means clustering methods in grouping Indonesia's provinces based on welfare indicators such as education, health, and income. After measuring the performances of both methods using the variance ratio, it was found that the average linkage method achieves better results. Hierarchical clustering methods were applied using the statistical program SPSS described in [7]. The goal of the study was to identify rural localities with the highest priority for the rural development measures to be used to stimulate rural socio-economic growth. In [8], the authors use the Decision Tree approach to deal with the future direction of development. A statistical hierarchical cluster analysis method is applied in [9] to identify groups of European countries using the QoL indicators and to recognize differences in quality of life levels. The clustering results show that there are three different groups of European countries: old European Union member states, new European Union members, and non-European Union member states. According to the analysis, the member states that joined the European Union early on have a higher quality of life compared to other countries.

3. Methodology

The development of AI began in the mid-20th century. The term Artificial Intelligence was introduced by John McCarthy, an American computer scientist, during the Dartmouth Conference 1956. This event is now widely regarded as the birth of AI as a field of study. [10], [11]. The development of theoretical approaches was accelerated at the end of the last century, but it encountered obstacles due to limitations in computing power. Since the year 2000, there have been significant advancements in computational capabilities, algorithmic innovations, and the development of sensors that generate massive amounts of data. As a result, various fields of AI, such as machine learning (ML), deep learning, computer vision, and robotics, have experienced accelerated growth.

Although the term ML is often used interchangeably with AI, those technologies differ in several ways. ML is a subset of AI that makes decisions by analyzing large amounts of data without explicit programming. ML algorithms could be divided into three categories: supervised, unsupervised, and reinforcement learning, as shown in **Figure 2**.

The main difference between supervised and unsupervised learning is the presence of labels. In the case of supervised learning, the algorithm learns from a labeled dataset, while in unsupervised learning, no explicit output labels are provided. Additionally, when a dataset contains both labeled and unlabeled data, we could talk about semi-supervised learning. The most common supervised tasks are regression and classification, while unsupervised tasks include clustering, visualization, and dimensionality reduction. The paper addresses unsupervised learning through clustering, which involves identifying patterns or groups of similar objects.

As clustering belongs to unsupervised learning, it is clear that it deals with (grouping of) unlabeled samples. There are four different principles on which clustering algorithms are based:

- Density-based: areas of high-density data points are grouped together, surrounded by areas of low-density data points.
- Distribution-based: all data points are assigned to a cluster based on their probability of belonging to that cluster.
- Centroid-based: algorithms use multiple centroids to cluster data points based on their Euclidean distance from each centroid. This is the most widely used clustering method.
- Hierarchical-based: It is usually applied to hierarchical data and creates a hierarchical representation of the clusters in a dataset.

The tests are conducted using two clustering methods: K-Means clustering and HDBSCAN.

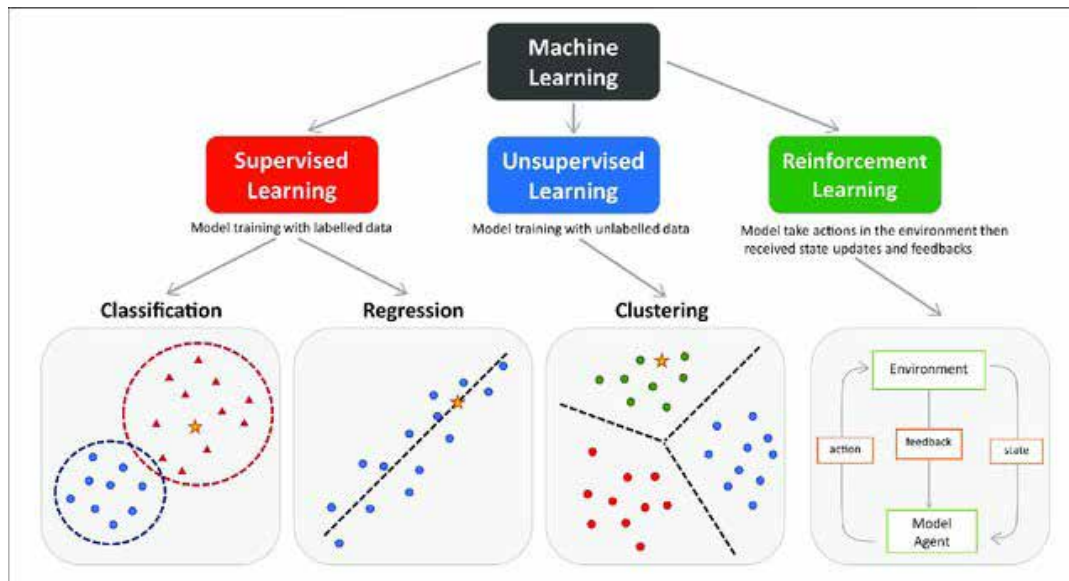


Figure 2

Figure 2 Visualization of the three main types of machine learning: supervised learning, unsupervised learning, and reinforcement learning. In supervised learning, the model is trained using labeled data for classification or regression tasks. In unsupervised learning, the model identifies patterns and structures in unlabeled data through clustering. Reinforcement learning improves the model's performance by taking action and learning from the feedback received from the environment [12].

3.1. K-Means clustering

K-Means is the most commonly used centroid-based algorithm. Some key math concepts involved in algorithms include the cluster centroid, calculated as the arithmetic mean of all the points belonging to the cluster, and an objective function that minimizes the sum of the squared Euclidean distances between each point and the centroid of its cluster.

The k-means algorithm starts by initializing the centroids randomly. This is followed by a two-step process:

- **Assignment:** Each data point is assigned to the nearest centroid, based on the minimum distance criterion, resulting in the creation of k clusters.
- **Update:** The centroids of the calculated clusters are updated by taking the mean of the data points assigned to it in the previous step.

This process repeats until the centroids no longer change significantly between iterations or until a specified number of iterations is reached.

3.2. HDBSCAN

HDBSCAN (Hierarchical Density-Based Spatial Clustering of Applications with Noise) is a sophisticated clustering algorithm that builds upon DBSCAN by transforming it into a hierarchical clustering algorithm. HDBSCAN offers various benefits, such as improved stability across different parameter selections and better management of clusters with varying densities [13]. Two parameters needed to initialize the algorithm are:

- **min_cluster_size:** It controls the minimum size of density clusters that will be formed.
- **min_samples:** It is used to determine the core points in the dataset. Higher values lead to more points being declared as noise.

The mathematical foundation of HDBSCAN is very complex, incorporating concepts from graph theory, particularly in its use of a Minimum Spanning Tree (it is a weighted graph obtained as a subset of the edges that connects all the vertices together, without any cycles, and with the minimum possible total edge weight).

4. Dataset

ML applications, such as clustering algorithms, rely on the use of datasets as their fundamental input. The dataset used in the paper is available in [14]. It contains city names, belonging country and continent, and associated features typically used to calculate the QoL index. These are Housing, Cost of Living, Startups, Venture Capital, Travel Connectivity, Commute, Business Freedom, Safety, Healthcare, Education, Environmental Quality, Economy, Taxation, Internet Access, Leisure & Culture, Tolerance, and Outdoors. Each row in the table represents a unique city, with columns representing defined attribute values calculated for the city. The database contains 266 rows with 21 columns. The list does not include all countries in the world, but it does contain some states from the USA. This makes it suboptimal from an economic perspective. However, since the purpose of the paper is not to conduct an economic analysis of clustering but rather to highlight the potential of AI, this issue should not pose a problem. In order to group countries according to the QoL index, we started by grouping the data (cities) based on their belonging to a country. Next, we calculated the mean values of each individual column for the cities within each country. These mean values represent the column value for the respective country. After the changes, the database contains data describing the 20 factors needed to describe the quality of life for 135 countries. To show the range and diversity of data encompassed within our analysis, we have chosen to visualize the distribution of one variable (cost of living), as displayed in **Figure 3**, while **Figure 4** explores the correlation between two variables (Housing and Cost of Living).

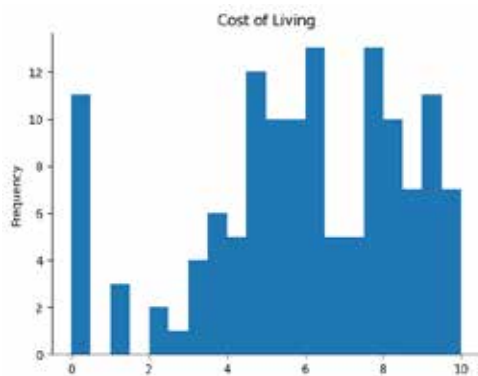


Figure 3 Histogram representing Cost of Living values.

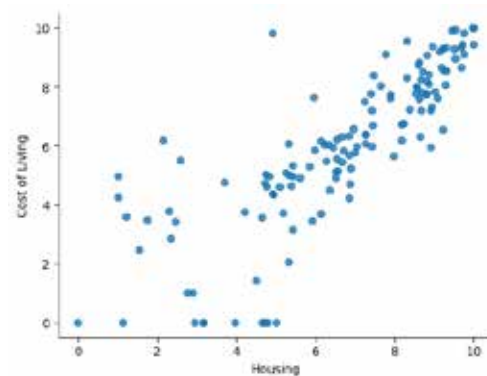


Figure 4 Correlation between Housing and Cost of Living.

Our goal with correlation analysis is to uncover patterns and dependencies between variables, enriching our understanding of quality of life's multidimensional nature. While our dataset comprises a comprehensive set of 20 variables capturing various dimensions of quality of life, we have selected these examples to provide a brief look into the richness and complexity of the data.

5. Results

The experiment is conducted using Scikit-Learn, a Python library [14] that offers a range of clustering methods. Another Python library, available in [15], is used for HDBSCAN. The following section presents their results.

5.1. K-Means clustering

Here, we present the outcomes of applying K-Means clustering to a dataset with a changing number of clusters from 2 to 6. By systematically varying the number of clusters and evaluating the resulting clustering solutions by applying different evaluation metrics, including silhouette score, Calinski-Harabasz score, and Davies-Bouldin score (more in [15]), it is possible to determine the optimal number of clusters that best capture the underlying structure of the data pertaining to quality of life indicators. According to the results shown in **Figure 5**, the silhouette score is the highest for the number of clusters 3, indicating the optimal solution.

```
For n_clusters = {'n_clusters': 2} the average silhouette_score is : 0.26
                                calinski_harabasz_score is : 53.09
                                davies_bouldin_score is : 1.50
For n_clusters = {'n_clusters': 3} the average silhouette_score is : 0.27
                                calinski_harabasz_score is : 41.61
                                davies_bouldin_score is : 1.29
For n_clusters = {'n_clusters': 4} the average silhouette_score is : 0.23
                                calinski_harabasz_score is : 36.09
                                davies_bouldin_score is : 1.48
For n_clusters = {'n_clusters': 5} the average silhouette_score is : 0.20
                                calinski_harabasz_score is : 31.93
                                davies_bouldin_score is : 1.46
```

Figure 5 The values of different coefficients used to evaluate the quality of clustering for a particular number of clusters.

The score (0.27) is slightly higher than the one achieved if the number of clusters is 2 (0.26). However, the Calinski-Harabasz score for a number of clusters 2 (53.09) overperforms the one achieved for 3 clusters (41.61). To conclude, the lower Davies-Bouldin scores indicate better clustering, which confirms 3 as the selected optimal number of clusters, with a value of 1.29, compared with 1.50 for the case of 2 clusters.

The final results of clustering countries are presented in **Figure 6**. According to the results, Cluster 0 predominantly includes the most economically developed countries, such as old European Union member states, and USA countries, including China and Czechia. Cluster 1 features a mix of new European Union members. Finally, Cluster 2, though smaller, includes countries like Bolivia and Nicaragua that may be experiencing less stable conditions. This instability can stem from a variety of factors, such as economic challenges, political transitions, or social unrest. There could also be incorrect input data that would explain some unexpected grouping results, like in the case of Montana.

	Cluster 1	Cluster 2	Cluster 3
0	Alabama	Argentina	Belize
1	Alaska	Armenia	Bolivia
2	Arizona	Azerbaijan	Gibraltar
3	Australia	Belarus	Maine
4	Austria	Bosnia and Herzegovina	Malta
5	Belgium	Brazil	Montana
6	California	Bulgaria	Nicaragua
7	Canada	Cambodia	Panama
8	China	Chile	Uzbekistan
9	Colorado	Colombia	Andorra
10	Czechia	Costa Rica	
11	Denmark	Croatia	
12	District of Columbia	Cuba	

Figure 6 The results of K-Means clustering for 3 clusters, just 12 countries are presented.

5.2. HDBSCAN

In HDBSCAN it is not possible to directly set the number of clusters as in k-means. HDBSCAN operates differently, and instead of specifying the number of clusters, the algorithm identifies clusters based on the densities of the data points. To regulate cluster formation, it is necessary to adjust the parameters that influence how the algorithm interprets density and the level of robustness required for a cluster to be considered a separate entity.

Running HDBSCAN with default settings reveals 2 clusters, including a high number of outliers. Therefore, additional tests are done by using different distance metrics for clustering. All the distance metrics supported by HDBSCAN are applied, and (some of) results showing the number of clusters and the number of noise points for each metric are presented in **Figure 7**. We can see that all metrics except matching detect high numbers of outliers. In most of the cases, a determined number of clusters is 2, rarely 3.

```
Metric: euclidean, Clusters: 2, Noise points: 106
Metric: l2, Clusters: 2, Noise points: 106
Metric: p, Clusters: 2, Noise points: 106
Metric: manhattan, Clusters: 3, Noise points: 101
Metric: cityblock, Clusters: 3, Noise points: 101
Metric: l1, Clusters: 3, Noise points: 101
Metric: chebyshev, Clusters: 2, Noise points: 109
Metric: infinity, Clusters: 2, Noise points: 109
Metric: hamming, Clusters: 2, Noise points: 81
Metric: canberra, Clusters: 2, Noise points: 48
Metric: braycurtis, Clusters: 2, Noise points: 51
Metric: matching, Clusters: 2, Noise points: 1
```

Figure 7 Results of HDBSCAN for different distance metrics using default settings.

```
Metric: euclidean, Clusters: 3, Noise points: 55
Metric: l2, Clusters: 3, Noise points: 55
Metric: p, Clusters: 3, Noise points: 55
Metric: manhattan, Clusters: 2, Noise points: 14
Metric: cityblock, Clusters: 2, Noise points: 14
Metric: l1, Clusters: 2, Noise points: 14
Metric: chebyshev, Clusters: 3, Noise points: 22
Metric: infinity, Clusters: 3, Noise points: 22
Metric: hamming, Clusters: 3, Noise points: 55
Metric: canberra, Clusters: 8, Noise points: 51
Metric: braycurtis, Clusters: 6, Noise points: 46
Metric: matching, Clusters: 2, Noise points: 1
Metric: jaccard, Clusters: 0, Noise points: 135
Metric: dice, Clusters: 0, Noise points: 135
Metric: rogerstanimoto, Clusters: 0, Noise points: 135
Metric: russellrao, Clusters: 0, Noise points: 135
Metric: sokalmichener, Clusters: 0, Noise points: 135
Metric: sokalsneath, Clusters: 0, Noise points: 135
```

Figure 8 Results of HDBSCAN for different distance metrics using min_cluster_size=2, min_samples=2.

As **Figure 8** shows, changing some of the crucial HDBSCAN parameter values (min_cluster_size=2, min_samples=2) significantly improves the clustering results.

5.3. Comparison

We compared the results obtained using K-Means and HDBSCAN with Euclidean metrics. Both algorithms divide the dataset into 3 clusters and use the same metric. The (partial) results for HDBSCAN clustering shown in **Figure 9** indicate significant differences from those achieved using K-means (**Figure 6**).

	Cluster 1	Cluster 2	Cluster 3	outliers
0	Kenya	Azerbaijan	Alabama	Armenia
1	Nigeria	Bosnia and Herzegovina	Alaska	Belgium
2	South Africa	Cambodia	Argentina	Belize
3	Tanzania	Ecuador	Arizona	Bolivia
4		Paraguay	Australia	Chile
5			Austria	China
6			Belarus	Colombia

Figure 9 The results of HDBSCAN, just the first 7 countries (alphabetically) are presented.

The differences in the results obtained from the K-Means and HDBSCAN algorithms highlight their distinct approaches to clustering. K-Means is effective for datasets with clusters that are roughly spherical and similar in size and density. On the other hand, HDBSCAN, a density-based clustering algorithm, identifies clusters based on varying density areas within the data. HDBSCAN identified many outliers, indicating that the dataset likely contains significant noise or regions of sparse data, which HDBSCAN interprets as not belonging to any significant cluster.

6. Summary

In this study, we explored the clustering of countries based on QoL factors using two different ML algorithms: K-Means and HDBSCAN. Our analysis revealed that while K-Means provided predictable and clear segmentations of countries, suggesting a straightforward categorization based on the provided indicators, HDBSCAN offered significantly different results. These findings emphasize the critical importance of choosing appropriate machine learning methods according to the specific nature and complexity of the data. The study shows how machine learning techniques can greatly improve socio-economic analysis and policy-making by providing valuable insights into the disparities in quality of life across different countries. This research promotes the wider use of machine learning in various fields, demonstrating its usefulness in complex decision-making scenarios. It also emphasizes the need for careful application and interpretation of these advanced analytical tools.

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BEYOND ANXIETY: EXPLORING FOREIGN LANGUAGE ENJOYMENT AS A PREDICTOR OF COMMUNICATION

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Abstract. The field of Second Language Acquisition (SLA) has long recognized the influence of individual learner differences. Recently, the development of Positive Psychology (PP) has sparked a surge of interest in the role of positive emotions within SLA research. While foreign language classroom anxiety (FLCA) has been extensively studied as a negative factor, the impact of positive emotions like foreign language enjoyment (FLE) deserves further investigation. Therefore, a more holistic approach, examining both positive and negative emotions within the same study, should be adopted. The current study addresses this gap by examining the interplay between FLE, FLCA, and willingness to communicate (WTC) in 270 students from various study programmes (Business, Electrical Engineering, Medicine and English majors) at the University of Split, Croatia. Data were collected through a self-administered, multi-part questionnaire featuring items measured on a standard 5-point Likert scale. This study employed a range of statistical techniques, including descriptive statistics to summarize the data, factor analysis with Varimax rotation to explore underlying factors of FLE, correlation analysis to assess relationships between FLE, FLCA and WTC, one-way analysis of variance (ANOVA) with post-hoc tests to compare means among students from different study programmes and hierarchical regression analysis to identify significant predictors of WTC. The results showed that students who experienced higher enjoyment levels were more willing to communicate and felt less anxious in the classroom. Conversely, higher FLCA levels were found to significantly hinder students' WTC. Our analysis further revealed statistically significant differences in FLE and FLCA levels among students enrolled in different study programmes. However, WTC levels did not differ significantly across these programmes. Finally, the hierarchical regression analysis confirmed that FLCA and Intrinsic Motivation and Personal Growth, as one of the three underlying dimensions of FLE, emerged as the most significant unique predictors. This intriguing finding underscores the value of factor analysis in revealing the multifaceted nature of enjoyment as an emotion and its lower-order dimensions.

This study contributes to a deeper understanding of how both positive and negative emotions influence the language learning process. By unravelling the relative influence of anxiety and enjoyment, this study may inform the development of pedagogical strategies that promote positive emotions and enhance willingness to communicate in the foreign language classroom.

Key words: *second language acquisition, positive psychology, foreign language classroom anxiety, foreign language enjoyment, willingness to communicate*

1. Introduction

There has been a major shift in education, with a focus moving from teachers to students. The 1980s marked a significant transition in foreign language learning, with a growing

emphasis on the learner's role in the process. This shift moved the focus from teacher-centered methodologies to a more learner-centered approach (Oxford, 1990) and was reflected in the transition from structural approach to communicative approach prioritizing the use of language in real-world communication (Nunan, 1990).

As English as a Foreign Language (EFL) embraces this student-centered approach (Emaliana, 2017), researchers are increasingly interested in how EFL students learn and what factors affect their success (e.g. Derakhshan et al., 2021; Mese & Sevilen, 2021). The field of language learning has shifted its focus to include students' emotions and how they impact learning (Dörnyei, 2010). This began with Arnold's (1999) call for attention to emotions in the classroom. Since then, many studies have explored this concept (e.g. Gregersen et al., 2014; Dewaele, 2019). Research now recognizes that positive emotions, not just negative ones, play a crucial role in various aspects of life, including learning a new language (Wang et al., 2021). Positive psychology, a field studying human flourishing (Seligman & Csikszentmihalyi, 2000), has highlighted the importance of positive emotions in language learning (Wang et al., 2021). As MacIntyre and Gregersen (2012) suggest, positive emotions can actually contribute to students' progress. In line with that, it is also important to note that there is a surge of interest in the influence of emotions on foreign language learning (e.g. Dewaele, 2019; Dewaele & Li, 2018; MacIntyre et al., 2019). Traditionally, researchers and educators emphasized combating negative emotions in learners. However, a new perspective suggests that eliminating negativity does not necessarily lead to positive emotions. In fact, any emotional response, even negative, might be preferable to disinterest or boredom in language acquisition. Effective foreign language teachers, as noted by Dewaele (2015), can stimulate learners' emotions to an optimal level and utilize that energy to encourage them to speak in the foreign language. A balanced combination of emotions can enhance learners' willingness to communicate (WTC) in the foreign language (Dewaele & Dewaele, 2018).

The theory of constructed emotions aligns with the earlier concept of emotions developing as dynamic systems in children (Fogel et al., 1992). They viewed emotions as "self-organizing systems" influenced by various components related to the individual's social and physical environment (Fogel et al., 1992:129). Importantly, no single element dictates the outcome. The authors suggest that enjoyment can arise from diverse starting points and interactions between these components, ultimately leading to a stable positive emotion (Fogel et al., 1992:129). This is in line with Horwitz et al.'s (1986) perspective on Foreign Language Classroom Anxiety (FLCA) which usually develops gradually. MacIntyre (2017) highlights the growing prominence of the dynamic systems approach in anxiety research, emphasizing the ongoing interaction between anxiety and various learner, situational, and other factors, such as language skills, physiological responses, self-appraisals, communication styles, interpersonal relationships, specific topics, and the learning environment itself (MacIntyre, 2017:23). These studies suggest that language learners experience a complex spectrum of positive and negative emotions, with varying intensities (Fogel et al., 1992; Horwitz, 2017).

Building upon the existing research, this study attempted to get insight into the complex interaction among FLE, FLCA and WTC and to explore the possible predictability of WTC by positive (FLE) and negative (FLCA) emotions. To this end the following hypotheses were tested: H1: A negative correlation is expected between FLCA and WTC, while a positive correlation is anticipated between FLE and WTC. H2: No significant differences in FLCA, WTC and FLE levels are expected among students from different academic programmes. H3: FLCA is hypothesized to be a better predictor of WTC compared to FLE.

2. Literature review

2.1. FLE and FLCA

Dewaele and MacIntyre (2014) introduced the concept of FLE into SLA research to explore its connection with FLCA. They distinguished FLE, a complex emotion involving challenge and perceived ability, from the more simple pleasure of something enjoyable. They developed a new FLE scale to measure both personal and social aspects of enjoyment in language learning. Additionally, they included an FLCA scale focusing on physical symptoms of anxiety. Their groundbreaking study, involving over 1,700 learners with diverse language backgrounds, was the first to explore positive and negative emotions together. It was found out that there was a moderate negative correlation between FLE and FLCA. In other words, they function independently, i.e. high FLE does not necessarily mean low FLCA, and vice versa. The research linked higher FLE and lower FLCA to factors like multilingualism, confidence in the foreign language, proficiency, older age, and being Western. Interestingly, females reported experiencing both higher FLE and FLCA compared to males, although the difference was minor. Learner descriptions of enjoyable experiences in the FL classroom emphasized the social aspects such as positive relationships with peers and teachers built through humour, praise, and a sense of mutual respect. Activities that provided learners with some autonomy were also frequently mentioned. Another study by Dewaele and Alfawzan (2018) supported these findings, demonstrating that FLE has a positive impact on learning, while FLCA hinders it.

According to the above mentioned studies, it is very important to include positive emotions, such as FLE in the study of classroom emotions. FLCA is defined as “a distinct complex of self-perceptions, beliefs, feelings and behaviours related to classroom learning arising from the uniqueness of the language learning process” (Horwitz et al., 1986:128). In contrast, FLE goes beyond mere pleasure. It is a deeper emotion that involves intellectual engagement, focused attention, and a sense of optimal challenge. Boudreau et al. (2018) expand on this concept, suggesting that FLE is not just about enjoying an activity, but finding the learning process itself to be intellectually stimulating and captivating. To further explore the link between emotions and language learning, Dewaele and MacIntyre (2019) conducted a follow-up study that incorporated participants’ personality traits, teacher-related variables, and qualitative data on both enjoyable and anxiety-provoking experiences in the FL classroom. The study involved over 750 FL learners from various countries who completed an online questionnaire. Similar to their earlier work, the focus remained on learner-internal factors influencing FLE and FLCA. However, this study also examined learner-external variables. The research revealed that teacher-related factors, along with cultural empathy, were the strongest predictors of FLE. In contrast to that, neuroticism emerged as the most significant predictor of FLCA, with teacher influence having no effect. These results support previous research (e.g. Dewaele et al., 2018; Dewaele et al., 2019) suggesting that sources of FLE are primarily linked to the teacher, while sources of FLCA are more self-driven.

2.2. WTC

The concept of WTC is observed in the context of learning a second language (L2). WTC is described as the crucial step just before someone actively uses the language to communicate (Peng, 2015). Specifically in L2 learning, it refers to the learner’s readiness to engage in conversation using the new language (MacIntyre et al., 1998). Research suggests that successful communication in a second language heavily relies on a learner’s WTC (Zarrinabadi, 2021). Many factors, both direct and indirect, influence a person’s WTC in an L2 (Zarrinabadi, 2021).

L2 communication is a complex process influenced by various aspects beyond just language skills. These include cultural, political, social, motivational, emotional, and pedagogical factors. Since its introduction by MacIntyre and Charos (1996), WTC has been a popular research topic, particularly in Western contexts, but also in other regions, including Japan, China, Iran and Turkey.

3. Method

3.1. Participants and demographics

This study involved a sample of 254 full-time university students (43% female and 57% male students) from the University of Split, Croatia. Their ages ranged from 19 to 28 years ($M = 21.72$; $SD = 2.003$). The student body comprised business (29%) and electrical engineering (47%) students from the University Department of Professional Studies, English language and literature students (11%) from the Faculty of Humanities and Social Sciences and medical students (13%) from the School of Medicine. All participants were native Croatian speakers. A significant majority (77%) reported using English in everyday situations, primarily for entertainment, communication, or business purposes. Finally, on a 5-point scale, participants reported their self-perceived English proficiency as above average ($M = 3.87$; $SD = 0.88$).

3.2. Instrument

The first section gathered demographic information, including age, gender, study programme, use of English in everyday situations, and State Matura Exam results in English (high or low level). Following the demographic data collection, the study employed a self-administered, multi-part questionnaire to assess the key constructs of the study: Foreign Language Enjoyment (FLE), Foreign Language Classroom Anxiety (FLCA), and Willingness to Communicate (WTC). Participants responded to the questionnaire items using a standard 5-point Likert scale. The response options ranged from “absolutely disagree” (1) to “strongly agree” (5).

3.2.1. Foreign Language Enjoyment (FLE)

To assess students’ enjoyment in an English language classroom, a 21-item FLE scale developed by Dewaele and MacIntyre (2014) was utilized. The scale explored student perceptions of factors fostering their enjoyment (teacher positive characteristics and enjoyable classroom atmosphere, a sense of self-accomplishment, dynamic peer interaction, etc.). All FLE-related items were worded positively to reflect desired classroom enjoyment.

3.2.2. Foreign Language Classroom Anxiety (FLCA)

The second scale with eight established FLCA items was employed to assess general foreign language anxiety (Appendix). These eight items, reflecting nervousness, lack of confidence, anxiety, confusion, etc. were extracted by Dewaele and MacIntyre (2014) from the original FLCA scale (Horwitz et al., 1986). Consistent with the original FLCAS, two items were worded to indicate low anxiety, and six items were worded to reflect high anxiety. For the low-anxiety items, responses were reverse-coded during analysis, ensuring that higher scores reflected greater anxiety.

3.2.3. Willingness to Communicate (WTC)

A 10-item version (adapted from the original 12-item instrument), 5-point Likert-scale instrument developed by Mihaljević Djigunović and Letica (2009) was used in this study. This instrument focuses on the construct of WTC in English, emphasizing the desire and motivation to actively use English for communication despite potential discomfort or errors.

3.3. Procedure

The self-administered, multi-part questionnaire used to determine levels of FLE, FLCA and WTC in English classrooms was administered during regular class time at the beginning of the academic year 2023/2024. To ensure anonymity and encourage honest responses, students completed the questionnaire independently, taking approximately 15-20 minutes. Students received a detailed explanation of the study's purpose, methodology, and anticipated outcomes. It enabled participants to make an informed decision about joining the study. Additionally, they were provided with instructions on how to complete the questionnaire efficiently. Participation in the research was entirely voluntary.

3.4. Data Analysis

As a first step in the analysis of the data, the reliability of the instrument was calculated. In this study, the internal consistency of the 21 FLE items had an alpha reliability coefficient of 0.82 ($\alpha=0.82$), whereas the reliability of the 8 FLCAS items was 0.86 ($\alpha=0.86$). As for the WTC scale, after examining item-total correlations, two items focusing on general comfort with speaking English in a social setting were removed to enhance the scale's internal consistency. The modified 10-item WTC scale demonstrated a Cronbach's alpha of 0.74, indicating acceptable reliability.

Descriptive and inferential statistics were then used to analyze the data. First, the means and standard deviations of the questionnaire were computed. Second, factor analysis was conducted to explore the underlying structure of the FLE scale. Understanding these factors makes it possible to gain a deeper understanding of the various aspects that influence FL learning enjoyment. Third, Pearson product-moment correlations were used to investigate the relationships among variables of interest. Next, one-way analysis of variance (ANOVA) with post-hoc tests was conducted to explore differences in FLE factors, FLCA and WTC across different study disciplines. Finally, the hierarchical regression was performed to test the predictability of WTC by FLE factors and FLCA.

4. Results

4.1. Descriptive data

Descriptive statistics, including means, minimum scores, and maximum scores, for the FLE, FLCA, and WTC scales are shown in Table 1. These scores were based on the 5-point Likert scale, from *strongly disagree* (1) to *strongly agree* (5), used in the questionnaire.

Table 1 Descriptive statistics of FLE, FLCA and WTC scores

	M	SD	Min.	Max.
FLE	3.83	1.85	1	5
FLCA	2.84	1.21	1	5
WTC	2.49	1.12	1	5

As presented in Table 1, the mean percentage score on the FLE, FLCA and WTC scales were $M=3.83$ ($SD=1.85$), $M=2.84$ ($SD=1.21$) and $M=2.49$ ($SD=1.12$) respectively. Since the scores were based on the 5-point Likert scale, it seemed reasonable to establish thresholds and categorize the scores into low, moderate, and high enjoyment, anxiety, and willingness to communicate levels. The thresholds were chosen by dividing the 5-point Likert scale into three equal intervals. The cut-off points were as follows: low: 1.00 to 2.50; moderate: 2.51 to 3.50; high: 3.51 to 5.00. The descriptive data revealed interesting patterns. Students reported high levels of enjoyment ($M=3.83$; $SD=1.85$), indicating a positive attitude towards foreign language learning. In contrast, scores for foreign language classroom anxiety fell within the moderate range ($M=2.84$; $SD=1.21$) suggesting that while students may experience some situational anxiety in the language classroom, it does not seem to be overwhelming.

Interestingly, scores on the WTC scale ($M = 2.49$, $SD = 1.12$) fell within the low range. This suggests that despite enjoying the language as indicated by the FLE scores, students might experience a greater hesitancy to actively communicate in the foreign language classroom. An analysis of individual item scores revealed a positive learning environment, with a high percentage of students agreeing or strongly agreeing on several key aspects. The percentages were rounded to the nearest whole number. In other words, a closer look at individual items revealed several strengths of the learning environment. A remarkable 89% of students agreed it was *cool to know a foreign language*, demonstrating a positive attitude towards language learning. Furthermore, a very high proportion (92%) of students acknowledged that *making mistakes is part of the learning process*. Nearly all students also reported positive perceptions of teachers, with 94% finding them *friendly* and 91% perceiving them as *supportive*. In comparison to the above-mentioned high percentages of positive responses, somewhat lower scores were obtained for items 5 and 7 indicating that half of the students did not perceive themselves as *worthy members* of the FL class (51%) and that around a third (32%) perceived themselves as *different* in the FL class.

Despite the generally positive findings reported on the FLE scale ($M = 3.83$, $SD = 0.82$), scores on the FLCA scale ($M = 2.84$, $SD = 1.21$) suggest that some students might still experience anxiety in the foreign language classroom. Despite a relatively high percentage of students indicating comfort in speaking situations (e.g., 50% *did not panic*, 47% *did not feel their heart race*, and 46% *did not report nervousness and confusion*), anxiety remained a concern for many students. Nearly a third (30%) reported *feeling their heart pound*, and around a quarter (28%) indicated they *started to panic during unprepared speaking*, *not feeling confident* when speaking in FL class (28%) and always perceived *others to be better FL speakers* (33%).

Beyond the overall WTC score ($M = 2.49$, $SD = 1.12$), analyzing individual items can provide valuable insights into students' communication preferences and anxieties. While students might enjoy some aspects of communication such as *talking to classmates* (56%) and the majority *showed interest in attending FL class* (71%), *paying attention to grammar rules* (52%) and *using simple structures to avoid making mistakes* (42%) seem to outweigh these positive aspects.

4.2. Factor analysis

The 21-item FLE scale assesses a wide range of student experiences and emotions in foreign language learning. Principal component analysis (PCA) using SPSS was conducted on the 21 FLE scale items to explore the underlying structure of the data. Prior to PCA, the correlation matrix was examined, revealing the presence of many coefficients of 0.3 and above. The Kaiser-Meyer-Olkin value was 0.87 exceeding the recommended value over 0.6 whereas the Bartlett's Test of Sphericity was statistically significant, supporting the factorability of the correlation matrix. Principal component analysis revealed the presence of four factors with eigenvalues exceeding 1, explaining 30.75%, 11.15%, 9.2% and 5.26% of the variance respectively. A scree plot indicated a clear break after the third component, justifying the retention of three factors for further analysis. For the interpretation of the components, Varimax rotation was used. The rotated solution revealed strong loadings on these three factors. The three factor solution explained a total of 51.11% variance with Factor 1 contributing 19.92%, Factor 2 - 18.13% and Factor 3 - 13.05%. The results of factor analysis, used to identify the underlying dimensions that these items represent, are presented in Table 2.

Table 2 Varimax rotated loadings

Item	Factor 1 SLE	Factor 2 IM&PG	Factor 3 PPI
16. The teacher is friendly.	0.842		
17. The teacher is supportive.	0.793		
15. The teacher is encouraging.	0.792		
14. The peers are nice.	0.634		
18. There is good atmosphere.	0.626		
10. It's a positive environment.	0.602		
11. It's cool to know a FL	0.564		
13. Making errors is part of the learning process.	0.543		
4. I enjoy it.		0.713	
9. In class, I feel proud of my accomplishments		0.648	
7. I'm a worthy member of the FL class.		-0.636	
8. I've learnt interesting things.		0.631	
6. I learnt to express myself better in the FL.		0.626	
1. I can be creative.		0.607	
12. It's fun.		0.601	
2. I can laugh off mistakes		0.478	
3. I don't get bored.		0.455	
5. I feel as though I'm a different person during the fl class.		-0.354	
20. We have common "legends", such as running jokes.			0.825
21. We laugh a lot.			0.739
19. We form a tight group.			0.728

The factor analysis of the FLE scale revealed three key factors that influence student emotions in foreign language learning that can be labelled as follows: - *Supportive Learning Environment* (Factor 1) - relating to positive teacher characteristics and enjoyable classroom atmosphere; *Intrinsic Motivation and Personal Growth* (Factor 2) - reflecting students' intrinsic enjoyment and engagement in learning the FL as well as a sense of accomplishment and self-worth; *Positive Peer Interaction* (Factor 3) - highlighting strong peer connection, shared experiences and enjoyment of social interaction.

4.3. Correlations

To explore the relationships between student enjoyment, anxiety, and willingness to communicate, correlations between the FLE scale, FLCA scale, and WTC scale were calculated. The results are presented in Table 3.

Table 3 Correlations between FLE (T), FLCA and WTC

	FLE (T)	FLE (F1) SLE	FLE (F2) IM&PG	FLE (F3) PPI	FLCA	WTC
FLE (T)	1	0.848**	0.809**	0.633**	-0.273**	0.287**
FLE (F1) SLE		1	0.482**	0.396**	-0.283**	0.227**
FLE (F2) IM&PG			1	0.292**	-0.266**	0.350**
FLE (F3) PPI				1	-0.013	0.017
FLCA					1	-0.792**
WTC						1

Note. N=254; **p < 0.01

As predicted in H1, total FLE demonstrated a significant positive correlation with WTC and a significant negative correlation with FLCA. Those students who experienced higher enjoyment levels were more willing to communicate ($r=0.287$, $p<0.01$) and felt less anxious in the classroom ($r=0.273$, $p<0.01$). Very strong statistically significant correlation was also found between FLCA and WTC ($r=-0.792$, $p<0.01$) indicating that students' foreign language classroom anxiety significantly hindered their willingness to communicate in the classroom. However, a closer examination of FLE factors and WTC revealed a more nuanced picture. Two FLE factors (SLE and IM&PG) showed significantly positive correlations with WTC ($r=0.227$, $p<0.01$; $r=0.350$, $p<0.01$, respectively) and negative correlations with FLCA ($r=-0.283$, $p<0.01$; $r=-0.266$, $p<0.01$, respectively). In contrast, enjoyment stemming from positive peer interaction (F3) did not exhibit a statistically significant relationship with either students' willingness to communicate or anxiety levels.

4.4. One-way analysis of variance (ANOVA)

Finally, in order to answer the second research question on the potential difference in levels of FLE, FLCA and WTC across three fields of study - business, electrical engineering, English language and literature and medicine - one-way between-groups ANOVA with post-hoc tests was used.

When three FLE factors were analyzed, the results further showed significant differences among groups in FLE factors 2 (IM&PG) and 3 (PPI).

Table 4 Levels of FLE, FLCA and WTC by discipline

	Business		Electrical Engineering		English		Medicine		
	M	SD	M	SD	M	SD	M	SD	
FLE	82.77	7.74	79.36	9.54	81.14	7.47	78.24	9.96	F(3,250)=2.98 p=0.03
FLCA	21.77	7.11	20.47	6.86	22.79	7.64	24.45	4.77	F(3,250)=3.35 p=0.02
WTC	32.10	6.12	32.65	6.04	33.32	6.09	30.12	5.87	F(3,250)=1.85 p=0.14

The ANOVA results presented in Table 4 suggest that statistically significant differences in FLE levels were found between business and electrical engineering students. Business students experienced higher levels of enjoyment in FL classroom than their colleagues studying electrical engineering ($F=2.98$, $p=0.03$). As for FLCA levels, medical students reported to be significantly more anxious in FL classroom than electrical engineering students ($F=3.35$, $p=0.02$). In contrast to these findings, no statistically significant differences were found in WTC levels among different groups of students.

When ANOVA was conducted on three FLE factors, the results showed significant differences among groups in FLE factors 2 and 3. The results are presented in Table 5.

Table 5 Levels of FLE (F1), FLE (F2) and FLE (F3) by discipline

	Business		Electrical Engineering		English		Medicine		
	M	SD	M	SD	M	SD	M	SD	
FLE (F1)	36.03	3.72	34.68	4.83	35.50	4.26	34.00	4.07	F(3,250)=2.16 p=0.094
FLE (F2)	35.84	3.85	34.38	4.29	37.39	3.35	34.79	5.54	F(3,250)=4.57 p=0.004
FLE (F3)	10.90	2.37	10.30	2.44	8.25	2.72	9.45	3.03	F(3,250)=8.30 p=0.000

As can be seen from the Table 5, students majoring in English language and literature had significantly stronger feelings of fun and enjoyment as well as self-accomplishment compared to electrical engineering students. The largest number of significant differences was found in levels of enjoyment motivated by positive peer interaction. Business students reported significantly higher levels of enjoyment due to social cohesion in class than students majoring in English and medical students. Similarly, electrical engineering students enjoyed significantly more with their peers than their colleagues studying English. The results provided partial support for H2.

4.5. Regressions

Several hierarchical regressions were performed on the data in order to test the predictability of WTC by FLCA and underlying FLE factors. The results of the hierarchical regressions are summarised in Table 3.

Table 6 Hierarchical regressions: FLCA and FLE factors as predictors of WTC

	WTC		
Step 1	St. β	t	Model summary
Gender	0.146	2.285*	F (2,241)=2.612 p=0.075
Age	-0.011	0.168	
Step 2			
Gender	0.260	3.906***	F (3,240)=8.671 p=0.000
Age	-0.005	-0.074	
State Matura	-0.299	-4.513***	
Step 3			
Gender	0.335	5.360***	F (6,237)=12.672 p=0.000
Age	-0.62	-1.082	
State Matura	-0.216	-3.420**	
FLE (F1)	0.132	1.919	
FLE (F2)	0.352	5.268***	
FLE (F3)	-0.105	-1.663	
Step 4			
Gender	0.004	0.091	F (7,236)=65.102 p=0.000
Age	-0.068	-1.751	
State Matura	-0.037	-0.846	
FLE (F1)	-0.067	-1.408	
FLE (F2)	0.183	3.975***	
FLE (F3)	-0.011	-0.267	
FLCA	-0.758	-17.030***	

Note. N=254; *p < 0.05; **p < 0.01; ***p < 0.0005

The hierarchical regression analysis confirmed our hypothesis that FLCA is the strongest predictor of WTC. Background variables (gender and age) entered in the first step explained a small portion (2.1%) of the variance in WTC scores. Gender emerged as the only significant predictor at this stage. When academic achievement (State Matura Exam score) was added in the second step, it accounted for an additional 7.7% of the variance, with both gender and State Matura Exam score making statistically significant contributions. Subsequently, including the three FLE factors explained a further 14.5% of the variance. In this model, gender, State Matura Exam score, and FLE-F2 (Intrinsic Motivation and Personal Growth) were significant predictors. Finally, FLCA entered in the last step significantly increased the explained variance by 41.6%. The final model explained a total of 66% of the variance in WTC scores. Notably, FLCA (beta = -0.761) and FLE-F2 (Intrinsic Motivation and Personal Growth) (beta = 0.183) emerged as the most significant unique predictors. These results confirm our hypothesis (H3) about FLCA being the strongest predictor of WTC.

5. Discussion

The current study attempts to shed light on three individual variables, FLE, FLCA and WTC. Drawing on MacIntyre and Dewaele's (2014) proposition that both positive and negative emotions influence language learning, this study aims at investigating the interplay among FLE,

FLCA and WTC. To delve deeper into the multifaceted nature of FLE, an exploration of its underlying structure was undertaken. This approach aimed to move beyond a single, broad measure of FLE and capture the specific aspects that influence students' enjoyment of foreign language learning.

The mean scores on the FLE and FLCA scales in this study provide valuable insights. The average FLE score ($M=3.8$) and FLCA score (2.84) align with findings reported by Khajavy et al. (2018) and Deweale & MacIntyre (2014) suggesting a generally positive level of enjoyment and moderate levels of anxiety among foreign language learners. These observations establish a foundation for examining the relationships between FLE, FLCA, and Willingness to Communicate (WTC) in our student population.

The results of this study replicate and extend previous findings about the significant correlation among FLE, FLCA and WTC indicating that students who experience more supportive learning environment (FLE-F1) and intrinsic enjoyment along with a sense of self-accomplishment (FLE-F2) demonstrate lower levels of anxiety and tend to be more willing to communicate in class (e.g. Deweale & MacIntyre, 2014; Deweale & Alfawzan, 2018; Dewaele, et al.; 2016, Khajavy, et al., 2018; Zaharuddin et al., 2023). Interestingly, enjoyment that derived primarily from positive peer interaction (FLE-F3) did not demonstrate a significant association with either WTC or FLCA. This unexpected finding highlights the multifaceted nature of FLE. Our decision to employ factor analysis was crucial in revealing these distinct dimensions within FLE.

H2 predicted no significant differences in FLE, FLCA, or WTC based on participants' study programmes. While WTC levels did exhibit some variation, FLE and FLCA scores remained consistent across programmes. This finding suggests that factors specific to different study programmes might influence students' WTC in the foreign language. Therefore, H2 received limited support. These findings were somewhat unexpected. While significant differences were not observed in WTC, FLE and FLCA scores did vary slightly between some programme groups. This suggests that program-related factors may exert a more nuanced influence on enjoyment than previously thought. Also, when the multi-faceted FLE scale is analyzed from the factor perspective, a deeper understanding into individual differences of student population might be gained. Further research is needed to understand these subtle variations.

The findings of this research align with previous studies (e.g. Dewaele, 2019; Fujii, 2021). As anticipated (H3), Foreign Language Classroom Anxiety emerged as a stronger predictor of Willingness to Communicate compared to Foreign Language Enjoyment. This confirms the significant negative influence of anxiety on students' willingness to communicate in the classroom setting. Although FLE itself did not significantly predict WTC, it is noteworthy that a specific dimension within FLE, Intrinsic Motivation and Personal Growth (FLE-F2), emerged as a positive predictor. This finding suggests that fostering students' intrinsic motivation and sense of personal accomplishment in language learning can positively impact their willingness to communicate, even if the overall enjoyment construct (FLE) shows a weaker association.

6. Conclusion

The importance of fostering positive learning experiences for individual students is well-recognized by many language educators. This includes cultivating motivation, perseverance, resilience, and positive emotions, all crucial elements for successful foreign language acquisition (MacIntyre & Mercer, 2014:156). In addition, educators acknowledge the vital role of positive classroom dynamics between learners and teachers, particularly in settings that emphasize communication and interactions that hold personal meaning for students. The perceived relevance of the FL content, difficulty level, and student backgrounds (e.g. prior language experience, personality traits, learning styles) can all contribute to a complex, positive or negative, emotional experience in the FL classroom. Additionally, acknowledging programme-specific factors influencing student emotions is essential. For instance, students in programmes emphasizing logical thinking (e.g. engineering) might find the intuitive aspects of FL learning challenging and would benefit from language learning approaches that bridge the gap between logic and creative expression. Similarly, since some academic programmes (e.g. medicine) are known for their demanding schedules and high-stakes assessments, it seems reasonable to believe that students might carry this pressure into the FL classroom, feeling anxious about making mistakes or not performing well in another subject.

In order to create a more inclusive and effective learning environment for all students, teachers should acknowledge these diverse needs, employ a variety of teaching methods and establish supportive and encouraging classroom climate that fosters enjoyment and reduces anxiety. In addition, by nurturing, not only students' intrinsic motivation and sense of personal growth, but also other underlying dimensions within the broader concept of enjoyment, a positive influence on their willingness to communicate could be cultivated.

Future research should continue to explore the complex interplay of student and programme-specific variables gain a more comprehensive understanding of the complex emotional landscape of the FL classroom.

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APPENDIX

Cilj ovoga upitnika je otkriti osjećate li zadovoljstvo tijekom nastave stranoga jezika, strah od govora u nastavi stranoga jezika te pokazujete li spremnost na komunikaciju.

Molimo Vas da niti jednu tvrdnju ne preskočite. Ne postoje točni i netočni odgovori.

Obvezujemo se čuvati u tajnosti sve navedene podatke i koristiti ih isključivo u istraživačke svrhe. Zahvaljujemo na susretljivosti i spremnosti da sudjelujete u ovom istraživanju.

Ivana Čizmić, v.pred. i dr.sc. Jasmina Rogulj, prof. struč. stud.u t.i.

Spol: Ž / M

Starosna dob: a) 19 b) 20 c) 21 d) 22 e) 23 f) _____

Studij: _____

Koristite li se engleskim u svakodnevnom životu? DA / NE

Koju razinu državne mature ste polagali? a) višu / b) nižu

Koju ste ocjenu dobili na maturi iz engleskog jezika?

a) 1 b) 2 c) 3 d) 4 e) 5

To what extent do you agree with the following statements? Please indicate your level of agreement with the following statements by circling the corresponding number: (1) strongly disagree, (2) disagree, (3) neutral, (4) agree, (5) strongly agree.

The FLE (Foreign Language Enjoyment Scale)					
1. I can be creative	1	2	3	4	5
2. I can laugh off embarrassing mistakes in the FL	1	2	3	4	5
3. I don't get bored	1	2	3	4	5
4. I enjoy it	1	2	3	4	5
5. I feel as though I'm a different person during the FL class	1	2	3	4	5
6. I learnt to express myself better in the FL	1	2	3	4	5
7. I'm a worthy member of the FL class	1	2	3	4	5
8. I've learnt interesting things	1	2	3	4	5
9. In class, I feel proud of my accomplishments	1	2	3	4	5
10. It's a positive environment	1	2	3	4	5
11. It's cool to know a FL	1	2	3	4	5
12. It's fun	1	2	3	4	5
13. Making errors is part of the learning process	1	2	3	4	5
14. The peers are nice	1	2	3	4	5
15. The teacher is encouraging	1	2	3	4	5
16. The teacher is friendly	1	2	3	4	5
17. The teacher is supportive	1	2	3	4	5
18. There is good atmosphere	1	2	3	4	5
19. We form a tight group	1	2	3	4	5
20. We have common "legends", such as running jokes	1	2	3	4	5
21. We laugh a lot	1	2	3	4	5

The FLCA scale (Foreign Language Classroom Anxiety scale)					
1. Even if I am well prepared for FL class, I feel anxious about it	1	2	3	4	5
2. I always feel that the other students speak the FL better than I do	1	2	3	4	5
3. I can feel my heart pounding when I'm going to be called on in FL class	1	2	3	4	5
4. I don't worry about making mistakes in FL class	1	2	3	4	5
5. I feel confident when I speak in FL class	1	2	3	4	5
6. I get nervous and confused when I am speaking in my FL class	1	2	3	4	5
7. I start to panic when I have to speak without preparation in FL class	1	2	3	4	5
8. It embarrasses me to volunteer answers in my FL class	1	2	3	4	5
The WTC scale (The Willingness to Communicate scale)					
1. I like speaking English without paying attention to grammar rules	1	2	3	4	5
2. Before I use a new word in English, I want to make sure when and how it is used in a sentence	1	2	3	4	5
3. In FL class I don't like using complex sentences in English	1	2	3	4	5
4. I rather use simple structures while speaking English to avoid making mistakes	1	2	3	4	5
5. In FL class I don't like discussing complex topics in English	1	2	3	4	5
6. I like talking to other students in FL class	1	2	3	4	5
7. I feel distressed to volunteer answers in my FL class	1	2	3	4	5
8. I do not feel comfortable when speaking English in front of other students	1	2	3	4	5
9. I often do not feel like attending FL class	1	2	3	4	5
10. I panick every time I have to speak English in FL class without preparation	1	2	3	4	5

DIS/ADVANTAGES OF DIGITAL LEARNING/TEACHING: THE CASE OF TEACHING ESP TO POST PANDEMIC GENERATION OF STUDENTS

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Digital learning/teaching refers to the use of any type of technology to learn-teach in the classroom. Nowadays as the use of digital equipment has become an indispensable part of our daily routines and they play a significant role in our lives, the need to re-dimension classroom behaviour is growing daily. Classroom behaviour should be reshaped from the perspective of the student and the lecturer as well. However as with every new paradigm there are advantages and disadvantages. Further studies need to be performed in order to define whether the post pandemic generation of students and the increase of functional illiteracy are interrelated. The advantages and disadvantages of digital learning/teaching are present in all the subjects and across universities; however, we are going to explore the issue based on teaching ESP (English for Specific Purposes) to AUT (Agricultural University of Tirana) students. ESP courses are taught during the first-year bachelor cycle as a compulsory module. In addition to the difficulties encountered during the transition from high school to university, first-year students are faced with new subjects, new ways of teaching and learning as well as different types of projects. Firstly, the study focuses on traditional versus digital teaching - its advantages and disadvantages. Secondly the paper explores traditional versus digital learning, pros and cons per each. Another approach will focus on the results drawn by a questionnaire conducted with first-year students to identify advantages and disadvantages of digital learning and teaching as well as the impact of Covid-19 pandemics and online schooling. Results will also compare the change in students' attitude from the beginning of the year to the end of the first term and the beginning of the second term.

Key words: *digital learning/teaching, AUT, post pandemic generation*

A. Introduction

Digital learning/teaching refers to the use of any type of technology to learn-teach in the classroom. E-learning or e-teaching stands for the use of electronic technology of information in learning and teaching environments. Because the use of information technology is widespread in every aspect of our society, the school educational system cannot make an exception. Nowadays as new "e"- terms are coined frequently, where "e" stands for electronic we have e-learning, e-Albania (i.e. e-government), e-business etc. One would think that this is a recent phenomenon but scholars have created a digital learning timeline (Mark David Walker, Feb 2024), showing that in 1960 Patrick Suppes and Richard Atkinson used computer assisted learning at Stanford

University for mathematics teaching drill practice. In 1970 John Seely Brown invented a computer-based teaching aid; SOPHIE (a SOPHisticated Instructional Environment). In 1980 Seymour Papert developed LOGO language for use in schools. In 1990 the term e-Learning term became popular. In 2000 MIT OpenCourseWare project published university course material on-line for free. In 2010 - 2012: year of the MOOC; Massive Online Open Courses. In 2020 the COVID-19 pandemic made distance learning become standard world-wide.

How covid reshaped teaching and learning strategies

When Covid-19 struck people did not know that the world and some areas of life-work balance would create new dimensions. The lockdown put the whole world at a stop and online working became the new era. As schools went online the need to redefine teaching and learning strategies emerged. Although the world was going through digital transformation none of us was ready for this new reality. Online schools presented new unknown difficulties for teachers and students. Lecturers who were used to traditional teaching methods had difficulties coping with the new reality. On the other hand, even the students had their own obstacles. All the people suddenly had to step out of their comfort zone and challenge themselves to be adapted to new methods. In addition, people living in low- or middle-income countries had other obstacles. According to a report delivered by the World Bank (May 2020) teachers and students in the Western Balkans had different issues and difficulties when compared to OECD or EU countries. Even before the global pandemic broke out, Western Balkan education systems already faced serious challenges. To varying degrees, they did not deliver the skills the labour market needs. According to a World Bank study over 78 percent of 15-year-olds in Kosovo, and over 50 percent in Albania, North Macedonia, and Montenegro are functionally illiterate. Illiteracy is a well-defined phenomenon. It has been investigated since the 1970s and researchers have investigated many characteristics of illiteracy (Huetting and Mishra, 2014). According to the original notion, the difference between functional illiterates and illiterates is that illiterates are unable to read, write, and understand short sentences. In contrast functional illiterates are unable to use their acquired literacy skills in daily life (UNESCO, 1978). Further studies need to be performed in order to define whether the post pandemic generation of students and the increase of functional illiteracy are interrelated. Online teaching presented the Albanian educational system with persistent inequities in learning outcomes by gender, location, and income group. There were considerable differences for pupils living in remote areas and lack of internet access or technological devices was present. The whole new paradigm introduced during the pandemics has definitely yielded worse results.

Clash of cultures – traditional teaching versus students' approach to digital schooling

Over the recent years the use of technology has invaded our lives for better and for worse. As in every sphere of human life even in the field of education the presence of high-tech equipment and their use in the classrooms has reshaped the attitude of teachers and students. Despite the continuous efforts to invest in technology in classrooms a lot is yet to be done. Not all the classrooms have the necessary equipment, thus often students make use of their mobile phones to search for information. At this point we cannot fully say that we offer exclusively digital teaching methodology. Currently traditional teaching is overwhelming in our daily classroom attitude. The chalk has not gone out of date yet. On the other hand, the students' attitude is different. Students are not willing to write but they often get pictures of the board; they often find it convenient to write classwork in their mobile notes. It goes without saying that this

generation of students as well as the present-day teacher have increasingly struggled with the traditional methods and the ongoing technological developments in the world to keep a balance between both. It cannot be denied that traditional teaching methods with practical activities and face-to-face interactions give rise to the elaboration of soft skills, or interpersonal skills. The key solution to this growing phenomenon is finding an equilibrium. Different subjects have different priorities and students' needs are not the same. The new reality shifted the dynamics and shocked the existing system.

Teaching Gen Z -Traditional learning vs digital learning

Generation Z is the demographic cohort generation born from 1997 to 2012. For some years now our classrooms have been inhabited by Gen Z students. They do not necessarily possess “*digital literacy*” characteristics, but they can definitely search for any type of information through electronic devices. However, this lifestyle has constantly promoted Gen z students with superficial understanding and short attention span. Self-discipline and poor time management are other issues that the Gen z students struggle with. While these students can be defined as the generation that serves as a bridge between traditional and digital learning it is difficult even for the lecturers to get their attention. Research conducted by Microsoft in 2015 (Spring) showed that the average human attention span dropped from 12 seconds in 2000 to 8 seconds in 2013. This decrease in attention span will probably shrink in the upcoming years. Higher education institutions will face even more difficulties in the future. The fact that students can easily access information via their smartphones creates among them the illusion of knowledge, thus creating overconfidence. To cope with these challenges instructors, have to re-dimension their teaching methods in order to promote critical thinking among students and make Gen z focus on learning in order to make them successful in their future careers.

Teaching English for Specific Purposes (ESP) to Agricultural University of Tirana (AUT) Gen Z students

AUT (Agricultural University of Tirana) offers English Language Courses, ESP (English for Specific Purposes) courses during the first-year bachelor cycle in all specialities as a compulsory module. The ESP module was introduced several years ago after having taught General English through a system of placement tests. Due to the continuous reforms in the pre-university school system where foreign languages were taught since the first grade the need for ESP special courses emerged. The course has been tailored to meet the needs of our students in different specialities English for Business and Finance, English for Veterinary Medicine, English for Agriculture and Environment, English for Food and Technology and English for Forestry. However different from what is perceived by the mass that Gen Z students are good at English the reality is quite different. They often report that they use Google Translate even for basic information. They do not often understand texts in different subject areas, or they lack interest and do not delve into specific topics.

B. Methodology

The study conducted one questionnaire, but in two different age groups:

- the first group involved high school Gen Z pupils,
- whereas the second group Gen Z university students from the Faculty of Economy

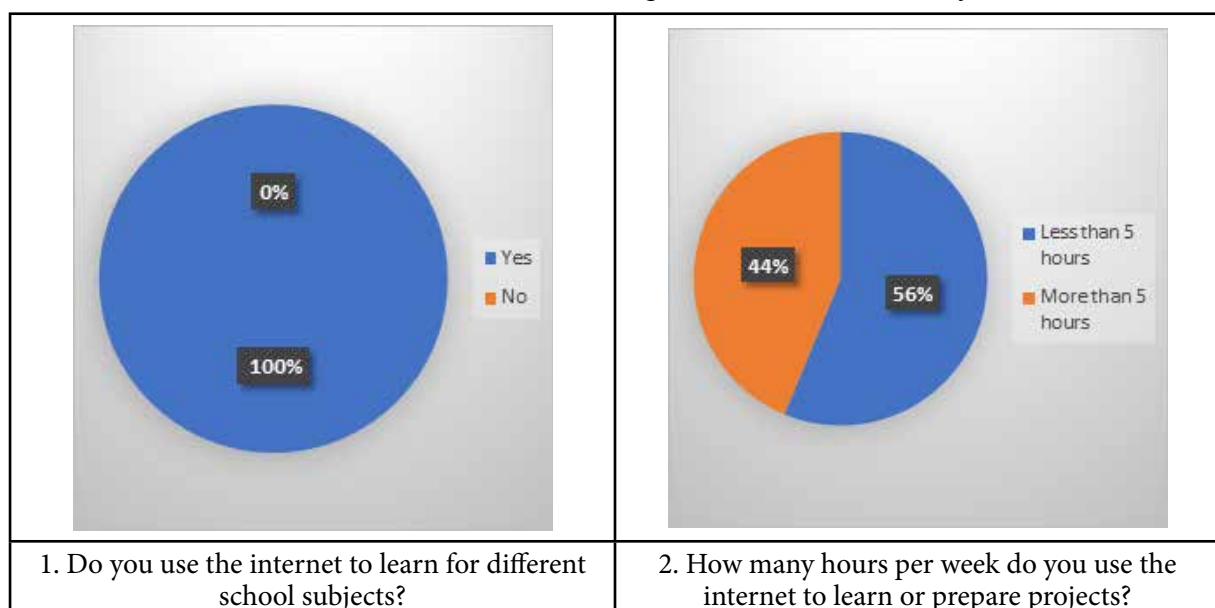
and Agribusiness, Department of Agribusiness Management, 1st year 2023-2024. The questions revolved around the use of technology for learning purposes, the effect of the pandemic period and online teaching-learning in their general educational background as well as the approach and the differences between high school and university years.

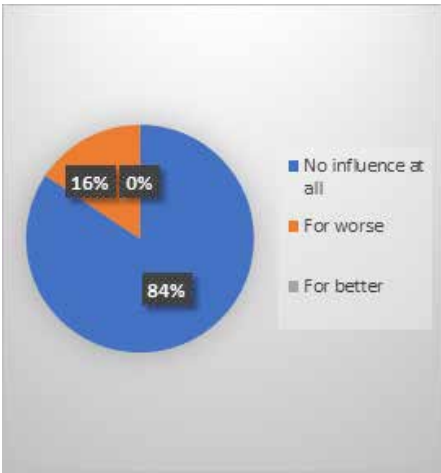
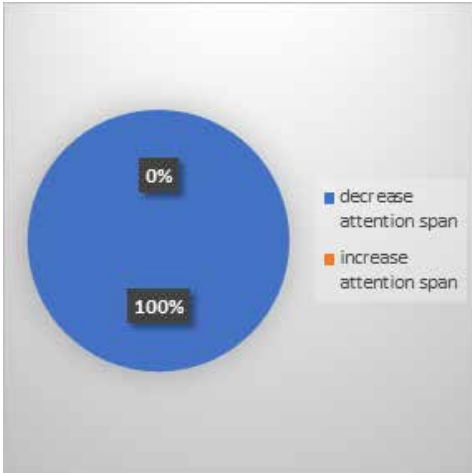
- Survey questions
 1. Do you use the internet to learn for different school subjects?
 2. How many hours per week do you use the internet to learn or prepare projects?
 - a) less than 5 (five hours)
 - b) more than 5 (five hours)
 3. To what degree has online teaching-learning during the pandemics influenced your educational background?
 - a) for better
 - b) for worse
 - c) no influence at all
 4. Does the use of your smartphones influence on your attention span?
 - a) increase attention span
 - b) decrease attention span
 5. Has your approach to using internet for learning purposes changed during your high school years from grade 10 – 12, as compared to this year as university students?
 - a) increased
 - b) decreased
 - c) constant

C. Results of the survey

The high schoolers were a small group of **32 pupils** that served as a sample for their age range group. All of the 32 pupils (100%) use the internet for school studies. 18 pupils (56%) reported that they use the internet for less than 5 hours per week, whereas 14 pupils (44%) for more than 5 hours per week. As far as the influence of online learning during the pandemics is concerned, none of them (0%) reported that it has played a better role in their educational background, 5 (16%) a worse role and 27 (84%) report no influence at all. How the use of smartphones influences their attention span all of them responded that it decreased their attention.

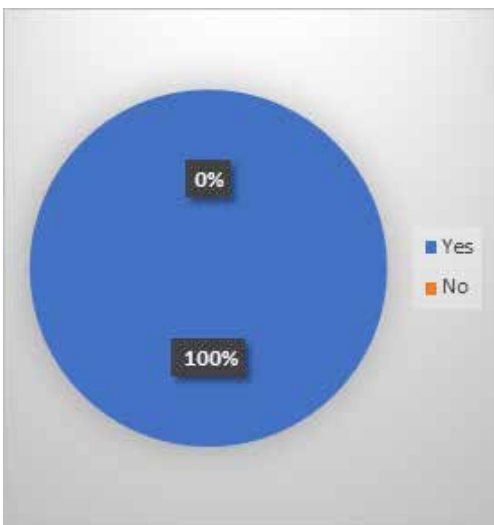
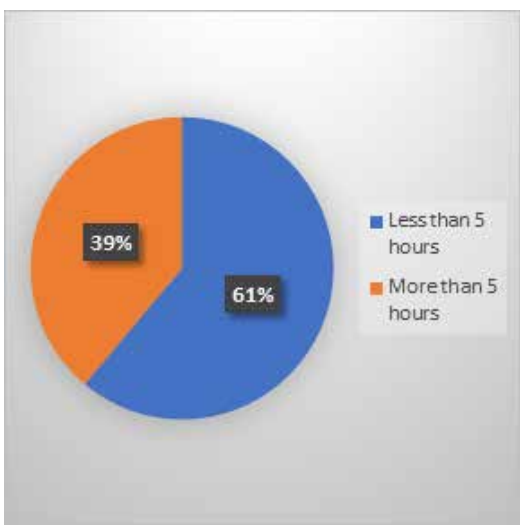
The above-mentioned data have been presented into charts as follows:

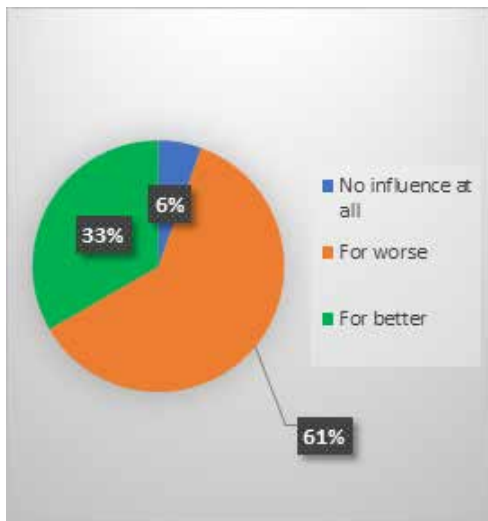


	
<p>3. To what degree has online teaching-learning during the pandemic influenced your educational background?</p>	<p>4. Does the use of your smartphones influence on your attention span?</p>

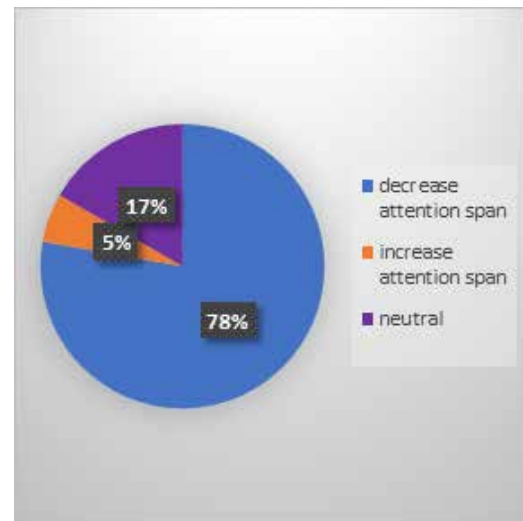
The total number of participants in the survey was **72 students** out of 100. All of the students use the internet for school studies. 44 students (61%) reported that they use the internet for less than 5 hours per week, whereas 28 (39%) more than 5 hours per week. As far as the influence of online learning during the pandemic is concerned 24 (33%) reported that it has played a better role in their educational background, 44 (61%) a worse role and 4 (6%) report no influence at all. How the use of smartphones influences their attention span 56 students (78%) responded that it decreased their attention, 4 of them (5%) thought quite the opposite i.e. it increased their attention, whereas 12 students (17%) were neutral. Considering the use of internet for learning purposes while comparing high school years to university 47 (65%) students report that it is constant, 22 (31%) say that they have been using internet more as freshmen, while 3 (4%) report lower usage of internet for learning purposes.

The above-mentioned data have been presented into charts as follows:

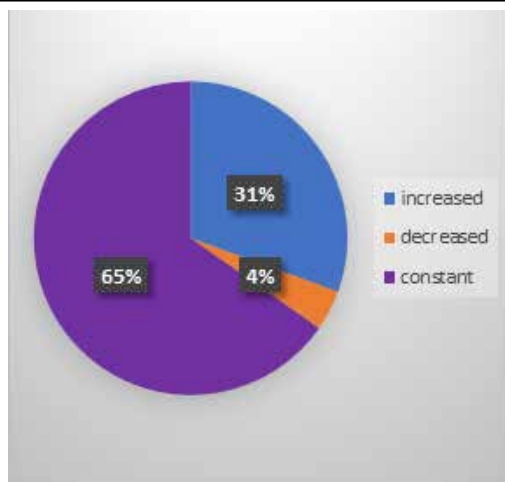
	
<p>1. Do you use the internet to learn for different school subjects?</p>	<p>2. How many hours per week do you use the internet to learn or prepare projects?</p>



3. To what degree has online teaching-learning during the pandemics influenced your educational background?



4. Does the use of your smartphones influence on your attention span?



5. Has your approach to using internet for learning purposes changed during your highschool years from grade 10 – 12, as compared to this year as university students?

D. Discussions

All the participants in the survey belong to Gen Z, however deeper analysis shows that there are distinctions between their experiences. There is also a difference between public and private schools. Private schools during the pandemics had more successful results than public schools. It must be emphasized that due to functional illiteracy students often don't focus on the answer, but misunderstand the questions.

E. Conclusions

The educational environment has definitely changed and nowadays Gen Z is presented simultaneously with advantages and disadvantages introduced by the whole process of digitalization.

All these advantages and disadvantages are also a real challenge for the lecturers. While digital teaching is a must, sometimes lack of proper or updated equipment leads to technical issues and classes are taught via traditional methods.

While a hundred percent of both high schoolers and students use the internet for studies, at different time ranges, the majority declares that online learning has influenced their educational background, by considering the outcome worsened. Despite the neutral results it is interesting to highlight that there are some students who think that it has improved their background (without commenting how).

Attention span is directly influenced by the use of excessive technology (all studies support this), yet surprisingly some students disagree. Only a minority of students need technology more in their learning process as university students.

However, we think that traditional education will coexist with digital education even in the years to come.

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FINANCIAL LITERACY OF HIGH SCHOOL STUDENTS AND UNIVERSITY STUDENTS IN THE FIELD OF ECONOMICS

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Abstract. Financial literacy can be defined as the ability to understand and apply basic financial concepts and, as such, plays a key role in shaping an individual's financial well-being. In this work, research was conducted with a focus on assessing the level of financial literacy among young people between the ages of 18 and 35. Analyzing key areas of financial literacy, such as lending, investing, saving, as well as general concepts, deficiencies in current educational practices were identified. The results indicate the challenges that young people face in this domain, emphasizing the need to strengthen their financial education. Regarding the above, it was determined that the level of financial literacy and knowledge about consumer credit increases with the level of education of the respondents. The results of the correlation analysis, conducted in the SPSS program, in both regards indicate a strong statistical connection between the observed variables. Proposals were formulated with the aim of improving the financial education of young people and strengthening their ability to make informed decisions, as well as achieving long – term financial stability.

Keywords: *financial literacy, financial education, educational practices*

1. Introduction

Financial literacy is essential for personal financial success and the stability of society. In today's world of rapid changes in the global financial market, financial decisions are becoming more and more complex and have an increasing impact on the individual and the wider community. In this context, the understanding of basic financial terms and the ability to apply knowledge in practice become crucial for efficient management of personal finances and adaptation to economic challenges. At the beginning of this paper, financial literacy is defined and an overview of some research in America and Europe is presented. In the second part of the paper, the financial literacy of high school students and students of Šibenik-Knin County is investigated. The aim of the paper is to examine the level of knowledge of some basic financial concepts, money management habits and general awareness of financial issues among the target population. A survey questionnaire was conducted, consisting of 32 questions, and data was collected on their knowledge, habits and attitudes related to finances. The goal of the research is to indicate the level of financial literacy of young people from high schools and colleges with an economic focus and to confirm that with the acquired financial status they are ready to make more informed decisions and be financially stable in the long term. In the context of the research goal, it was set to investigate how pronounced the relationship between the level

of education and the level of financial literacy is, and the relationship between the level of education and the separated conceptual categories on consumer credit. Based on the above, two hypotheses were set and they were confirmed by the Pearson correlation coefficient in the SPSS program. Finally, possible programs were proposed, which would be integrated into the school curriculum and which would contribute to better financial education.

2. Financial literacy through theory

Financial literacy represents the level of skill in understanding personal finances and often refers to the awareness and knowledge of key financial terms needed to manage personal finances (World Bank, 2014). Financial literacy is considered a fundamental and necessary skill for survival in the modern world. Knowing how to successfully manage personal finances and at the same time survive in modern society is only possible by adopting financial literacy as a form of basic knowledge and vocabulary about finances (Tejero et al., 2019). Financial literacy is a measure that expresses the degree to which individuals understand and use information related to personal finances (Musah et al., 2022). Many people's lack of financial knowledge limits their ability to optimally manage their finances. Consumers of financial services are often at a disadvantage compared to providers of financial services due to imbalances in power, information and resources. Users find it difficult, or at high costs, to get enough information about financial services. The information may also be too complex for the average user of the service, making it difficult to understand and evaluate. Improving financial literacy can significantly contribute to reducing power and information imbalances (World Bank, 2010). Financial decisions have become even more complex due to the emergence of new technologies, new payment methods, the emergence of cryptocurrencies, as well as high inflation rates. The level of financial literacy is quite limited and many have difficulties in understanding some basic concepts such as interest account, risk diversification, inflation and the like. The financial decision becomes a factor that affects the quality of life, while the activities of each individual aimed at satisfying personal needs are placed within the framework of finance, from which it follows that financial literacy is the concept of every individual living in society (Ozdemir, 2022).

Lusardi & Mitchell (2023) believe that strong interventions are needed to solve the problem of lack of financial literacy and that it is necessary to insert this topic into teaching plans and curricula in high schools, as well as undergraduate and graduate studies. They also suggest that measures of financial literacy be added to national statistical indicators, along with data on consumption and savings. The education system prepares pupils and students for financial challenges through the knowledge and skills necessary to enter the global economy (Arrington Tschache, 2009). The study of financial literacy should be a combination of knowledge about the ways and concepts of financial management and should also provide a combination of abilities in discovering strengths and weaknesses in money management (Maharini Adiandari, 2022). Financial education has become necessary as a result of the development of the financial market and demographic changes, while globalization and technological innovations have forced the individual to make daily financial decisions related to effective money management in order to create financial well-being, which is why the requirements for the introduction of financial education are considered reasonable (Balén, 2017). Suomen Pankki Finlands Bank (2020) launched a series of activities to promote financial literacy in February 2020 and prepared a proposal for a national strategy. The mission of the Finnish Financial Literacy Strategy is to encourage individuals' understanding of the importance of finance in their lives and to encourage ethical and sustainable financial behavior. The vision of the strategy is for Finland to become a world leader in financial literacy by 2030 (Suomen Pankki Finlands Bank, 2020).

In 2010, the World Bank published a study entitled “Croatia - Diagnostic Review of Consumer Protection and Financial Literacy”. The document states that one of the best long-term methods to ensure a high level of consumer protection is to improve financial education and financial literacy. The conclusions of the same study show the lack of effective campaigns to promote awareness and literacy among consumers to better understand banking products and services and suggest the development of financial education programs. After that, in 2015, the first National Strategic Framework for Consumer Financial Literacy was adopted in the Republic of Croatia for the period from 2015 to 2020, with the aim that citizens of all age groups have access to financial education. The results of measuring the level of financial literacy in the Republic of Croatia in 2019 show a slight increase compared to 2015. The average rating of financial literacy of consumers in the Republic of Croatia is 12.3 out of a total of 21 points (59%), compared to 11.7 points (56%) from In 2015, the level of financial literacy in the Republic of Croatia came close to the average financial literacy score of the G20 countries from 2017 (12.7 points, or 60%) (Narodne novine, 68/2021). In June 2021, a new National Strategic Framework for Consumer Financial Literacy was adopted for the period from 2021 to 2026.

3. Previous research

According to research by Contreras & Bendix (2021) from the Milken Institute, published in 2021, many individuals in the US, regardless of age, lack the basic knowledge and skills needed to make financial decisions, and such a situation seriously threatens their financial condition. Suter et al. (2023) conducted research in German high schools on how teaching financial literacy to 16-year-old high school students affects their behavior in risk and time preference tasks. Teaching financial literacy has been found to encourage subjects to behave more patiently, be more consistent, and be more risk averse. The research conducted among first-year undergraduate students in Slovakia aimed to identify the factors that most influenced the level of financial literacy and to analyze the degree of this influence. The research results suggest that the gender of the student, the education of the father, the financial situation in the family and the work experience of the student are among the most important factors of financial literacy. The results also indicate that it is important for children to acquire basic financial education from an early age, in order to develop positive habits in money management. Corsini and Giannelli (2021) in a study conducted on a sample of 481 economics students confirm that the same students are financially literate and that their financial literacy improves with the attendance of economics courses. Andreou and Philip (2018) measured the understanding of basic concepts closely related to personal debt and fraudulent investment in a sample of 881 Cypriot students and clearly confirmed their understanding is closely related to acquired economic knowledge. Students, aged 14 to 16, from different types of schools in the German province of Hesse, with an average grade of 55.20% of the achieved points, indicated that the level of financial literacy defined in a sample of 886 students is relatively low (Bruhl, 2019). In a sample of 3,000 Spanish high school students, it was proven that financial education changes students' awareness of the future consequences of their current choices (Bover et al., 2018). Mizzi (2021) demonstrates a clear connection between financial literacy and the study of economics among secondary school students through 14 secondary school economics teachers in Malta in four focus groups of students, emphasizing how learning economics forms the basis of acquiring financial knowledge that cannot be acquired from everyday experience. Vehovec et al. (2015) conducted research in Croatia and showed that education, household income, and the work status of respondents have the greatest influence on financial literacy. Also, it was concluded that regional affiliation has a minimal influence on financial literacy and

that differences in financial literacy can be better explained by other variables, so employed respondents show a higher level of financial knowledge compared to unemployed respondents. Male respondents show higher financial literacy than women, while older respondents show a higher level of financial knowledge. Ankten research, conducted among high school students in 2022, under the leadership of the Croatian Agency for the Supervision of Financial Services, emphasizes the need to improve the financial literacy of young people. Also, it is pointed out the necessity of integrating financial education in schools, in order to imbue young people with the skills needed to manage finances.

4. METHODOLOGICAL FRAMEWORK OF RESEARCH

In the research conducted in February 2024, a total of 131 students from Šibenik- Knin County participated. Out of the total number of respondents, 48 are graduate and undergraduate economics students (37% of the sample) and 83 are students of secondary economic schools (63% of the sample). Considering the short time period of the research and the limitation to one county, the research sample is acceptable.

4.1. The goal of the research

Financial literacy is the basis of assessing the ability to understand financial concepts. In this research, emphasis is placed on the overall relationship between the level of education and financial literacy measured through the achieved grades in the answers and on the relationship between the level of education and knowledge about consumer credit also measured through the achieved grades in the answers. The previous mentioned researches highlighted to a large extent the connection between the observed aspects. At the threshold of previous research, this research emphasizes how the level of education has a different effect on financial literacy, which increases with the level of education. The aim of the research is to establish clearly established relationships and to indicate the level of financial literacy with regard to the level of education of the respondents. With the same goal, insight into the level of financial literacy of pupils and students and insight into the knowledge of some general terms about consumer credit is given. The same insight will indicate the importance of acquired economic knowledge for understanding financial concepts.

4.2. Research tasks and hypotheses

Based on the set goal, the research tasks are also set, which are aimed at determining the connection between the level of education and the level of financial literacy and at determining the connection between the level of education and knowledge of basic terms about consumer credit. In accordance with the defined subject, goal and tasks of the research, two research scientific hypotheses are set:

H1. It is assumed that the level of financial literacy increases with a higher level of education.

H2. It is assumed that a higher level of education is significantly related to a higher level of knowledge about the concepts of consumer credit.

4.3. Sample, instrument and research methods

The target population of this research is pupils and students of economics majors in Šibenik- Knin County. They gave clear answers to the survey questions about the level of financial

literacy, which were modeled on the questions of Štedopis, the Institute for Financial Education. In addition to the general definition of the level of financial literacy, the research focused specifically on the general knowledge of students about consumer credit, and in this context it was revealed how familiar the respondents were with its term, its purpose, and the interest rate and repayment period, and considering the amount of advertisements regarding them they surround the same loan.

During their educational journey, pupils and students should acquire skills, attitudes and behavior resulting from acquired financial knowledge, which should ultimately provide them with financial well-being. Financial education can be seen as a control and preventive measure of everything related to investment, savings, interest, inflation and other financial components that coexist with the growth and development of everyday human activity. In the context of the respondents' answers, a clear insight was gained not only into the level of their financial knowledge, but also into the quality of the education system. Basically, the results indicate an extremely high level of financial literacy among Croatian pupils and students who are ready to step into creating their own financial well-being. The survey questionnaire contained three concretely separated parts. The first part included general data on the gender, age and level of education of the respondents, the second part included 32 questions about the level of financial literacy of the respondents, while the third part specifically contained five questions about familiarity with consumer credit. The collected points were converted into grades from 1 to 5, and the same grades were the basis for establishing a statistically significant relationship between the degree of financial literacy and knowledge about consumer credit, as dependent variables, and the level of education as an independent variable.

The research methodology includes the use of survey methods, statistical methods and correlation analysis. The results of the applied methods are presented in the continuation of the paper.

4.4. Research results

Out of a total of 131 respondents, of which 48 were students and 83 students, according to gender, 33 male and 97 female participants participated in the study, while only one person was undecided about their gender. If it is taken into account that 25% of male and female students, 74% of male and female students and 1% of unspecified students from the category of higher educational level participated in the research, it could be concluded that high schools and faculties of economic orientation in Šibenik-Knin County are attended by more people female.

In order to confirm the set research hypotheses, a correlation analysis was performed in the statistical program SPSS. The same analysis established a statistically significant relationship between the level of education and the degree of financial literacy, as well as the level of education and knowledge about consumer credit. The results of statistical significance are shown in Table 1 and Table 2.

Table 1 Correlation of respondents' status and level of financial literacy

Correlations			
		status	fin_literacy
status	Pearson Correlation	1	0,615**
	Sig. (2-tailed)		0,000
	N	131	131

fin_literacy	Pearson Correlation	0,615**	1
	Sig. (2-tailed)	0,000	
	N	131	131
**. Correlation is significant at the 0.01 level (2-tailed).			

Source: Created by authors

The first hypothesis (H1) read: It is assumed that the level of financial literacy increases with a higher level of education. The obtained correlation indicates a medium strong connection between the observed variables. Pearson's correlation coefficient of 0.615 indicates a significant statistical relationship between the level of education and the level of financial literacy. Based on the obtained analysis, the first scientific hypothesis (H1) is accepted as true. The analysis confirms a high level of financial literacy on the part of both pupils and students, and it increases with the continuation of studies.

Table 2 Correlation of respondents' status and level of knowledge about consumer credit

Correlations			
		status	knowledge_credit
status	Pearson Correlation	1	0,785**
	Sig. (2-tailed)		0,000
	N	131	131
knowledge_credit	Pearson Correlation	0,785**	1
	Sig. (2-tailed)	0,000	
	N	131	131
**. Correlation is significant at the 0.01 level (2-tailed).			

Source: Created by authors

The second hypothesis (H2) read: It is assumed that a higher level of education is significantly related to a higher level of knowledge about the terms of consumer credit. Correlation analysis, through a clearly expressed Pearson coefficient of 0.785, indicates an extremely high correlation between the level of education and knowledge about consumer credit. Based on the above, the second scientific hypothesis (H2) is accepted as true. The same hypothesis and analysis confirm extremely high knowledge of all concepts of consumer credit and the same knowledge increases with the level of education.

5. Conclusion

The results of the research are clear. Pupils and students of secondary schools and faculties of economics in Šibenik-Knin County are extremely financially literate. They clearly distinguish the concepts of consumer credit and clearly understand all general and key components of financial literacy. In the context of results, the educational system is defined as effective. Pupils and students in the context of financial literacy leave schools and colleges with a high degree of knowledge about financial concepts and with a pronounced attitude and behavior regarding the application of the same concepts in everyday life. However, if we exclude economic majors, the financial education of students in other high schools and colleges has room for improvement. Pupils and students of non-economic majors generally do not have systematic financial education, and the recommendation would be to integrate financial literacy into teaching programs. Financial literacy should be part of compulsory teaching in different classes and study programs. Furthermore, the availability of various courses and workshops on financial

literacy, adapted to different age groups, the use of games, simulations and group work would probably encourage greater engagement of pupils and students. Monitoring and evaluating the progress of pupils and students can provide insight into the achieved outcomes and, accordingly, the curriculum can be adapted to the needs. Financial education should not be limited only to formal educational institutions, it is necessary to systematically implement actions and raise awareness of the importance of financial literacy for all those involved in making financial decisions. Launching websites that offer free financial literacy lessons, videos and quizzes, as well as developing apps that help users learn financial concepts through a variety of interactive content can significantly improve the availability of financial education for all generations. For example, developing interactive games and simulation programs can enable users to make real financial decisions and learn to manage their finances under controlled conditions. Various seminars and workshops combining practical and theoretical knowledge can be organized in cooperation with local communities, libraries and non-profit organizations. Volunteer programs can also be organized where mentors, experts in the field of finance, volunteer to help individuals learn financial skills. Informing society about the importance of financial literacy can also be carried out through media campaigns on television, radio and social networks, as well as by publishing educational articles in newspapers, magazines or blogs. Adopting and implementing some of these ideas can significantly raise the level of financial literacy in society and ensure that all citizens have access to the knowledge needed to manage their finances. This paper provides valuable empirical data on the level of financial literacy of pupils and students of economics in the Šibenik-Knin County and can be used for further research, as well as the development of educational policies for the purpose of improving the financial literacy of the entire society.

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FLIPPING THE BUSINESS ENGLISH CLASSES

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1. Abstract.

Although not an entirely new teaching approach, the pandemics and the surge in educational technologies have urged course instructors and researchers of English for Specific Business Purposes (ESBP) to work more toward the practice of flipped classrooms. Additionally, the focus of teaching ESP in business has been towards introducing more computer-mediated communication into the curriculum, aiming at helping students to develop the potential communicative skills they might need in their future employment.

This paper examines the practices of traditional and flipped classroom approach in a Business English course for Bachelor students of the first-year majoring in Economics and Policies for Rural Development, Agricultural University of Tirana, Albania.

Through data analyses, collected using a questionnaire, the following issues were addressed: (i) the students' perceptions and preferences on a flipped classroom approach and a traditional learning approach, (ii) the impact that the abovementioned approaches have on three interdependent instructional goals, i.e. interaction, production and reflection, and (iii) enabling students to improve their skills especially in computer-mediated communication in the workplace.

The findings indicate that flipped classroom approach impacts student experience significantly. It encourages students to take the initiative in learning process and gives them ample time to study at their own pace and according to personal needs

Key words: *Flipped classes, Business English, ESP.*

2. Introduction

Flipped classroom is a relatively recent concept where the workload shifts from in-class to homework and vice versa. Published initially by Lage, Platt and Treglia (2000) and described later thoroughly by Bergmann & Sams, (2012) as the teaching approach where activities conventionally carried out in class, are required to be executed at home while on the other hand tasks and activities previously assigned as homework are carried out in groups, in pairs or with the assistance of the course instructor as class activity (Bergmann & Sams, 2012: 13. The key principles behind flipped classroom which are 'active learning' and 'student centred learning' align with the core principles of ESP, which is "an approach to language teaching in which all the decisions as to content and method are based on the learner's reason for learning" (Hutchinson and Water, 1987: 19).

As flipping the classroom is often combined with the use of information communication technologies (ICT), the idea of flipped learning is becoming more and more popular as it brings an innovative perspective to traditional education and many academic institutions are understandably keen to introduce it as a pedagogical approach in order to tap into their students' familiarity with new media. Various academics of ESP, who have studied at the outcomes employing digital tools in a flipped classroom, point out an encouraging impact on student progress, and satisfaction (Liu, 2006). The use of ICT has been increasingly influential on pedagogy and course design over the past decade (Woodrow, 2018). Flipping the classroom and increasing the use of digital tools means that instructors may also take advantage of the positive motivating factors that many learners report that they experience in working with on-line tasks, many of which are not constrained by the classroom walls (Liu, 2006).

The role of the teacher in a flipped classroom approach switches from a presenter of the knowledge and the centre of the activities to a more assistive role. They encourage students to be more active while taking on the role of the facilitator. Bergmann and Sam (2012) state that in the flipped model, the time is completely restructured, students ask questions about the content that has been delivered via video before the lesson, and the remainder of the time is used for more extensive hands-on activities and/or directed problem-solving time.

To serve the flipped approach, the traditional instruments used such as class handouts, textbooks, PowerPoint lectures, etc., leave their place for other forms of instruction such as the use of online education platforms (which emerged and became popular, especially during Covid19 pandemic) such as google classroom, Kahoot, YouTube videos and other digital tools. These digital tools are valuable for a teaching approach without walls, where students can choose to work outside the classroom.

This paper will find the answers to the following three research questions through qualitative and quantitative data gathered:

- a) What are the students' perceptions and preferences about the flipped classroom approach and the traditional learning approach? Which one do they find more suitable to meet their needs for language and communication?
- b) What is the impact that the above-mentioned approaches have on three interdependent instructional goals, i.e. interaction, production and reflection?
- c) What is the influence of a flipped class approach and the traditional learning approach in enabling students foster their skills in computer-mediated communication in the workplace?

3. Rationale for the study

Covid-19 pandemic emphasized the need for technology mediated education throughout the world. Teachers and course instructors almost overnight had to adapt their teaching methods employing remote teaching and learning digital devices. Many higher education institutions started using different LMS (Learning Management Systems) and the software facilitating the process soared instantly. The aim of this research is to investigate the perceptions of the students who take up Business English Courses about flipped classrooms approach using in teaching. The outcome of the research would be paramount in designing BE (Business English) courses and deciding on the teaching methods to be employed in the future, because it will enable course instructors to comprehend the motivation of students in flipped learning.

Furthermore, students' acceptance and assurance will play their part in further progress of any novel technology. In addition, the outcome of the study will benefit language instructors in overcoming challenges that students come across in flipped classrooms. This research also, will be valuable in finding out whether the usage of flipped classroom approach through tech devices proves to be efficient or not. As a result, it may be concluded that this research will have multidimensional gains.

4. Literature Review

According to Acarol (2019), due to the emergence of technology, many new teaching methods have been developed, flipped learning being one of these methods. By introducing the learners with the didactic material outside the classroom, the course instructor uses videotapes, online material, and different articles. In contrast to the online learning, flipped classroom approach encourages the learners to take a more active role in the process.

Flipping the classroom may benefit ESP language acquisition, yet, it comes with some drawbacks. Aiming at increasing students' language proficiency, flipped classroom enables teachers to reconsider time in class and allocate it to activities that could not previously be used due to time constraints of the lesson. While giving students a chance to improve their professional communication, it also encourages autonomous learning. However, the learners might possess inadequate autonomous learning ability, impacting negatively the implementation of flipped classroom, which is completely dependent on independent learning capacity of the students. Although, teachers provide learners with plenty of reading resources or materials in advance, the learners in a flipped classroom setting are required to explore the content of learning in greater depth by themselves (Sakulprasertsri, 2017). The learning-teaching activities around the four skills of the language such as listening to audio materials, providing information based on videos watched, grammar drilling or writing projects could be done at home through audio recordings, videos etc., therefore providing more time to practice English in class and more time to study at home. While watching videos stimulates students' language abilities, the learners might have problems with the adapting to the flipped learning if they are not autonomous learners. Additionally, they may be distracted on the Internet which may interfere with the learning process. As a consequence, staying focused and motivated is a challenge for autonomous learners without self-discipline.

Flipped classroom approach requires the cooperation between the teacher and the learners in order to implement the approach successfully. Firstly, the learners' reluctance to get involved in online learning may turn the approach ineffective in producing the intended outcomes (Yavuz & Ozdemir, 2019). Secondly, the role of infrastructure and digital tools is equally important. As we discussed earlier, these elements are fundamental for successful autonomous learning."

Flipped classroom approach might be limited by the lack of ICT resources and appliances as well as internet connection. Considering the fact that, flipped classroom approach encompasses videos and relies heavily on electronic devices, the ICT infrastructure has a significant role in ensuring the successful implementation of the approach.

5. The research methodology

The research method carried out in this study is quantitative and qualitative. The literature review revealed that many research papers have focused on flipped classrooms but in Albanian context, this research is a new one. The study was carried out among the first year Bachelor

students majoring in Economy and Policies for Rural Development, at the Faculty of Economy and Agribusiness, Agricultural University of Tirana, Albania during the academic year 2022-2023.

The sample comprised 90 students grouped in three classes. During the first semester, the traditional approach of teaching BE was employed with the content presented in class by the course instructor and homework assigned at the end of the class based on the activities carried out within the teaching session. The class routine involved mainly warm-up activity, going over homework, introduction of the new content and guided and independent practice.

During the second semester the class was inverted, thus using the flipped approach implementing the following stages: warm-up activity, Q&A time on video, optional tailor-made activity based on video: short quiz, recognition exercise, guided and independent practice: role-play, discussion, case study, giving a presentation.

The instrument used to gather data was a semi-structured questionnaire. It was created using Microsoft word and then converted into Google docs, leading to the final version of the questionnaire on Google forms. The questionnaire on Google form was delivered in the form of a link to the participants of the study. Data were processed and analysed using triangulation and the Statistical Package for the Social Sciences (SPSS) software version. In the current research different important statistical tests were used to test frequencies and most of them have been displayed in the form of tables. The results have been arranged in tables so the responses of the learners throw light into their perception of a flipped classroom, whether they consider it more/less satisfying to their needs for language and communication in actual and/or future profession and whether they think that BE classes should be implementing flipped classroom approach at the university.

6. Results

As it was mentioned earlier, the major trait of flipped classroom is giving homework, usually in the form of a video to familiarize the students with the upcoming topic Therefore, the first set of questions aimed to understand the students' opinions and experiences regarding the changes made to homework assignments.

- 91 percent of the students *declared that homework given prior to class was helpful and it made it easier to follow the activities performed in class.*
- When asked whether *they preferred the traditional way of doing homework of the inverted, flipped method*, the students responded 89 percent in favour of the latter.
- There was a positive reply of the respondents to the questions "*Does the flipped classroom approach help you understand the content easily?*" 82 % of the students felt that they were able to understand the content better and faster
- When asked whether they found *that the flipped classroom allowed them to control their pace of learning*, 78 percent of the students declared that they felt positive that they did.
- We also aimed to find out student's preference of particular form of prior-to-class preparation. Our respondents were asked to put the following forms into the order according to their preferences:
 - *Watching a video*
 - *Listening to an audio, podcast*
 - *Reading a text*

- *Looking up new words*
- *Summarize the video*
- *Doing grammar exercises*

The students' preferences were in favour of watching a video as the main activity to prepare before class with 88 % of answers. Doing grammar exercise resulted to be the least preferred activity when preparing for class with 24% of students' answers.

- The students were asked further to identify several ways *how the prior-to-class homework (in the form of watching a video) helped them during the class activities.*
 - 92 % of participants declared *that they felt more motivated and were more actively participating*
 - 87 % stated that *they felt more confident and at ease when they entered the class*
 - 55 % answered that *they were able to memorize more content in this way –*
 - A few of them, 4 % of participants pointed out that *they were lagging behind, since* it was not convenient for them to access material every time due to lack of internet or smart phone.

The above data indicate a promising result regarding the students' perception on the effectiveness of the flipped classes in ESP. They indicate that this approach has proved helpful and triggers motivation to enhance their language skills.

- When asked whether they think that the flipped classroom approach should be used during all their studies at the university, 82 % of the respondents would favour it all the time, 12 % of the respondents declared they would prefer it to be used sometimes while 6 % preferred not to use it anymore.

The success of the flipped classrooms depends on both the careful preparation and the implementation of the video based learning, so, the students were asked to list some benefits and limitations of using videos as a homework and preparation for class activities.

The table below gives an overview of the results.

Table 1. Benefits and limitations of using a video as a homework.

Benefits	Limitations
I can watch the video when I want, many times if I want	Sometimes the videos are long, I cannot concentrate
I understand more what happens in class	No internet
There are subtitles which help with new words	Sometimes, I put it off for later
I text my friends after the video and we talk about it	I like listening to the teacher more in class
I have more time to practice in class	
I search more about the topic if I find it interesting from the video	

Considering all the above data collected from the students' answers, it can be concluded that flipped classroom approach provides several benefits in ESP language instruction. The students' responses to the questionnaire were positive and they prefer flipped classroom to the traditional way of language learning.

7. Discussion

The flipped classroom approach is an innovative teaching method preferred to be used in higher education because it caters the demands of students with the help of ICT and digital

tools. The study showed that the students' perception of flipped classrooms among the students studying Business English in the faculty of Economy and Agribusiness was positive.

In this study, learners' perceptions of flipped classroom were explored by analysing data from the questionnaire. The participants perceived both advantages and drawbacks of flipped classroom. Participants in the study admitted that flipped classroom was a fruitful teaching approach because it motivated them to be more actively involved and manage time more efficiently. As a result, flipped classroom might improve participants' learning performance compared to the traditional way of teaching.

There was a progress indicated in the students' ability to understand the content of the lesson better and more easily through prior-to-class homework videos. Furthermore, it was found out that compared to traditional classes, the approach encouraged students to participate more actively and be more motivated for learning. As with every other approach, there are also drawbacks such as infrastructure, internet connection and digital devices that may be not available to everyone.

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Track 1

Accounting and Finance

COMPARATIVE ANALYSIS OF STOCK INDICES IN SOUTHEAST EUROPE

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Abstract. Capital markets are a very important intermediary between companies that need capital for their business ventures and creditors who participate in the capital market in order to increase the value of their stake in the long term. The most important capital markets are the bond market, the stock market and the foreign exchange market. One of the key stock market performance indicators are the stock market indices that measure the value of the stock or a segment of the stock market that can be classified according to economic activity. They are used to observe the behavior of a group of stocks, and by reviewing the average behavior of a group of stock over the years investors can gain an insight into the performance of a group of shares. The region of Southeast Europe is still in a period of transition, and the current macroeconomic situation deters investors from trading on the relevant capital markets they consider it a risky investment. The main focus of this paper is the structure of stock market indices that use the free-float market capitalization methodology and the interpretation of the reason of their movements in the last six months. The relevant stock market indices are BELEXline (Serbia), SBITOP (Slovenia), BUX (Hungary), BIFX (Bosnia and Herzegovina), MONEX (Montenegro) MBI10 (North Macedonia) and finally CROBEX (Croatia). The aim of this paper is to interpret the influence of external factors on the stock market indices.

Key words: *capital markets, stock market, stock indices*

1. Introduction

Any marketplace where securities trading occur can be referred as financial markets. They play a vital role in allocating wanted capital between creditors who want to increase their stake and businesses who need capital for their business ventures, thus merging businesses and creditor's needs. Main functions of financial markets are:

- capital formation,
- price determination,
- liquidity provision,
- risk management,
- information dissemination and
- promoting economic stability and growth.

Some of the most important types of financial markets are the bond market, the stock market, the forex market (these markets make up the capital market), the over-the-counter market, and rising in popularity, the cryptocurrency market. For the purpose of writing this paper, the authors will present up close the stock market in Southeast Europe.

2. Capital markets

Capital markets are made up of the suppliers and users of funds. Suppliers include households as well as institutions like pension and retirement funds, life insurance companies that generate excess cash. On this market financial products such as equities (stocks) and debt securities (bonds) are mostly traded. Trading on capital markets takes place on primary markets where the issued bonds and stock appear for the first time and on secondary markets where previously issued stocks and bonds are being traded. As said earlier, the most relevant capital markets are the bond market, the stock market and the foreign exchange market.

2.1. Stock markets

Stock markets refers to several exchanges in which shares of publicly held companies are bought and sold. Such financial activities are conducted through formal exchanges and via OTC marketplaces that operate under a defined set of regulations. The stock market allows buyers and sellers of securities to meet, interact and transact. The markets allow for price discovery for shares of corporations and serve as a barometer for the overall economy. Buyer and sellers are assured of a fair price, high degree of liquidity and transparency as market participants compete in the open market. Stock markets provide a secure and regulated environment where market participants can transact in shares and other eligible financial instruments with confidence and low operational risk. Companies sell stocks to gain additional funds to grow their business, launch new products or pay off debt. The first time a company issues stocks to the public is called the initial public offering or IPO.

THE STOCK MARKET EXPLAINED

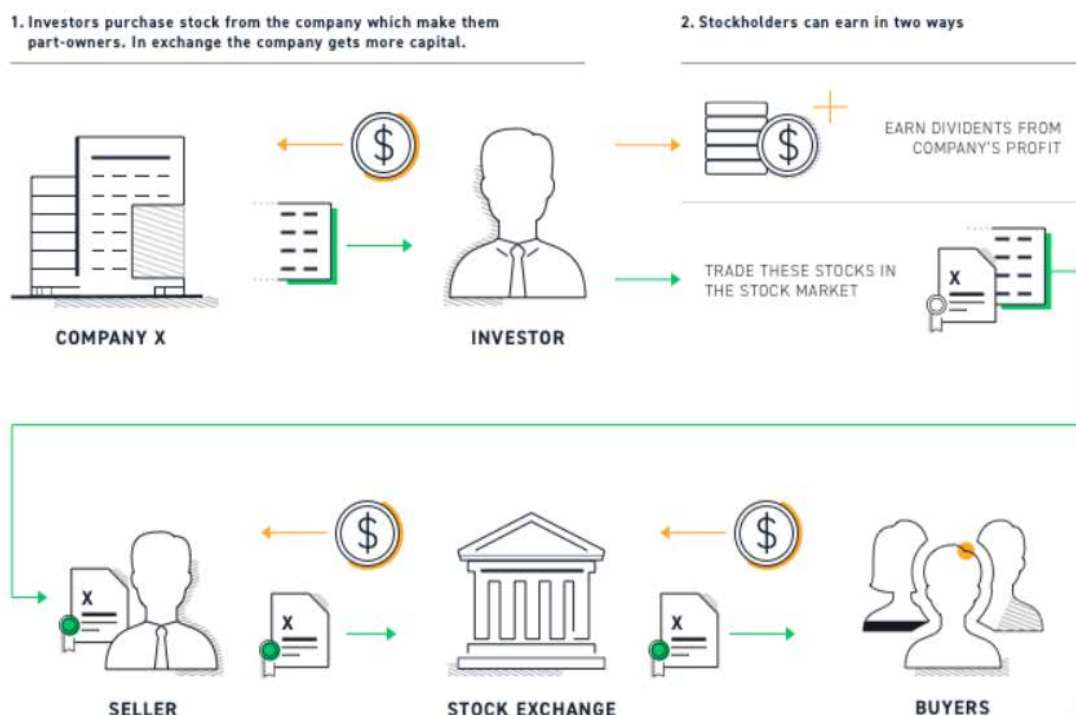


Figure 1 Functioning of stock market

2.2. Stock indices

The stock market index is a measure of the total value of the stock market or a segment of it based on average price. Stock indices can be valued using weighted average, so stocks with a higher price have a higher weight and have higher impact on the index apart from stock with a lower price. One of the most known stock indices are:

- Dow Jones Industrial Average (DJIA) – stock index published by the Dow Jones Corporation and consists of the 30 largest publicly traded companies in the USA,
- S&P 500 – stock index consisting of the 500 largest US publicly traded companies,
- Nasdaq Composite – stock index containing all the stocks that are traded on Nasdaq, most of them are technology firms,
- FTSE 100 – stock index of the 100 most capitalized British corporations listed on the London stock Exchange,
- DAX – stock index of the 30 largest German companies that are traded on the Frankfurt Stock Exchange,
- CAC 40 – stock index of the 40 biggest French companies that are traded on the Paris Stock Exchange,
- Nikkei 225 – stock index of the 225 largest publicly owned companies in Japan that are traded on the Tokyo Stock Exchange and
- MSCI Europe – stock index created by Morgan Stanley Capital International, which covers stocks across 15 developed market countries in Europe (Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the UK).

3. Stock indices in Southeast Europe

3.1. The Belgrade Stock Exchange (*Beogradska Berza*)

The Belgrade Stock Exchange was founded in 1894 with the first transactions concluded in 1895. After the Second World War, the Stock Exchange was closed and resumed operations in 1989 as the Yugoslav Capital Market. In 1992, the Yugoslav Capital Market changed its name to the Belgrade Stock Exchange. In the 1990s, the most traded securities were corporate debt instruments, government bonds and similar. Although the first trades in share were carried out in 1991, it was only in 2000 that a significant step forward was made when shares from the privatization process were included in the secondary market. Today, the Belgrade Stock Exchange is a modern market-oriented exchange which operates the only securities exchange in Serbia.

3.1.1. Stock index BELEXline

The BELEXline index represents the basic benchmark index of the Belgrade Stock Exchange with the aim to precisely describe price movements on the domestic capital market. BELEXline is a stock index weighted by market capitalization that is in free circulation (free float) which is not adjusted for paid dividends. It consists of shares that are traded on the Regulated Market of the Belgrade Stock Exchange which meet the criteria for entry into the index. The weight of components in the index is limited to a maximum of 10% in relation to the free float market capitalization of the index. The index committee is the body of the Belgrade Stock Exchange that decides what issuers can be located within BELEXline.

BELEXline - 19.04.2024.

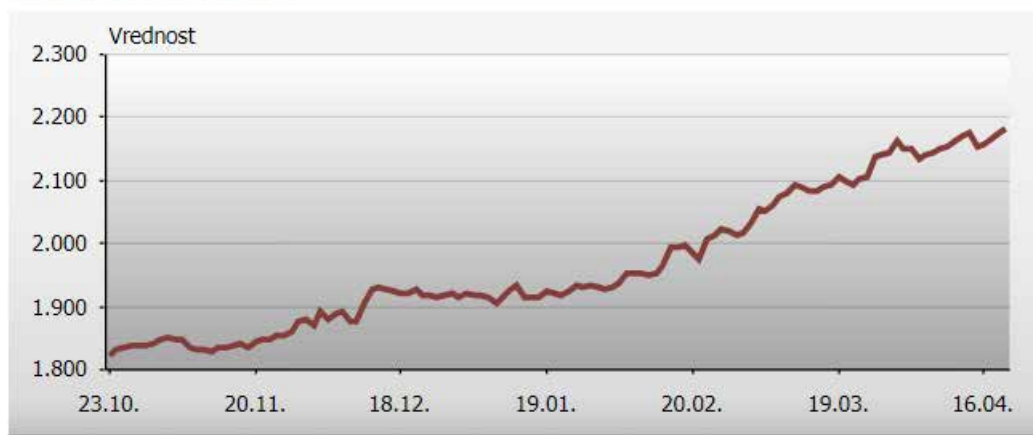


Figure 4 Value of BELEXLine as of 19/04/2024

As visible in the figure, the official stock market index of the Belgrade Stock Exchange BELEXLine recently had a value of around 2.050,00 points and it is the highest the stock market index has ever had. The stocks that have been most successful from 10/2023 are Fintel energija a.d. (which reported 3 times higher net profit in 2023 comparing it to 2022), NIS a.d. (eng. *Petroleum industry of Serbia* although they reported 50% less net profit in 2023 comparing it to 2022).

3.2. The Ljubljana Stock Exchange (*Ljubljanska borza*)

The first traces of the Ljubljana Stock Exchange began in early 1922, when businessmen gathered around the industrialist Dragotin Hibar, endeavouring to set up another stock exchange besides the one in Zagreb. Upon the opening of the exchange on 18/08/1924, 27 securities were traded and the majority were state securities and the rest were securities of Slovenian financial institutions and industrial enterprises. After a break of almost 50 years, trading was resumed in the early 1990's. Stockbrokers last gathered on the stock market floor on 14/12/1995 and since then trading has been exclusively electronic. On 30/12/2015, the Zagreb Stock Exchange bought shares from the CEESEG group (earlier major stockholder). Since 2017, in addition to managing the organized market, the stock exchange has also been managing a multilateral trading platform called the SI ENTER market. The latter enables trading in securities that are not listed on the stock exchange market and compared to the OTC market, ensures more transparent and better exchange rate design.

3.2.1. Stock market index SBITOP

SBITOP is the official stock market index of the Ljubljana Stock Exchange, calculated from 31/03/2006. It consists of shares listed on a regulated market operated by the Exchange, with SBITOP weighted composition being mostly dependent on market capitalization, free float and liquidity of each share. The number of shares in SBITOP shall not be smaller than 5 or greater than 15. The weight of a single share in SBITOP must not exceed 30%.

Index Movement in Last 6 Months ▾



Figure 5 Value of SBITOP as of 21/04/2024

The main stock market index in Slovenia (SBITOP) increased 213 points or 17.04% since the beginning of 2024, according to trading on a contract for difference (CFD) that tracks this benchmark index from Slovenia.

Historically, the Slovenia Stock Market (SBITOP) reached an all time high of 2675.70 in September of 2007. Slovenia Stock Market (SBITOP) - data, forecasts, historical chart - was last updated on April 21st of 2024.

3.3. The Budapest Stock Exchange (*Magyar Értéktőzsde*)

The Budapest Stock Exchange (BSE), established in 1864, stands as Hungary's primary stock exchange, pivotal in enabling the trading of securities and fostering capital formation within the nation. Throughout its history, it has dynamically evolved, adapting to shifts in market dynamics and regulatory landscapes. Key facets of the BSE encompass its diverse array of listed securities, spanning stocks, bonds, derivatives, and structured products, offering investors avenues to engage with Hungarian enterprises and government debt. Furthermore, the BSE maintains crucial market indices like the BUX Index, aiding investors in assessing returns and market trends. Operating within a regulatory framework overseen by entities such as the Hungarian National Bank and the Hungarian Financial Supervisory Authority, the exchange ensures transparency and investor safeguarding. Facilitating interactions among diverse market participants including investors, broker-dealers, market makers, and listed companies, the BSE fosters liquidity and market efficiency. Leveraging electronic trading platforms, the exchange enables seamless transactions and provides real-time market data, underpinning its role as a linchpin in Hungary's financial ecosystem, bolstering domestic capital market development and fostering economic advancement.

3.3.1. Stock market index BUX

The BUX index, the primary index of the Budapest Stock Exchange, was established in 1991 to provide an overview of the performance of key stocks in the Hungarian market. Over

time, the index has gone through various stages of development and adaptation, from its initial composition of 12 stocks to changes in its makeup and criteria for inclusion or exclusion of stocks. Its history reflects changes in market conditions, including geopolitical events, economic crises, and Hungary's accession to the European Union. Today, the BUX index is a key indicator of the performance of the Hungarian capital market, providing investors with insight into the movement of prices of the most important stocks on the Budapest Stock Exchange.

The BUX index consists of the most important stocks listed on the Budapest Stock Exchange. Its composition typically includes leading Hungarian companies from various sectors such as finance, energy, telecommunications, trade, and industry. The specific companies that make up the BUX index may change over time depending on their importance in the market, financial performance, and other factors. It is also important to note that the composition of the index may be subject to periodic revisions to ensure its relevance and representativeness for the Hungarian capital market.



Figure 6 Value of BUX as of 21/04/2024

The main stock market index in Hungary (BUX) increased 5866 points or 9.68% since the beginning of 2024, according to trading on a contract for difference (CFD) that tracks this benchmark index from Hungary.

Historically, the Hungary Stock Market (BUX) reached an all time high of 67076.42 in April of 2024. Hungary Stock Market (BUX) - data, forecasts, historical chart - was last updated on April 21st of 2024.

3.4. The Sarajevo Stock Exchange (*Sarajevska burza*)

The Sarajevo Stock Exchange (SASE), established in 2002, stands as the primary securities exchange in Bosnia and Herzegovina, serving as a vital platform for trading a variety of financial instruments, including stocks, bonds, and investment funds. Playing a pivotal role in

capital formation and economic growth, SASE provides investors with opportunities to engage in the Bosnian financial market. Key aspects of SASE encompass its listing and trading services for securities issued by Bosnian entities and international organizations, enabling portfolio diversification and investment in the local economy. Moreover, SASE maintains market indices such as the SASX-10 Index, serving as benchmarks for assessing investment returns and market trends. Operating within a regulatory framework overseen by the Securities Commission of Bosnia and Herzegovina, SASE ensures transparency, fairness, and investor protection. Drawing various participants including investors, brokerage firms, listed companies, and market intermediaries, SASE fosters liquidity, efficient price discovery, and trading activities. Leveraging electronic trading platforms, SASE provides real-time market data and facilitates seamless execution of orders, enhancing market efficiency and participant interaction. Overall, SASE plays a crucial role in Bosnia and Herzegovina's financial infrastructure, contributing to the development of the domestic capital market and bolstering investor confidence.

3.4.1. Stock market index BIFX

The Bosnian Investment Fund Index (BIFX) is the first index published by the Sarajevo Stock Exchange. It consists of the shares of the 11 investment funds registered in the Federation of Bosnia-Herzegovina (formerly Privatization Investment Funds - PIFs).

BIFX is a price index, meaning that no cash dividends are reinvested in the index, therefore it reflects only the price development of the included shares. By its purpose, it is considered a benchmark index, whose main goal is to provide investors a general view and evaluation of the current market trends in the segment of investment funds listed at the Sarajevo Stock Exchange. BIFX is a (full) market capitalization index with no capping procedures.



Figure 7 Value of BIFX as of 21/04/2024

In this period, BIFX's largest value was in October 2023 where it was 742 points and since then it has decreased to 652 points as of today. The conclusion is that Bosnian Investment funds have been poorly trading on both domestic and global markets.

3.5. The Montenegro's Stock Exchange (Montenegroberza)

The Montenegro Stock Exchange (MNSE), established in 1993, serves as the primary securities exchange in Montenegro, providing a vital platform for trading various financial

instruments such as stocks, bonds, and investment funds. Its role in facilitating capital formation, supporting economic development, and offering investors opportunities in the Montenegrin financial market is crucial. Noteworthy features of MNSE include its provision of a marketplace for listing and trading securities issued by Montenegrin companies, government entities, and international organizations, enabling portfolio diversification and exposure to the local economy. Moreover, MNSE maintains market indices like the MNSE Index, serving as benchmarks for assessing investment returns and market trends. Operating under the supervision of the Capital Market Authority of Montenegro (CMA), MNSE ensures transparency, fairness, and investor protection through its regulatory framework. Attracting various participants including investors, brokerage firms, listed companies, and market intermediaries, MNSE facilitates trading activities, maintains market liquidity, and fosters efficient price discovery. Leveraging electronic trading platforms, MNSE provides real-time market data and facilitates seamless execution of buy and sell orders, enhancing market efficiency and participant interaction. Overall, MNSE stands as a critical component of Montenegro's financial infrastructure, contributing significantly to the development of the domestic capital market and bolstering investor confidence.

3.5.1. Stock market index MONEX

MONEX is the general (benchmark) index of the Montenegro Stock Exchange aimed at describing the price movement of the most representative shares on the Official and Free market segment of the Montenegro Stock Exchange. Index MONEX represents the successor of the index MONEX20. MONEX is an weighted by market capitalization that is in free circulation and which is not adjusted for dividends paid and is not shielded from the dilutive effect that occurs as a result from dividend payments. The share of the free float market capitalization of an individual share in the total free float market capitalization of the index on the day of regular audit cannot exceed 10%.

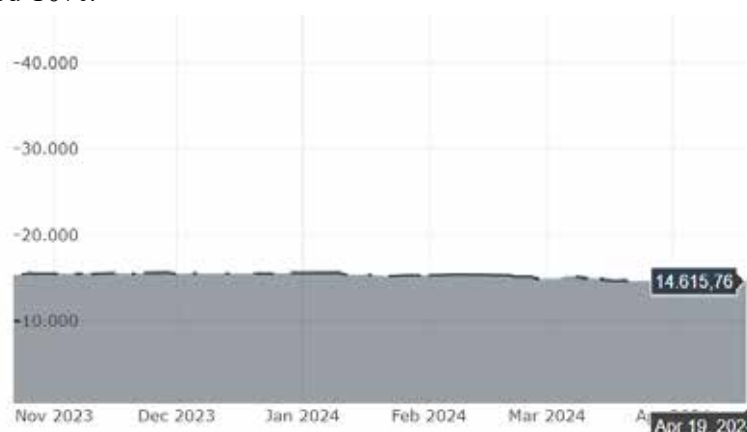


Figure 8 Value of MONEX as of 21/04/2024

The main stock market index in Montenegro (Monex) decreased 784 points or 5.03% since the beginning of 2024, according to trading on a contract for difference (CFD) that tracks this benchmark index from Montenegro.

Historically, the Montenegro Stock Market Index (MONEX INDEX) reached an all time high of 15632.05 in November of 2023. Montenegro Stock Market Index (MONEX INDEX) - data, forecasts, historical chart - was last updated on April 21st of 2024.

3.6. Macedonian Stock Exchange (*Makedonska berza*)

The Macedonian Stock Exchange (MSE), founded in 1995, stands as the primary securities exchange in North Macedonia, serving as a pivotal platform for trading various financial instruments, including stocks, bonds, and investment funds. Its role in facilitating capital formation, supporting economic growth, and offering investors opportunities in the Macedonian financial market is crucial. Key attributes of the MSE encompass its provision of a marketplace for listing and trading securities issued by Macedonian companies, government entities, and international organizations, enabling portfolio diversification and exposure to the local economy. Additionally, the MSE maintains market indices like the MBI-10 Index, serving as benchmarks for assessing investment returns and market trends. Operated under the supervision of the Securities and Exchange Commission of North Macedonia (SECNM), the MSE ensures transparency, fairness, and investor protection through its regulatory framework. Drawing various participants including investors, brokerage firms, listed companies, and market intermediaries, the MSE fosters trading activities, maintains market liquidity, and promotes efficient price discovery. Leveraging electronic trading platforms, the MSE provides real-time market data and facilitates seamless execution of buy and sell orders, enhancing market efficiency and participant interaction. Overall, the Macedonian Stock Exchange plays a pivotal role in North Macedonia's financial infrastructure, significantly contributing to the development of the domestic capital market and fostering investor confidence.

3.6.1. Stock market index MBI10

The MBI10 index, also recognized as the Macedonian Stock Exchange (MSE) Broad Market Index, serves as a comprehensive measure of the performance of the most liquid stocks traded on the Macedonia Stock Exchange. Established by the Macedonia Stock Exchange (MSE), this benchmark index consists of the ten most actively traded stocks listed on the MSE, aiming to offer investors a succinct overview of the Macedonian stock market's overall performance. By closely monitoring the price fluctuations of these selected stocks, the MBI10 index provides valuable insights into the prevailing trends and sentiments within the Macedonian equity market.

Since its inception, the MBI10 index has evolved into a fundamental tool for investors, analysts, and market participants seeking to evaluate the performance and volatility of the Macedonian stock market. It serves as a pivotal reference point for assessing investment returns and constructing portfolios. In essence, the MBI10 index plays a pivotal role in enhancing transparency, liquidity, and visibility within the Macedonian equity market, thereby fostering its development and attracting both domestic and international investors. The index's diverse composition, encompassing various sectors such as finance, telecommunications, energy, manufacturing, and services, further enhances its utility in providing investors with a comprehensive representation of the Macedonian stock market, enabling them to make informed investment decisions based on the overall performance of the exchange.



Figure 9 Value of MBI10 as of 21/04/2024

The main stock market index in Macedonia (MBI 10) increased 937 points or 15.33% since the beginning of 2024, according to trading on a contract for difference (CFD) that tracks this benchmark index from Macedonia.

Historically, the North Macedonia Stock Market Index (MBI 10) reached an all time high of 10057.77 in August of 2007. North Macedonia Stock Market Index (MBI 10) - data, forecasts, historical chart - was last updated on April 21st of 2024.

3.7. The Zagreb Stock Exchange (*Zagrebačka burza*)

The Zagreb Stock Exchange (ZSE), established in 1991, serves as Croatia's primary securities exchange, acting as a vital platform for trading various financial instruments including stocks, bonds, investment funds, and derivatives. Its pivotal role in facilitating capital formation, supporting economic development, and providing investors with opportunities in the Croatian financial market is indispensable. Key features of the Zagreb Stock Exchange include its provision of a marketplace for listing and trading securities issued by Croatian companies, government entities, and international organizations, thereby enabling portfolio diversification and exposure to the Croatian economy. Additionally, the ZSE maintains several market indices such as the CROBEX Index, which serve as benchmarks for assessing investment returns and market trends across different sectors and segments of the Croatian stock market. Operated under the supervision of the Croatian Financial Services Supervisory Agency (HANFA), the ZSE ensures transparency, fairness, and investor protection through a robust regulatory framework. Drawing various participants including investors, brokerage firms, listed companies, and market intermediaries, the ZSE facilitates trading activities, maintains market liquidity, and fosters efficient price discovery. Leveraging electronic trading platforms, the ZSE provides real-time market data and facilitates seamless execution of buy and sell orders, thereby enhancing market efficiency and enabling seamless interaction among market participants. Overall, the Zagreb Stock Exchange plays a critical role in Croatia's financial infrastructure, significantly contributing to the development of the domestic capital market and fostering investor confidence.

3.7.1. Stock market index CROBEX

The CROBEX, the main index of the Zagreb Stock Exchange, commenced its history in 1997, reflecting the movements of the 20 most liquid stocks in the market. Following an initial period of instability, the index felt the impact of the global financial crisis in 2008 but gradually recovered, adapting to changes in the structure and performance of companies. Croatia's accession to the EU in 2013 further influenced the capital market, while the CROBEX continues

to serve as a key indicator of the Croatian market, reflecting both local and global economic trends.

The CROBEX index comprises the average value of the shares of the 20 most liquid companies on the Zagreb Stock Exchange, serving as a measure of the performance of the Croatian capital market, tracking changes in the prices and liquidity of the most important shares. The movement of the CROBEX is monitored as an indicator of the overall health and direction of development of the Croatian economy and serves as an important tool for investors in assessing market trends and making investment decisions.

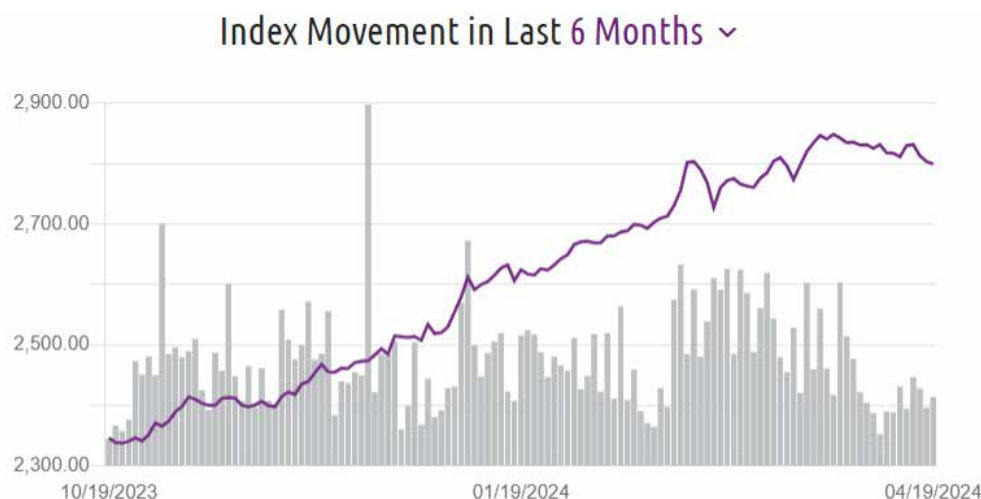


Figure 10 Value of CROBEX as of 21/04/2024

The main stock market index in Croatia (CROBEX) increased 284 points or 11.21% since the beginning of 2024, according to trading on a contract for difference (CFD) that tracks this benchmark index from Croatia.

Historically, the Croatia Stock Market (CROBEX) reached an all time high of 5392.94 in October of 2007. Croatia Stock Market (CROBEX) - data, forecasts, historical chart - was last updated on April 21st of 2024.

4. Conclusion

This research analysed the performance of stock indices in Southeast Europe over the past six months, focusing on the BELEXline (Serbia), SBITOP (Slovenia), BUX (Hungary), BIFX (Bosnia and Herzegovina), MONEX (Montenegro), MBI10 (North Macedonia), and CROBEX (Croatia). The findings highlight significant variations in stock market performances across the region, influenced by a range of macroeconomic, political, and sector-specific factors.

BELEXline demonstrated the highest growth among the indices analyzed. This surge can be attributed to the strong performance of key stocks such as Fintel energija a.d. and NIS a.d., reflecting investor confidence in Serbia's energy sector and overall economic stability.

SBITOP experienced a substantial increase of 17.04% since the beginning of 2024. This indicates Slovenia's economic resilience and the attractiveness of its market to investors. The robust performance of leading companies in the index has bolstered this growth.

BUX also showed notable growth of 9.68%, reflecting positive investor sentiment towards the Hungarian market. Factors such as favorable economic policies and strong corporate earnings contributed to this upward trend.

BIFX recorded a decline, suggesting weaker performance among Bosnian investment funds.

This could be a result of economic challenges and political uncertainties affecting investor confidence.

MONEX fell by 5.03%, highlighting potential difficulties within the Montenegrin market. Factors such as lower foreign investment and economic instability might have contributed to this decrease.

MBI10 showed a significant increase of 15.33%, indicating positive trends in the North Macedonian market. Improved economic conditions and investor optimism in key sectors likely drove this growth.

CROBEX increased by 11.21%, showcasing the stability and growth of the Croatian market. Strong performances in the tourism and manufacturing sectors have played a critical role in this rise.

The analysis underscores the importance of monitoring macroeconomic indicators, political developments, and sector-specific performances when evaluating stock market trends in Southeast Europe. Investors should remain vigilant about these factors to make informed investment decisions.

Stable economic policies and growth prospects in countries like Slovenia and Hungary have positively impacted their stock markets. Continued emphasis on sound economic management will be crucial for sustained growth.

Political stability plays a significant role in investor confidence. Countries facing political uncertainties, such as Bosnia and Herzegovina, may see adverse effects on their markets.

Identifying high-performing sectors, such as energy in Serbia and tourism in Croatia, can provide valuable investment opportunities. Diversification across well-performing sectors can mitigate risks and enhance returns.

Enhanced economic cooperation and integration within Southeast Europe could attract more foreign investment and boost overall market performance.

Further research could delve deeper into sectoral performance within these indices to understand the drivers of growth in specific industries. Additionally, examining the impact of specific political and economic events on market volatility would provide more granular insights into the dynamics of these markets.

By understanding the interplay of these factors, investors and policymakers can better navigate the complexities of the Southeast European stock markets and leverage opportunities for growth and stability.

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THE ROLE AND IMPORTANCE OF THE INSURANCE SECTOR IN THE FINANCIAL SYSTEM OF THE REPUBLIC OF CROATIA

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Abstract. The insurance sector should play a crucial role in the financial system of a particular country. It serves as a cornerstone for financial stability, risk management, and economic development. Firstly, insurance provides individuals, businesses, and institutions with protection against various risks. By transferring these risks to insurers, individuals and businesses can mitigate potential financial losses, thereby promoting economic stability and confidence. Moreover, the insurance sector facilitates long-term savings and investment. This is particularly true for life insurance which fosters a culture of financial preparedness and resilience. Additionally, insurance companies invest premiums in diverse financial instruments, contributing to the liquidity and efficiency of the overall financial market. Although in 2022 the Croatian insurance sector had a share of 5,79% in total assets of financial sector intermediaries it has a vital role in the country's financial system contributing significantly to the overall stability and prosperity of the financial system and the broader economy.

Key words: *insurance sector, financial system, Republic of Croatia*

1. Introduction

Insurance company denotes a legal entity with head office in the Republic of Croatia pursuing the life or non-life insurance business, and which has received the authorisation from the Croatian Financial Services Supervisory Agency and which is registered in the court register of the competent commercial court (Insurance Act, Official Gazette No. 30/2015, 112/2018, 63/2020, 133/2020, 151/2022). The same Act stipulates the insurance activities which includes the conclusion and performance of non-life and life insurance contracts, other than compulsory pension, compulsory health, and compulsory social insurance.

Apergis & Poufinas (2020) describe insurance as one of the crucial activities in a globalised economic and financial environment. The insurance sector plays a key role in the financial systems acting as a basis for risk management, financial stability, and economic development. It provides individuals, businesses, and institutions with protection against numerous risks, including accidents, natural disasters, health issues, and property damage. By transferring these risks to insurers, businesses and individuals can mitigate potential financial losses. In doing so, it promotes economic stability and confidence.

Furthermore, the insurance industry enables long-term savings and investments. Life insurance products, such as annuities and retirement plans, encourage individuals to save for the future, encouraging a culture of financial awareness and resilience. Also, insurance companies invest premiums in diverse financial instruments, contributing to the liquidity and efficiency of the overall financial market.

Additionally, the insurance sector promotes entrepreneurship and investment by providing coverage for business ventures and projects. Insurance policies, such as liability insurance and

business interruption insurance, reassure investors and lenders, reducing the perceived risks associated with entrepreneurial activities. This, in turn, encourages entrepreneurship, fosters innovation, and stimulates economic growth.

In the Republic of Croatia, the insurance sector has a key role in supporting the country's economic development objectives. By safeguarding individuals and businesses against unforeseen events, encouraging long-term savings and investment, and facilitating entrepreneurship and investment, the insurance sector contributes significantly to the overall stability and prosperity of the financial system and the broader economy. Some of the papers dealing with the issue of investigating the role of insurance on overall economic development of a particular country are described below.

Employing a sample of 29 countries in Europe in the period 1992 – 2005, Haiss & Sümegi (2008) study the role of insurance companies' premiums and investments on GDP growth. After performing a cross-country panel data analysis, they find a positive influence of life insurance on GDP growth in the sample countries, Norway, Iceland and Switzerland. However, in Central and Eastern European countries, this impact is larger for liability insurance.

Ul Din, Abu-Bakar & Regupathi (2017) try to examine if insurance supports economic growth using the sample of 20 developed and emerging countries in the period 2006–2015. Their study finds a significant and positive relationship between life insurance, expressed with net premiums written and insurance density, and economic growth for developed countries while this holds true for developing countries as well when level of insurance development is expressed with share of premium in GDP. When it comes to non-life insurance segment, it has statistically significant relationship with economic growth in developing countries when all three proxies are used. However, when using the sample of developed countries, the results are statistically significant when premium per capita is employed as a proxy for insurance.

Mohy ul din, Regupathi & Abu-Bakar (2017) investigate the effect of insurance on economic growth using a set of countries with different level of development. They find, among other things, a positive and statistically significant relationship between both life and non-life insurance segments, stock-market development, trade openness, and economic growth in the long-term. Moreover, their findings highlight positive and significant association between non-life insurance and economic growth in the short-term for the UK, the USA, India, China, Pakistan, and Malaysia.

Apergis & Poufinas (2020) examine the contribution of insurance growth to economic growth encompassing the sample of 27 OECD countries. The authors' results provide evidence that gross operating expenses, gross claims payments, gross written premium and share of premium in GDP are positively and significantly associated with economic growth.

2. The Level of Development of Croatian Insurance Market

The most commonly used measures of the level of insurance development include gross written premium per capita or insurance density as well as the share of gross written premium in GDP or insurance penetration. Insurance density, measured by annual gross written premiums divided by population relates to average spending on insurance premiums per capita, providing insight into individual-level insurance consumption. Together with the share of premium in GDP, which indicates the extent to which insurance services are utilized within an economy, are recognized as important development measures and applied by in papers by e.g. Ma & Pope (2008), Han et al. (2010), Kwon & Wolfrom (2017), Abel & Marire (2021) to name a few.

Table 1 Dynamics of Development Indicators of Croatian Insurance Market

Insurance density (GWP per capita)		
TOTAL		LIFE
2017	293	95
2018	324	103
2019	349	101
2020	349	88
2021	437	n.a.
Insurance penetration (GWP in GDP)		
2017	2.2%	0.81%
2019	2.2%	0.82%
2019	2.4%	0.77%
2020	2.6%	0.73%
2021	2.7%	n.a.

Source: authors according to data from Insurance Europe, European insurance industry database for the years 2017-2020, <https://www.insuranceeurope.eu/statistics>, Croatian Insurance Bureau, 2022 Key Facts Insurance market in the Republic of Croatia for the year 2021, https://huo.hr/upload_data/site_files/50080073312399367632126070587_kljucne-informacije-2022-web.pdf

Observing the values of gross written premium per capita for total market, it can be noticed that it steadily increases from 2017 to 2019. That growth was halted in 2020 due to the coronavirus pandemic, whereas in 2021, a significant growth is evident again. Regarding share of gross written premium in GDP its constant growth is evident throughout the observed period. Insurance market development indicators in life insurance segment record significantly more modest values in terms of insurance density and gross written premium in GDP.

All indicators point to significant potential for growth in insurance premiums in the Republic of Croatia, especially when compared to European Union member states.

Table 2 Dynamics of Development Indicators of EU* Insurance Market

Insurance density (GWP per capita)		
TOTAL		LIFE
2017	2,125	1,374
2018	2,248	1,449
2019	2,188	1,304
2020	2,093	1,178
2021	n.a.	n.a.
Insurance penetration (GWP in GDP)		
2017	7.6%	4.61%
2018	7.9%	4.78%
2019	7.4%	4.19%
2020	7.4%	3.96%
2021	n.a.	n.a.

Source: Insurance Europe, European insurance industry database, <https://www.insuranceeurope.eu/statistics>

*Comprises EU member states plus Switzerland, Norway, Turkey and UK

As shown with Tables 1 and 2, insurance market development indicators in Croatia tend to be lower compared to EU countries. This suggests that insurance services are not as widely utilized or accessible in Croatia as they are in more developed EU markets. Moreover, EU insurance markets often offer a wider range of insurance products catering to diverse needs, including

primarily life insurance, property and casualty insurance, health insurance, and specialized lines such as cyber insurance. In Croatia, while basic insurance products are available, the market may be less developed in terms of product diversity and innovation. This primarily relates to the share of life insurance in the total gross written premium, as shown in Table 3. The lower dominance of life insurance in the total premium in Croatia reflects a combination of economic, cultural, social, and market-related factors that shape consumer behaviour and preferences in the insurance market.

Table 3 Dynamics of the share of life and non-life insurance in total premiums

Year/insurance segment	non-life	life
2017	67.6	32.4
2018	68.2	31,8
2019	71.0	29.0
2020	74.7	25.3%
2021	75.3%	24.7%

Source: Croatian Financial Services Supervisory Agency, Annual Report, various issues, <https://www.hanfa.hr/publications/annual-report/>

To sum it up, although Croatian insurance market is integrated into the broader European insurance landscape, differences in market maturity, consumer behaviour, regulatory frameworks, and economic factors contribute to variations in the level of development between Croatian and EU insurance markets. These are primarily economic conditions, such as GDP growth, unemployment rates, and income levels, influence insurance market development. Croatia's economic performance relative to EU countries can affect the demand for insurance products and the overall growth potential of the insurance market.

3. Position of Insurance Sector in the Croatian Financial System

Insurers form a part of the financial system and signify essential financial institutions as well as institutional investors. The significance of insurance companies in the financial system of the Republic of Croatia in 2022 is demonstrated by their share of assets in the total assets of all financial intermediaries. This is shown with Table 4.

Table 4 Structure of Assets and Relative Importance of Financial Intermediaries in the Republic of Croatia in 2022

Financial Intermediary	Assets*	Share**
Commercial banks	76,328	71.03
Mandatory pension funds	17,543	16.33
Insurance companies	6,222	5.79
Leasing companies	2,949	2.74
UCITS investment funds	2,166	2.02
Voluntary pension funds	1,057	0.98
Alternative investment funds	647	0.6
Pension insurance company	346	0.32
Investment funds established under special legal acts	147	0.14
Factoring companies	31	0.03
Housing savings banks	22	0.02
TOTAL	107,456	100

Source: Croatian Insurance Bureau, 2022 Key Facts Insurance market in the Republic of Croatia, https://huo.hr/upload_data/site_files/50080073312399367632126070587_kljucne-informacije-2022-web.pdf, p. 9

*** Absolute values u millions of €, share in %

As it can be seen from Table 4, the Croatian financial system is bank-centric with commercial banks playing a central and dominant role in providing financial services, mobilizing savings, and allocating capital within the economy. Commercial banks hold a large portion of financial assets and are key intermediaries between savers and borrowers. Other financial institutions, including insurance companies, exist but have a less prominent role in comparison. Specifically, insurance companies are ranked third in terms of their share of total assets among financial institutions (5.79%), immediately after banks and mandatory pension funds.

However, the assets of insurance companies in the financial sector have been slowly but gradually increasing, except for the year 2022. For example, the assets of Croatian insurers amounted to 5.6 billion euros in 2018, while at the end of 2022, they amounted to 6.2 billion euros. This is presented with Figure 1.

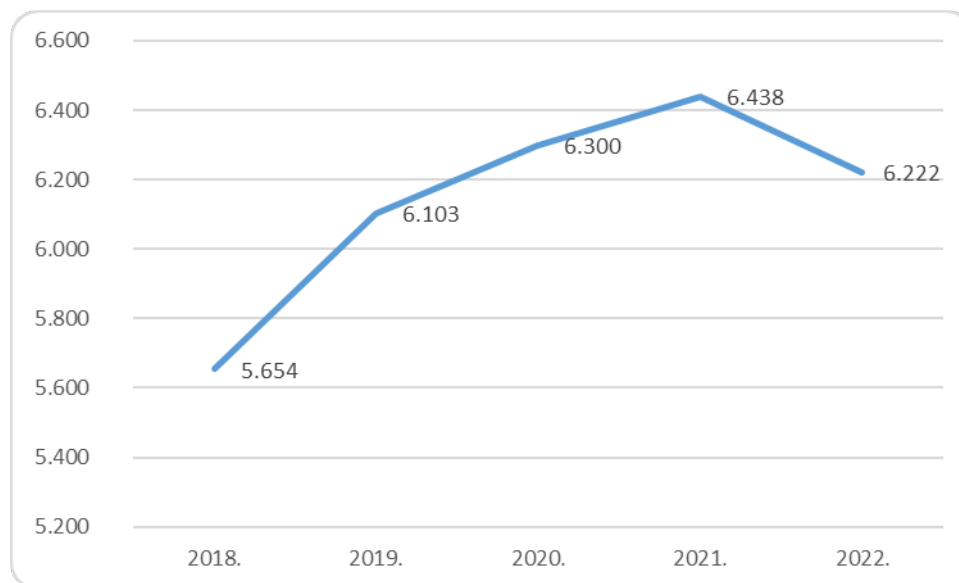


Figure 1 Dynamics of Total Assets of Insurance Companies in the Period 2018 – 2022*

Source: authors according to the data from Croatian Insurance Bureau,
Key Facts Insurance market in the Republic of Croatia, various issues

* All values in millions of euros, conversions from the Croatian national currency to euros in the period 2018 – 2021 have been made at the official middle exchange rate of the Croatian National Bank as at 31 December in a respective year

Another indicator of the level of development and representation of insurance sector in the financial system as a whole, is the structure of household savings presented with Figure 2. In this context, insurance companies and pension funds have a share of 27.59% in 2022 meaning that out of 100 euros of financial assets of an average resident of the Republic of Croatia, 28 euros are invested in pension funds and insurance.

Such structure of financial assets in the household sector specifies the need to promote and develop long-term dedicated savings. Overall long-term dedicated savings of the population are underrepresented and, in this sense, insurance companies should play a key role in the future.

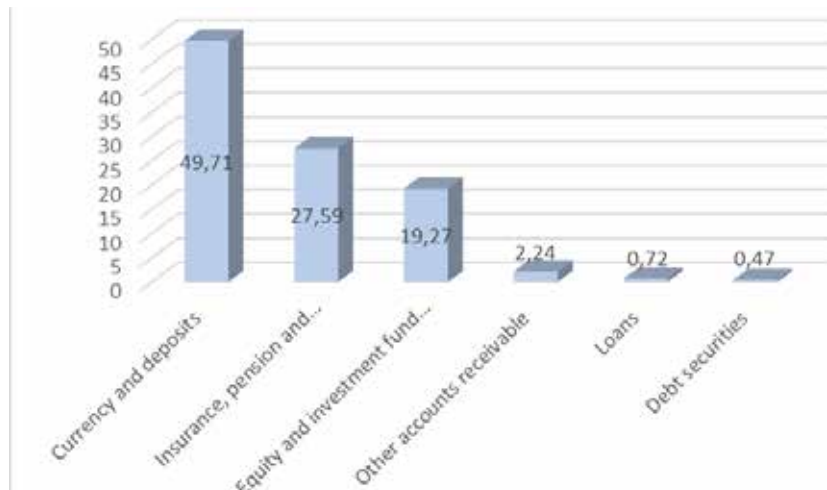


Figure 2 Financial Assets of the Household Sector in the Republic of Croatia in 2022 (%)

Source: Croatian Insurance Bureau, 2022 Key Facts Insurance market in the Republic of Croatia, https://huo.hr/upload_data/site_files/50080073312399367632126070587_kljucne-informacije-2022-web.pdf, p. 10

It has been previously stated that insurance companies represent important institutional investors. Insurance companies, along with pension and mutual funds, are among largest institutional investors in real-estate, bond, and stock markets (Haiss & Sümegi, 2008). Investments are a key component of insurance companies' assets, accounting for 74.7% of Croatian insurers' total assets and amounting to 4,645 million euros at the end of 2022 (Croatian Insurance Bureau, 2022 Key Facts, p. 11).

Insurance companies are generally conservative, long-term investors. They invest a large portion of their assets in government bonds. Specifically, at the end of 2022 investments in debt financial instruments accounted for 64.3% of total investments. With such investment policy, insurance companies are significant investor in the Croatian financial market, strongly contributing to the developmental role of the economy. Furthermore, due to the long-term nature of financial resources, they are a significant factor for the stability of the financial sector and market.

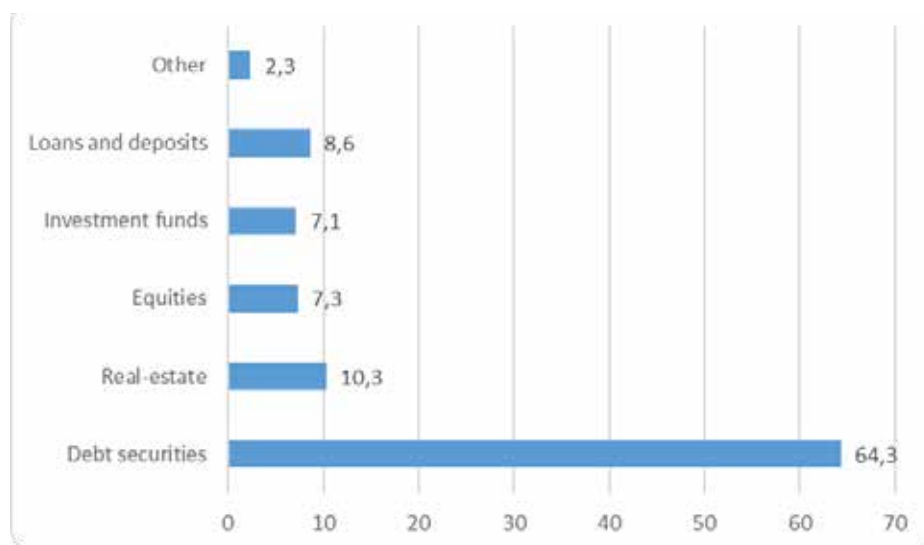


Figure 3 Structure of Croatian Insurance Companies' Investments in 2022 (%)

Source: Croatian Insurance Bureau, 2022 Key Facts Insurance market in the Republic of Croatia, https://huo.hr/upload_data/site_files/50080073312399367632126070587_kljucne-informacije-2022-web.pdf, p. 12

Specifically, as stated by Apergis & Poufinas (2020), insurance companies contribute to the financing of corporations and governments since they invest in both equity and debt, both public and private. According to the same authors, large fraction of insurers' investments in debt in equity "is returned to the local economy of the country where they domicile or do business, thus, suggesting that insurance contributes to the growth of an economy, through the use of the premiums it receives".

4. Conclusion

The insurance sector plays a crucial role in the financial system of any country, including the Republic of Croatia. It serves as a foundation for financial stability, risk management, and economic development. By providing protection against various risks, facilitating long-term savings and investments, and promoting entrepreneurship, insurance companies contribute significantly to the overall stability and prosperity of the economy.

Despite facing challenges such as the economic impact of the COVID-19 pandemic and lower levels of insurance market development indicators compared to EU countries, Croatian insurance market shows potential for growth. The steady increase in gross written premiums per capita and the share of gross written premiums in GDP indicate positive momentum in the insurance sector.

Furthermore, the role of insurance companies as institutional investors is noteworthy, with investments forming a significant portion of their assets. By investing in diverse financial instruments, including government bonds, insurers contribute to the liquidity and efficiency of the financial market and support economic development.

Looking ahead, there is a need to further promote and develop the insurance market in Croatia, focusing on enhancement of product diversity and innovation. Strengthening the role of insurance companies as long-term investors and encouraging dedicated savings among the population will also be essential for fostering sustainable economic growth and financial stability.

In summary, while challenges remain, the insurance sector in Croatia has the potential to play an even more significant role in supporting the country's economic development objectives and contributing to overall prosperity in the years to come.

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EFFECTIVE INTEREST RATE: CALCULATION AND IMPORTANCE IN DECISION-MAKING

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Abstract. Loan represents a specific debtor-creditor relationship between a lender and a borrower, with terms typically set by the lender and formalized in a contract between the parties. Interest, as the cost of loan, plays a pivotal role in this dynamic. Borrowers must carefully evaluate risks, comprehend borrowing terms, and compare offers to make informed financial decisions. The true cost of loan is conveyed through the effective interest rate, which ensures transparency by encompassing all relevant fees alongside the nominal interest rate. This paper aims to clarify the concept and methodology of calculating the effective interest rate achieved by using MS Excel and its Goal Seek macro. It also demonstrates importance of effective interest rates in comparing loan options across different credit institutions focusing on household general-purpose cash loans. In addition, this paper also gives overview and comparison of interest rates in Croatia and other European Union countries. Research shows that the effective interest rate offers a more precise view of total loan costs, aiding consumers in decision-making. Examining loans with identical amounts and repayment durations, with or without agreed-upon insurance premiums, highlights the need for consumers to evaluate additional terms and advantages offered by the credit institution when selecting a loan.

Key words: *effective interest rate, loan costs, household general-purpose cash loans*

1. Definition of effective interest rate

The effective interest rate represents the true cost of loan from particular credit institution, encompassing not only the nominal interest rate but also other loan expenses like fees and other direct costs. In the Republic of Croatia, the effective interest rate is precisely defined by the Decision on the effective interest rate and the Decision on amendments to the Decision on the effective interest rate issued by the Croatian National Bank. According to the Decision, the effective interest rate is “interest rate that represents the total cost of the credit to the consumer, expressed as an annual percentage of the total amount of the credit, and equates, on an annual basis, to the present value of all existing or future commitments (drawdowns, repayments and fees) agreed by the creditor and the consumer” (Official Gazette, 2017). This definition ensures a standardized representation of interest rates, enhancing transparency regarding borrowing costs and offering a more accurate and comprehensive overview of loan pricing. Credit institutions but no other lenders, as per the Decision, are obligated to compute and disclose the effective interest rate to the public and clients. This mandates banks and other loan providers to feature the effective interest rate prominently in their loan marketing efforts and provide the borrowers

with an informative form containing a clearly stated effective interest rate before finalizing any loan agreement.

The highest permissible effective interest rate for consumer loans is established as the statutory default interest rate for other relationships (which are not business transactions or commercial contracts, i.e., contracts between merchants and public entities) increased by two percentage points (Official Gazette, 2009). The statutory default interest rate is determined by increasing the interest rate applied by the European Central Bank to its most recent main refinancing operations conducted before the first calendar day of the current semester by three percentage points (Official Gazette, 2013).

The primary purpose of calculating the effective interest rate is to provide consumers with information on the total costs of the loan they must pay in relation to the loan agreement. The effective interest rate is influenced by: the nominal interest rate, the amount of various fees that the borrower is obliged to pay during the loan approval process, and the amount of loan insurance instruments (Šegota, 2012). The Consumer credit act stipulates that “total cost of the credit to the consumer means all the costs, including interest, commissions, taxes and any other kind of fees which the consumer is required to pay in connection with the credit agreement and which are known to the creditor,” and “‘total amount payable by the consumer’ means the sum of the total amount of the credit and the total cost of the credit to the consumer” (Official Gazette, 2009). The total cost of loan includes the costs of maintaining an account recording both payment transactions and drawdowns and other costs relating to payment transactions unless the opening of the account is optional and the costs of the account have been clearly and separately shown in the loan agreement or in any other agreement concluded with the consumer. (Official Gazette, 2009). The Decision on the effective interest rate mandates that if ancillary services relating to the consumer loan agreement, in particular insurance, are obligatory for securing the consumer loan, their cost shall be included in effective interest rate calculation (Official Gazette, 2017).

Expenses excluded from the effective interest rate calculation comprise default interest, which the borrower must pay for failing to meet loan agreement obligations, along with fees charged by a notary public and miscellaneous costs like postage and telegrams and like. Moreover, supplementary services offered by the bank are omitted from the effective interest rate calculation if the borrower is provided with prior notification regarding the service and retains the option to opt out at any time during the contract period without incurring additional charges or affecting the loan agreement (Škorić, 2021). Once the loan agreement is finalized, the credit institution is prohibited from introducing new fee.

2. Methodology of effective interest rate calculation

The calculation of the effective interest rate is based on the assumption that the provisions of the loan agreement are to remain valid for the period agreed and that both contractual parties will fulfil their obligations according to the terms and deadlines specified in the agreement. If agreement contains provisions allowing variations in the interest rate or provisions for variability of fees during the contract, the effective interest rate shall be calculated assuming that the interest rate and other costs will remain fixed relative to the level set on the date of contract conclusion (Official Gazette, 2017).

For the calculation of the effective interest rate, end of the period compound interest calculation is applied. Compound interest calculation method implies calculation interest on interest, while end of the period interest calculation is an interest calculation method where interest is calculated and added to the principal, at the end of the capitalisation period. In the

case of compound interest calculation method at the end of the period interest is calculated at the end of the capitalisation period on the principal increased by interest from the previous capitalisation periods.

“The basic equation used for effective interest rate calculation equates, on an annual basis, the total present value of drawdowns on the one hand and the total present value of repayments and payments of fees on other hand, i.e.:

$$\sum_{k=1}^m C_k (1+X)^{-t_k} = \sum_{l=1}^{m'} D_l (1+X)^{-s_l}, \quad (1)$$

where symbols have the following meanings:

X = effective interest rate;

m = the number of the last drawdown;

k = the number of drawdown tranches, thus $1 \leq k \leq m$;

C_k = the amount of drawdown k ;

t_k = the interval, expressed in years and fractions of a year, between the date of the first drawdown and the date of each subsequent drawdown;

so $t_1 = 0$;

m' = the number of the last repayment or payment of fees;

l = the number of repayment or payment of fees;

D_l = the amount of repayment or payment of fees,

s_l = the interval, expressed in years and fraction of a year, between the date of the first drawdown and the date of each repayment or payment of fees” (Official Gazette, 2017).

“The equation (1) can be rewritten using a single sum and the concept of flows (A_k) which will be positive or negative, in other words either paid or received during periods 1 to n expressed in years, i.e.:

$$S = \sum_{k=1}^m A_k (1+X)^{-t_k} \quad (2)$$

where S is the present balance of flows. If the aim is to maintain equivalence of flows, the value will be zero” (Official Gazette, 2017).

“The effective interest rate adjusted by the effect of the cash deposit and endowment life insurance policy shall be obtained by multiplying the effective interest rate by the correction factor. The correction factor is the quotient of total discounted loan payments and total discounted loan payments reduced by total discounted flows of the cash deposit or the endowment life insurance policy. The correction factor may not be lower than one. The effective interest rate adjusted by the effect of cash deposit and endowment life insurance policy shall be calculated in accordance with the following formulae:

$$EIR^* = EIR \times CF \quad (3)$$

$$CF = \max \left\{ 1, \frac{TDLP}{TDLP - TDFCD} \right\}, \quad (4)$$

where the labels have the following meanings:

EIR^* = the effective interest rate adjusted by the effect of cash deposit or the endowment life insurance policy;

EIR = the effective interest rate;

CF = correction factor;

$TDLP$ - total discounted loan payments;

$TDFCD$ - total discounted flows of the cash deposit or the endowment life insurance policy” (Official Gazette, 2017).

3. Example of the effective interest rate on the loans calculation

Given the complexity of the methodology used to calculate the effective interest rate on the loans (it may happen that solution to the defining equations for the effective interest rate is not unique (Šego, 2008)), a simplified illustration of the calculation is provided through an example using MS Excel and its Goal Seek macro function (Čulinović-Herc & Dimitrić, 2006).

To demonstrate the calculation of the effective interest rate on the loan, the following hypothetical scenario is considered:

A client takes a loan in the amount of 200,000.00 €. The payment of the granted amount is on December 31, 2022. Client pays a security deposit equivalent to 10% of the granted loan on the same date. Security deposit is refunded to the client increased by 2% annual rate on the day of the final instalment payment and interest is calculated by applying the end of period compound interest. A loan is repaid in equal monthly annuities (instalments) with fixed 10% annual end of period interest rate. Repayment period is one year and equivalent interest rate is applied.

The following symbols are used in the calculation of equal monthly annuity and creating a repayment plan: C - loan amount, p - nominal end of period interest rate, n - number of loan repayments periods, a - amount of equal annuities (instalments), $r = 1 + \frac{p}{100}$ - nominal end of period interest factor.

In the given example: $C = 200,000.0$ €, $p = 10\%$ (annually), $n = 12$.

Given that the period to which the nominal end of period interest rate refers and compounding period must be identical, it is necessary to convert the nominal annual end of period interest rate to the compounding period, which in this example is a month.

The corresponding monthly end of period effective interest rate p' is calculated according to the following expression:

$$p' = 100 \cdot \left[\left(1 + \frac{p}{100} \right)^{\frac{1}{m}} - 1 \right], \quad (5)$$

where m is the number of compounding periods in the period to which the nominal end of period interest rate refers. In the above example, $m = 12$. So, corresponding monthly end of period effective interest rate is

$$p' = 100 \cdot \left[\left(1 + \frac{10}{100} \right)^{\frac{1}{12}} - 1 \right] = 0,797414, \quad (6)$$

and monthly end of period effective interest factor

$$r' = 1 + \frac{p'}{100} = 1 + \frac{0,797414}{100} = 1,00797414. \quad (7)$$

The amount of equal annuities is determined according to the equation

$$a = C \cdot \frac{(r')^n \cdot (r' - 1)}{(r')^n - 1} \quad (8)$$

and equals

$$a = 200.000 \cdot \frac{1,00797414^{12} \cdot (1,00797414 - 1)}{1,00797414^{12} - 1} = 17.543,1 \text{ €}. \quad (9)$$

Table 1 The repayment plan

Maturity Date	Annuity	Interest payment	Principal payment	Principal amount
31.12.2022.				200.000,00
31.01.2023.	17.543,11	1.594,83	15.948,28	184.051,72
28.02.2023.	17.543,11	1.467,65	16.075,46	167.976,26
31.03.2023.	17.543,11	1.339,47	16.203,64	151.772,62
30.04.2023.	17.543,11	1.210,26	16.332,85	135.439,77
31.05.2023.	17.543,11	1.080,02	16.463,09	118.976,68
30.06.2023.	17.543,11	948,74	16.594,37	102.382,31
31.07.2023.	17.543,11	816,41	16.726,70	85.655,61
31.08.2023.	17.543,11	683,03	16.860,08	68.795,53
30.09.2023.	17.543,11	548,59	16.994,52	51.801,01
31.10.2023.	17.543,11	413,07	17.130,04	34.670,97
30.11.2023.	17.543,11	276,47	17.266,64	17.404,33
31.12.2023.	17.543,11	138,78	17.404,33	0,00
Total	210.517,32	10.517,32	200.000,00	

Note: Calculation by authors according to the procedure outlined in Čulinović-Herc & Dimitrić (2006)

The repayment plan consists of the following columns: maturity date, annuity, interest payment, principal payment and principal amount (outstanding debt). Maturity date is a date when a particular cash flow occurs and actual (calendar) number of days in a month and in a year is used. Interest payment at the end of period k is calculated on the principal amount at the end of period $k - 1$. The amount of principal payment at the end of period k is difference between annuity and interest payment at the end of period k and principal amount at the end of period k is difference between principal amount at the end of period $k - 1$ and of principal payment at the end of period . The repayment plan for the loan from the example is given in Table 1.

The effective interest rate is calculated from the repayment plan. Table 2 shows repayment plan for the loan from the example which includes: maturity date, short description of a cash flow at a particular date, net cash flow, discounted net cash flow, discounted loan disbursement and discounted security deposit flows.

The net cash flows of current and future payments and receipts related to the loan, is discounted by the annual percentage rate so that their net present value equals zero. The annual percentage rate that equates the net cash flow to zero is calculated using MS Excel Goal Seek macro and amounts to 11,83%.

Client pays 20,000.00 € of a security deposit on December 31, 2022 and security deposit is refunded to the client on December 31, 2023 increased by 2% end of period compound interest rate amounting to 20,400.00 €.

Table 2 Repayment plan with calculated annual percentage rate

Maturity Date	Description	Net cash flow	Discounted net cash flow (11,83%)	Discounted loan disbursement	Discounted security deposit flows
31.12.2022.	Loan disbursement	-200.000,00	-200.000,00	200.000,00	
31.12.2022.	Security deposit	20.000,00			20.000,00
31.01.2023.	1. annuity	17.543,11	17.380,30		
28.02.2023.	2. annuity	17.543,11	17.219,01		
31.03.2023.	3. annuity	17.543,11	17.059,21		
30.04.2023.	4. annuity	17.543,11	16.900,89		
31.05.2023.	5. annuity	17.543,11	16.744,04		
30.06.2023.	6. annuity	17.543,11	16.588,65		
31.07.2023.	7. annuity	17.543,11	16.434,70		
31.08.2023.	8. annuity	17.543,11	16.282,17		
30.09.2023.	9. annuity	17.543,11	16.131,07		
31.10.2023.	10. annuity	17.543,11	15.981,37		
30.11.2023.	11. annuity	17.543,11	15.833,06		
31.12.2023.	12. annuity	17.543,11	15.686,12		
31.12.2023.	Disbursement of security deposit	-20.400,00			-18.240,60
Total			0	200.000,00	2.159,40

Note: Calculation by the author according to the procedure outlined in Čulinović-Herc & Dimitrić (2006)

According to the prescribed methodology, the annual percentage rate must be further adjusted by the one-time equivalent of the discounted cash receipts and disbursements related to the cash deposit used to secure loan repayment. From equation (4), it follows that the corrective factor is

$$CF = \frac{200.000,00}{200.000,00 - 2.159,40} = 1,0109.$$

The corresponding effective interest rate is obtained by applying formula (3) and is equal to

$$EKS^* = 11,83 \times 1,0109 = 11,96.$$

In the hypothetical scenario provided, it becomes clear that the initial nominal annual end of period interest rate of 10% is elevated to 11,83% annually due to the inclusion of the security deposit expense. Subsequently, after further adjustment in accordance with the methodology for effective interest rate calculation, it progresses from 11,83% to 11,96%, reflecting the impact of the security deposit.

When evaluating loan options, the effective interest rate serves as a crucial indicator of the overall cost, with lower rates generally indicating more favourable borrowing terms. Prudent decision-making extends beyond this single metric to encompass the comprehensive terms and conditions of the financing arrangement.

This principle is exemplified in a comparative analysis of general-purpose loan offerings from Privredna banka Zagreb, specifically between the standard general-purpose loan and the general-purpose loan with loan protection insurance. In the case of standard general-purpose loan amounting to 10.000,00 € with a repayment period of 7 years provided from Privredna banka Zagreb, the annual nominal end of period interest rate is 6,68%, resulting in an effective interest rate of 6,88%. For a general-purpose loan with loan protection insurance for the same amount and repayment period Privredna banka Zagreb offers an annual nominal end of period interest rate of 5,59%. However, this option requires a one-time payment of a loan insurance premium totalling 514,92€. Effective interest rate in this case is 7,41% and exceeds that of the standard general-purpose loan.

Comparing these two loans solely in terms of the effective interest rate, it can be concluded that the standard general-purpose loan is more favourable compared to the loan with loan protection insurance. When comparing other data (Table 3), it is evident that with the loan having a higher effective interest rate, the bank offers a more favourable nominal interest rate, resulting in the consumer paying less interest overall for the same loan amount. Additionally, the loan would be insured, and the total repayment amount would be approximately the same as with the standard loan without loan protection insurance. A higher effective interest rate does not necessarily mean that the loan is more expensive, and therefore, when comparing loans, it is always essential to thoroughly examine other terms and conditions in the loan agreement in addition to the effective interest rate.

Table 3 Comparative analysis of general-purpose loan offerings from Privredna banka Zagreb

	Standard general-purpose loan	General-purpose loan with loan protection insurance
Loan amount	10.000,00 €	10.000,00 €
Repayment period	7 years	7 years
Fee amount	No fee	No fee
Interest rate	6,68%	5,59%
Loan insurance premium	-	514,92 €
Effective interest rate	6,88%	7,41%
Total interest	2.602,42 €	2.153,25 €
Monthly annuity	149,37 €	144,13 €
The total amount paid by the consumer:	12.602,42 €	12.668,17 €

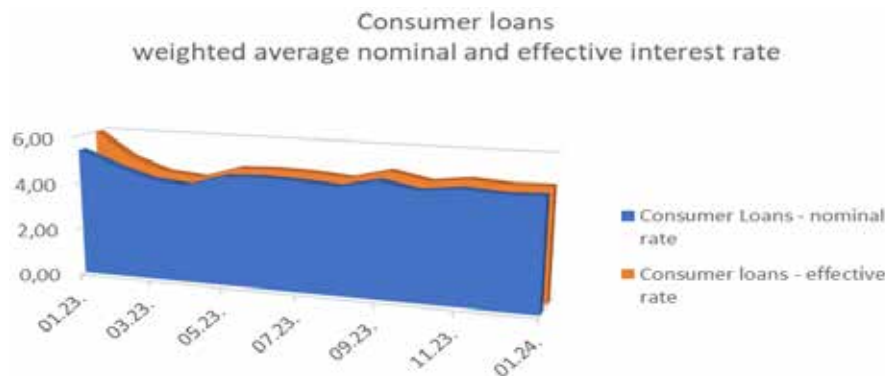
Note: Source of data is "Privredna banka Zagreb" [PBZ], n.d.

4. Overview and comparison of effective interest rates in Croatia and European Union

As previously stated, in specific cases spread between nominal and effective interest rate can be significant depending on the specific conditions of the loan.

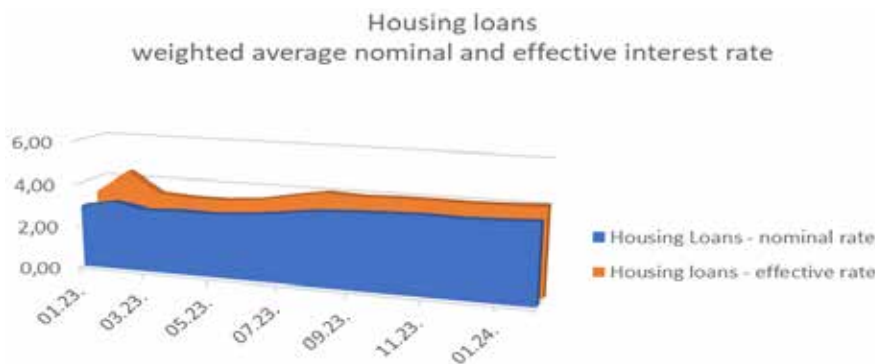
When observing total sum of loans given to households, differences between weighted average nominal interest rate and weighted average effective interest rates over the past year can be seen in Figures 1, 2 and 3. Spread between those two interest rates is relatively stable with rear peaks, which is expected given the fact that it shows average interest rates for total sum of loans.

Figure 1 Comparison of weighted average nominal and effective interest rate on consumer loans



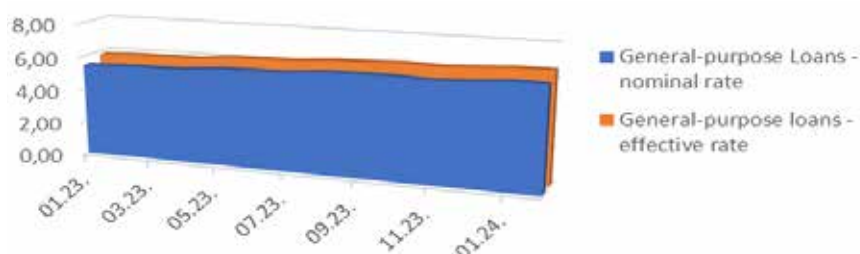
Note: Source of data is Croatian National Bank (CNB)

Figure 2 Comparison of weighted average nominal and effective interest rate on housing loans



Note: Source of data is Croatian National Bank (CNB)

Figure 3 Comparison of weighted average nominal and effective interest rate on general-purpose loans

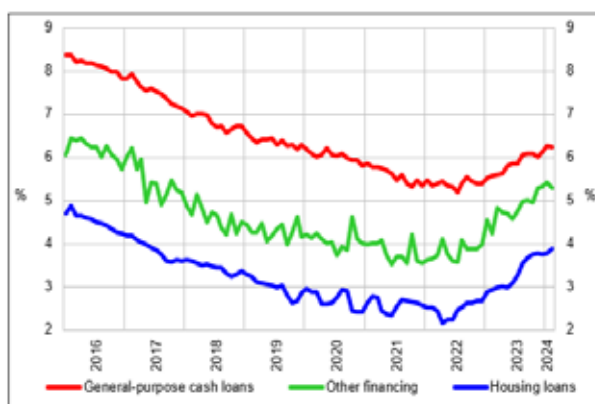


Note: Source of data is Croatian National Bank (CNB)

Analysis of different types of household loans shows that there are significant differences in interest rates among them. Figure 4 presents interest rates in Croatia in the period from year 2014 to 2024 for three main categories. In the observed categories, largest interest rates are on the general-purpose cash loans, while lowest interest rates are on the housing loans. Also, the

chart shows that interest rates on all loans had decreasing trend starting from the year 2014 till 2022, while in the last two years interest rates are significantly increasing.

Figure 4 Interest rates in Croatia, period from 2014 to 2024



Note: Source of data is Croatian National Bank (CNB)

After observing trend of interest rates within Croatia, it is also interesting to compare them across European Union. Figure 5 shows comparative analysis of effective interest rates on consumer loans across Europe. Consumer loans are the sub-category of specific-purpose loans. Categories are general-purpose loans and specific-purpose loans. It can be seen that in the last six years weighted average effective interest rates in Croatia are lower than the average of the European Union. Higher average interest rates of EU are significantly driven up by Estonia and Latvia whose rates are above 13%, followed by Lithuania, Greece, Slovakia and Portugal with interest rate of approximately 10%. The only countries with lower interest rates than Croatia are Luxembourg and Malta. Specific interest rates for each country are shown in the Figure 6.

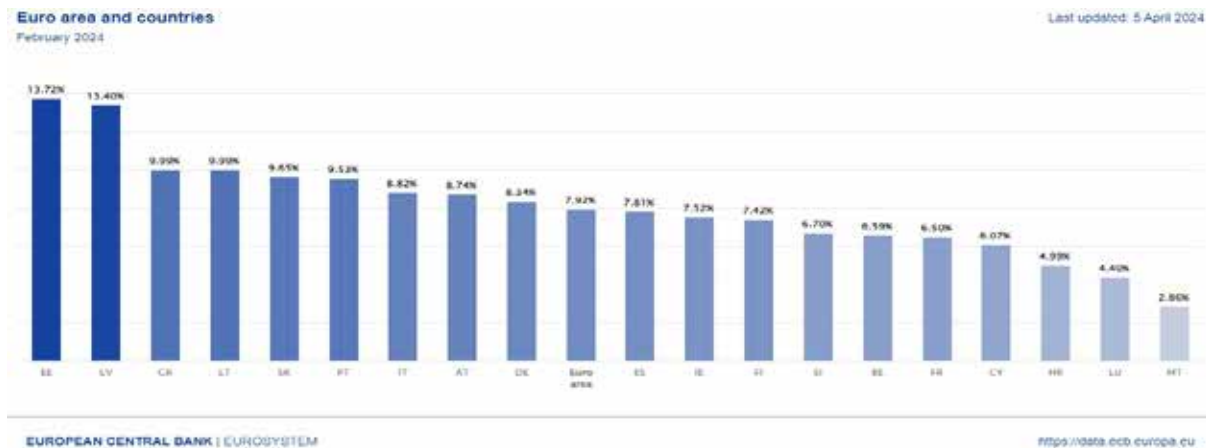
Figure 5 Effective interest rates in European Union, period from 2011 to 2024



Note: Source of data is European Central Bank (ECB)

Similar trends can also be seen in housing loans and other loans to households and CNB governor points out that higher difference in the last periods is the result of introducing euro as national currency. CNB analysis show that introduction of euro led to the relative reduction in interest rates, via two channels: due to lower sovereign risk premiums and lower regulatory costs for banks resulting from the harmonization with the Eurosystem monetary policy framework (CNB, 2003).

Figure 6 Country specific effective interest rates in European Union as at February, 2024



Note: Source of data is European Central Bank (ECB)

It should be noted that statistical data regarding financial institutions' interest rates published by CNB can differ from those published by ECB due to different methodology in grouping, organizing and publishing original data. Regarding effective interest rates, it should be pointed out that ECB methodology refers to narrowly defined effective interest rate as is defined for financial reporting purposes.

5. Conclusion

The effective interest rate provides a comprehensive view of the total cost of a loan, encompassing not only the nominal interest rate but also various fees and charges. By calculating the effective interest rate using the methodology prescribed by the Croatian National Bank, consumers can make more informed decisions when comparing loan options across different credit institutions.

The example calculation demonstrates how the effective interest rate can be higher than the nominal rate due to additional costs like security deposits. Comparing general-purpose loans from Privredna banka Zagreb shows that a higher effective interest rate does not necessarily mean a more expensive loan overall, as other factors like the nominal interest rate and total interest paid must also be considered.

Analysis of interest rate trends in Croatia reveals that effective rates have been lower than the European Union average for consumer loans in recent years. However, interest rates on all loan types have been rising since 2022 after a steady decline from 2014 to 2022.

In summary, the effective interest rate is a crucial metric for evaluating the true cost of a loan. While it provides a standardized basis for comparison, consumers should carefully examine all terms and conditions of a loan agreement to make the most informed borrowing decision.

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CHALLENGES OF FINANCING INVESTMENTS THROUGH STOCK ISSUANCE - CROATIAN EXAMPLE

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Abstract. In order for companies to generate profit, it is necessary for them to remain competitive, which is achievable only through new investments. Sources for this can be categorized into those from internal accumulation, borrowing from banks, issuing debt securities, and issuing new shares and exchanging them for capital on the stock market. The challenges of self-financing often involve insufficient funds for envisioned investment projects, and this method of financing also jeopardizes the liquidity of the company. This paper presents the main characteristics and methods of financing through stock issuance. Examples of financing through stock issuance by Croatian companies in the last twenty years are analyzed, highlighting the advantages and obstacles of this financing method. The paper seeks to explain the reasons why the capital of Croatian companies is still relatively closed compared to companies from developed market economies.

Keywords: *corporate financing, shares, initial public offering, closed corporate capitals.*

1. Introduction

Companies require funds for their growth and development. Although internal accumulation is the most common initial choice, companies often opt for external financing, i.e., financing from external sources. In bank-centric societies, companies are most commonly financed by loans from commercial banks. Such financing has several advantages, including the confidentiality of the relationship between banks and companies, significantly reducing the reputational risk a company may face due to loan rejection. However, for many companies with poor creditworthiness or inadequate collateral, favorable credit remains just a dream. As a result, business ideas cannot be realized, leading to a loss of competitive capability, and many companies are doomed to stagnation and often bankruptcy. This paper will analyze an alternative method of financing through financial markets for both rapidly growing young companies and medium-sized enterprises. It will describe the legislative framework for financing through financial markets in the Republic of Croatia, procedures and processes, analyze examples of financing through share issuance by Croatian companies over the past twenty years, and explain the reasons why the capital of Croatian companies is still relatively closed compared to companies in developed market economies.

2. Funding sources

According to the Miller-Modigliani theory, the capital structure has no effect on the economic value and cost of capital of a company. The capital structure refers to the combination of different securities used by companies to raise capital to finance their investment activities. Therefore,

the capital structure is the relative proportion of equity, long-term (and sometimes short-term) debt in the company's equity, and liabilities (balance sheet liabilities) of the company. (Vidučić, 2001, p. 784)

The traditional theory is based on minimizing the cost of capital for the company and maximizing its value. Advocates of this theory believe in the optimal capital structure that minimizes the company's financing cost. Since debt financing is cheaper for a company than equity financing, the total cost of the company's capital will be lower, and the company's value will be higher.

The pecking order theory builds on the Miller-Modigliani theory but additionally considers agency costs and costs of potential financial distress. When a company cannot meet its debt obligations to creditors through its operations, it indicates that the company has financing problems.

Models based on asymmetric information assume the existence of information asymmetry between managers and other employees of the company and external investors. (Vidučić, 2000, p. 242) This model is divided into the signaling theory, which suggests that managers have private information about the company's prospects, and the agency theory, which starts from the information asymmetry between managers and external investors, thereby defining the financing sequence preferred by managers.

The problems of self-financing often include insufficient funds for envisioned investment projects, and such a financing method can jeopardize the liquidity of the company. Additionally, shareholders have little control over this process, making deviations by managers possible.

Funding investment projects through commercial banks also bring certain challenges. Commercial banks have criteria that need to be met, including the company's creditworthiness, project feasibility, and quality collateral for the loan. Companies that cannot meet all three conditions often remain on the business sidelines.

The obstacles to financing through primary issuance and subsequent sale of shares on the secondary market are primarily the costs, dilution of ownership, fiscal discrimination, and complexity of the process. Since shareholders bear the economic risk foremost, they must also take on the risk because unlike loan funds, they do not have a guaranteed income. This means that as compensation for the risk taken, they demand higher returns on their capital. Additionally, the process of issuing and selling shares is quite complex and requires a significant amount of economic knowledge. Moreover, weak demand for shares is a failure on the part of managers, which is why many resort to the conventional method of financing through loans from banks.

Of course, there are many advantages to this financing method as well. Firstly, access to external sources enables faster growth for a company because the possibility of additional capital is much easier when the company is listed on the stock exchange. Listing on the stock exchange provides the company with a position that often allows for obtaining bank loans on more favorable terms than those not listed on the stock exchange. Additionally, the company can more easily adjust its financial structure by changing the ratio of debt and equity capital to finance itself under the most favorable conditions.

It's also important to emphasize the challenge of raising capital for young companies. Commercial banks simply do not cater to young companies, but rather focus on safer investments in established companies or personal consumption. Unfortunately, stock exchange authorities have not established sections specifically for offerings from young companies either. Here, we should look to more developed countries, where special sections have been created such as the English Investment Market, the French Nouveau Marché, or the German Neuer Markt. The requirement for listing on these markets is not primarily financial reports but rather development plans.

3. The process of raising capital

In order for companies to go public, they must meet legal requirements and exchange rules. Of course, first and foremost, they must have the approval of their shareholders at the general meeting of the company. In the Republic of Croatia, this area is regulated by the Securities Market Act (Official Gazette No 65/18).

When it comes to market choices, globally we have full listings (NYSE, ISE...), the market you're referring to is often known as the Unlisted Securities Market (USM) over-the-counter securities market (OTC). These markets primarily differ in terms of listing requirements and reporting criteria imposed on companies.

In Republic of Croatia, the Zagreb Stock Exchange operates. Founded in 1991, it continues the tradition of the Zagreb Stock Exchange for goods and securities, which operated between 1918 and 1946. Trading on the Zagreb Stock Exchange occurs with securities listed in one of the exchange's listings. It distinguishes between the prime, official, and regular market.

Issuance can be carried out through a public offering, which means the invitation is addressed to an indefinite number of people through public media, or through a private offering of securities, which means the invitation to subscribe to securities is addressed only to investment investors, the issuer's shareholders, employees, and up to twenty external investors.

Accordingly, the issuer is obliged to publish a prospectus (public offering) or provide potential investors with a prospectus for the issuance of securities (private offering). In addition to the invitation to subscribe to securities, the prospectus must contain complete, accurate, and objective information about the assets and liabilities, loss or profit, financial position, and prospects of the issuer, the purpose of raising funds, risk factors, and the rights conferred by the securities covered by the prospectus. Based on this information, potential investors can objectively assess the prospects and risks of the investment and make an investment decision.

When it comes to determining prices, there are two main methods for increasing a company's capital. The first involves the creation and sale of shares at an open price, while the second involves a closed price. In the first method, the placement of securities lasts for a very short time, usually just a few hours. Existing shareholders are asked to waive their preemptive rights. By waiving these rights, existing shareholders do not face dilution of their assets because the sale of new shares is conducted at a price close to the market price.

The second method of increasing capital involves predetermined issuance prices, followed by a longer placement period lasting at least ten days. With this method, a lower price is determined compared to the market price, and it includes the possibility of protecting existing shareholders from dilution of their assets. They do not have to exercise their right to subscribe to new shares; instead, they can sell it and prevent dilution of their assets.

The final way for a company to join the stock exchange is through introduction. In this case, there is no new issuance, and the company may not necessarily be interested in raising capital in the short term but simply wants to increase its presence in other capital markets. This is particularly important considering the growing internationalization of capital markets, as it provides a simple and inexpensive way to ensure international presence.

4. World trends and the reality in Croatia

Although the global pandemic briefly slowed down the world economy, the policy of increasing money supply by central banks, popularly known as quantitative easing, has revived Initial Public Offerings (IPOs) as a means of raising funds. The United States market

still stands out for the amount of funds raised through IPOs, but Asian markets are not far behind. Interestingly, a Polish company, InPost, raised a total of \$4 billion on the Frankfurt Stock Exchange. Companies from the technology and financial sectors have dominated the IPO process in recent years.

In recent times, there has been an increasing number of fast-growing Croatian companies whose market is global and who wish to finance their operations through an Initial Public Offering (IPO), where companies raise capital on regulated stock exchange markets from interested buyers in exchange for ownership stakes.

Below is a brief overview of the Zagreb Stock Exchange as a trading place for shares and an overview of IPOs from 2006 to the present day. Since the democratic changes in 1990, the capital market has needed to be revived several times because the number of securities listed there was too small, and consequently, the trading volume was too low. Unfortunately, privatization went another way, often non-transparently, mostly through direct contracts in which Croatian citizens did not have the opportunity to actively participate. One such attempt was the legal provision for the listing of public joint-stock companies. The listing requirements for shares on this market were considerably more lenient compared to the official market.

The growth of the Croatian capital market began in 2005 with the attempted takeover of the then-powerful pharmaceutical giant Pliva d.d. by the Icelandic company Actavis. It continued with the offering of shares from the state portfolio of companies such as INA d.d. and T-HT d.d. At that time, the Croatian public became acquainted with the capital market as a place where money could be made. However, most citizens were financially uneducated, thinking that the capital market was a one-way street where money could not be lost. Reality set in very quickly, with the 2008 bankruptcy announcement of the American financial giant Lehman Brothers.

The official index of the Zagreb Stock Exchange plummeted from 5,245.58 points on January 2, 2008, to just 1,722.19 points on December 31, 2008, within a year. In 2009, it continued to decline to its lowest recorded value of 1,262.58 points on March 9, 2009, meaning that CROBEX lost 75.94% of its value during that period. Since then, the Zagreb Stock Exchange has experienced a period of stagnation and has not fully recovered, except for some bright moments for companies in the tourism and financial sectors.

Figure 1 The movement of CROBEX over the past 5 years



Source: Zagrebačka burza, available at: <https://zse.hr/hr/indeks/365?isin=HRZB00ICBEX6&tab=index> (accessed 25th April 2024)

Although the Croatian capital market has not yet recovered, and it is uncertain when it will return to the levels seen at the beginning of 2008, it is important to note that even much larger and more well-known markets required a prolonged recovery. The S&P index, for instance, only

reached pre-crisis levels in 2013. However, despite many investors getting burned by investing in stocks on the Zagreb Stock Exchange, it doesn't mean that trading on it is unprofitable. In fact, the basics of investing dictate that one should buy undervalued assets and sell overvalued ones. Moreover, domestic stocks were extremely expensive at the end of 2007 and the beginning of 2008, mostly overvalued, indicating a classic bubble scenario. (Brkljača, 2024)

Table 1 Potential positive and negative impact on ZSE

POSITIVE IMPACT TO ZSE	THE NEGATIVE IMPACT TO ZSE
Economic growth	Opacity of the domestic capital market (use of nominee accounts, trading with undisclosed orders)
Credit rating upgrade	Loss of trust among minority shareholders in institutions meant to protect them
High levels of citizens bank savings and exceptionally low interest rates on those savings	Legal uncertainty – absence of final court judgments for any form of market abuse
Growth of EU economies, our largest trading partners	Insolvency and the resulting inefficiency of the ZSE
Significant liquidity in the entire monetary system	Low financial literacy among citizens of Croatia
Reduction of tax burden on citizens	Companies fleeing from the ZSE
	Pessimism among domestic investors
	Reactive and deceptive accounting allowing manipulation of items in financial statements

Source: Penda, I.A. (2019), Devastacija hrvatskog tržišta kapitala – što dalje?, *Financije i pravo*, Vol. 7, No.1

Motives for a company to opt for an IPO primarily include access to funds that will enable the company's growth and development. Additionally, there is a desire to transition from a small private company to a public one, enhancing the company's business image, as only good and promising companies can be listed on the stock exchange. The IPO process not only involves raising funds immediately but also follows the logic that a company listed on the stock exchange will achieve better results in the future, automatically becoming attractive to new investors and thereby increasing the share price.

Table 2 IPOs in the Republic of Croatia from 2006 to the present day

The name of joint stock company	The IPO date
INA d.d.	1.12.2006.
Jadransko osiguranje d.d.	18.4.2007.
Euroherc osiguranje d.d.	18.4.2007.
Magma d.d.	6.8.2007.
HT d.d.	5.10.2007.
Veterina d.d.	23.10.2007.
Atlantic grupa d.d.	19.11.2007.
Optima telekom d.d.	7.1.2008.
Granolio d.d.	19.11.2014.
Tankerska Next Generation d.d.	5.2.2015.
Luka Rijeka d.d.	6.5.2015.
Podravka d.d.	18.6.2015.
Addiko d.d.	11.7.2019.
Meritus plus d.d.	8.8.2019.
Ciak grupa d.d.	31.7.2020.
Meritus ulaganja d.d.	2.6.2021.
SPAN d.d.	8.7.2021.

Source: www.zse.hr (autor processing)

On the other hand, the disadvantages of an IPO include the high costs associated with the IPO process itself. Moreover, the company must transparently disclose operational data to enable trading transparency, which makes them more open but potentially vulnerable to competition. Many owners fear losing control of the company after an IPO, perhaps not immediately, but if the company requires additional capital, there is a possibility of diluting their stake. Loss of control directly affects decision-making power. Additionally, the so-called agency problem arises because managers as agents of the owners may act in their own interest rather than in the interest of maximizing shareholder value.

5. Conclusion

The paper raises questions about why the capitals of Croatian companies are so closed and consequently why the Croatian capital market is still underdeveloped. The answer, among other things, lies in relatively weak financial literacy among both citizens and a large number of business people, fear of losing control over the company, and lack of trust in regulatory and judicial institutions. Despite the fact that most companies that have opted for an IPO on the Zagreb Stock Exchange have done well, it was not a sufficient incentive for the process to become more widespread. Accordingly, it is necessary for all stakeholders to make a positive move in the foreseeable future that would result in less dependence of companies on business banks and increase trading volume on the Zagreb Stock Exchange, making it attractive to all investors.

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IMPORTANCE OF EXCISE DUTIES IN CROATIA

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Abstract. Excise duties are one of the forms of indirect taxes that are mandatory in all member states of the European Union. Excise duties are a form of sales tax that is applied to one or more products. The guidelines of the European Union include that each member must introduce excise duties on energy, tobacco and tobacco products, as well as alcohol and alcoholic beverages. In the framework of this paper, we will present what products are excise duties calculated on in the Republic of Croatia and show the method of calculating them using examples. This will also show the impact of excise duties on the prices of the products to which excise duties are applied. It is known that revenues from excise duties are the revenue of the state budget of each individual European member state. Therefore, the share of revenue from excise duties in total tax revenue of the Republic of Croatia will be shown. By comparing revenues from excise duties with other tax revenues, their importance for the Republic of Croatia will be determined. In the framework of this paper, we intend to present a comparison of revenues generated from excise duties in order to determine whether there is a trend of growth of these revenues in the era of inflation.

Key words: *excise duties, energy products, alcohol, tobacco, tax revenues*

1. Introduction

Excise duties are a form of sales tax that taxes one or more products. Income from excise duties represents the income of the state budget. In 1985, the European Union started the process of harmonization of excise duties on the territory of the European Union in the White Book. The European Commission adopted the first package of guidelines related to the harmonization of taxation in 1987 and in it provided for the taxation of three groups of products: tobacco and tobacco products, alcohol and alcoholic beverages, and mineral oils. With the development of the economy, the guidelines were corrected, but the groups of products subject to excise duties remained the same.

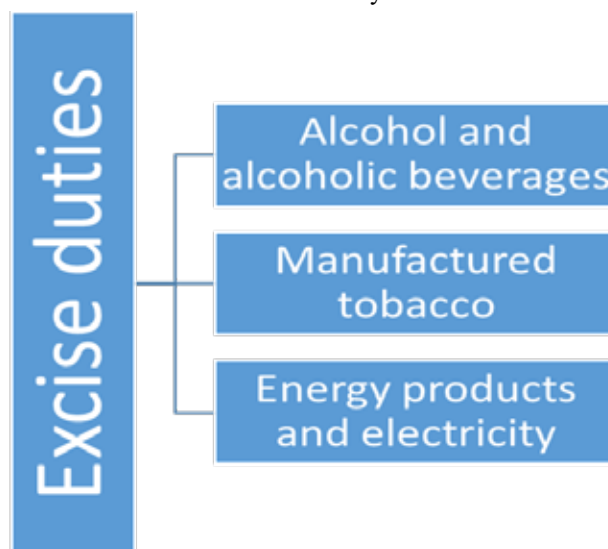
In accordance with the agreement on January 1, 1993, the members of the European Union abolished the luxury rates of value added tax in accordance with the proposal of the EU Commission from 1987 on the harmonization of the value added tax system. In this way, the EU Commission strengthened the role of special taxes and allowed the introduction of special taxes on those products that states consider to be taxed more than the standard rate.(Jelčić et al.)

Therefore, some countries have introduced similar taxes for some other products, but they are mostly called special taxes.

The basic principle of excise duty is the taxation of products according to the principle of

destination, which means that excise duty is paid in the country where the consumption occurs. Products are taxed at the tax rates applicable in the country of consumption.

Picture 1. Excise duty in Croatia



Source: creation of the author

2. Excise duties in the Republic of Croatia

In accordance with the guidelines within the European Union and in Croatia, three groups of products are taxed: alcohol and alcoholic beverages, tobacco and tobacco products, and energy products. Given that the guidelines define that the excise duty is calculated in the country where the good is consumed, that also affects the definition of the taxpayer, i.e. the producer and importer of the defined products.

2.1. Alcohol and alcoholic beverages

A taxpayer is an authorized holder of an excise warehouse, importer, producer or receiver of alcohol and alcoholic beverages.

Drinks that contain more than 2% alcohol are called alcoholic beverages. The exception is beer and wine, which are taxed according to special tax rates.

Alcohol and alcoholic beverages are considered to be:

- beer - 1 % vol of the actual alcoholic strength by volume contained in one hectolitre of the finished product,
- wine, other beverages obtained by fermenting other than beer and wine and intermediate products - 1 hectolitre of the finished product,
- other beverages obtained by fermentation except beer and wine - products belonging to other still beverages or other sparkling beverages obtained by fermentation, intermediate products shall be deemed to be all products having an actual alcoholic strength by volume exceeding 1.2%vol., but not exceeding 22% vol.
- ethyl alcohol - 1 hectolitre of pure alcohol expressed as volume percentage measured at 20°C.

The excise duty base on beer is 1% of the volume share of pure alcohol contained in a hectoliter of the finished product, and the base on wine, other beverages obtained by fermentation except

beer and wine, and intermediate products is one hectoliter of the finished product. A hectoliter of pure alcohol contained in ethyl alcohol is expressed in volume percentages measured at a temperature of 20 degrees Celsius.

Table1. Excise duty rate on Alcohol and alcoholic beverages

Product	Excise duty rate
Still wine	0,00 EUR/hl
Sparkling wine	0,00 EUR/hl
Wine produced by independent small wine producers.	50 % below the standard national rate
Other fermented beverages other than beer and wine	0,00 EUR/hl
Other fermented beverages other than beer and wine produced by independent small producer.	50 % below the standard national rate
Intermediate products	- 106,18 EUR/hl ($\geq 15\%$ vol.)
	- 66,36 EUR/hl ($< 15\%$ vol.)
Intermediate products produced by independent small producers	50 % below the standard national rate

Source: creation of the author according to: <https://carina.gov.hr/featured/excise-duties/excise-duty-rates/alcohol-and-alcoholic-beverages-excise-duty-rates/9000>

Example of alcohol excise duty calculation:

The amount of excise duty on the example of Antique pelinkovac of 0.7 liters 35% of alcohol.

Excise duty rate for Ethyl alcohol is 796.34 EUR/hl pure alcohol.

$796,34/100 \cdot 0.7 \cdot 35\% = 1.951$ EUR

Price of Antique pelinkovac is 15.99 EUR.

$1.951/15.99 \cdot 100 = 12.20\%$

Excise duty for ethyl alcohol is 12.20% of the price.

2.2. Manufactured tobacco

An excise duty payer is a producer and importer of tobacco products and the subject of taxation are tobacco products.

Excise duty base for tobacco products:

- cigarettes – 1000 pieces and retail selling price
- cigars and cigarillos – 1000 pieces
- fine cut smoking tobacco for the rolling of cigarettes and other smoking tobacco – 1 kilogram
- e-liquids – 1 ml
- heated tobacco products - 1 kilogram of net weight of the tobacco mixture contained in the heated tobacco product
- novel tobacco products (example steam stones, hookah squeeze pasta) – 1 kilogram

Table 2. Manufactured tobacco – Excise duty rates

Manufactured tobacco	Excise duty rate
Cigarettes	Specific excise duty – 53,10 EUR per 1000 cigarettes Ad valorem excise duty – 34% of the retail selling price Minimum excise duty – 117,87 EUR per 1000 cigarettes
Cigars and cigarillos	114,15 EUR per 1000 pieces
Fine cut smoking tobacco for the rolling of cigarettes	114,15 EUR per 1 kg
Other smoking tobacco	114,15 EUR per 1 kg
Tobacco products:	
E-liquids (with or without nicotine)	0,00 EUR per 1 ml
Heated tobacco products	185,82 EUR per 1 kg
Novel tobacco products	114,15 EUR per 1 kg

Source: creation of the author according to: <https://carina.gov.hr/featured/excise-duties/excise-duty-rates/manufactured-tobacco-excise-duty-rates/9002>

Example of calculation of excise duty: cigarettes

The amount of excise duty on the example of a box (20 pieces) of Dunhil cigarettes that costs 4.60 EUR.

Specific excise duty – 53, 10 EUR per 1000 cigarettes $53,10/1000 \cdot 20 = 1,062$

Ad valorem excise duty – 34% of the retail selling price $4,60 \cdot 34\% = 1,564$

Total excises duties = 2,626

$2,626/4,60 \cdot 100 = 57,09\%$

Excise duty for cigarettes is 57,09% of price.

2.3. Energy products and electricity

An excise duty payer is an authorized holder of an excise warehouse, importer, producer and supplier of energy products and electricity. The taxpayer submits an application to the competent office of the Customs Administration for entry into the register of excise duty payers and obtains a special authorization for business.

Subjects of taxation on which excise duty is paid on energy products and electricity.

Duties base for petrol, diesel and kerosene - 1000 litres at basic conditions of temperature of 15° C, and base for electricity and natural gas – megawatt hours. Energy products and electricity.

Table 3. Excise duty rate on Energy product

Energy product	Excise duty rate
Leaded petrol	597,25 EUR/1000 l
Unleaded petrol	406,00 EUR/1000 l
Diesel – motor fuel	353,00 EUR/1000 l
Diesel – heating fuel	21,00 EUR/1000 l
Blue diesel	0,00 EUR/1000 l
Kerosene – jet fuel	353,04 EUR/1000 l
Kerosene – heating fuel	232,53 EUR/1000 l
LPG – motor fuel	13,27 EUR/1000 kg
LPG – heating fuel	13,27 EUR/1000 kg
Electricity	
- business use	0,50 EUR/MWh
- non-business use	1,00 EUR/MWh

Source: creation of the author according to: <https://carina.gov.hr/featured/excise-duties/excise-duty-rates/energy-products-and-electricity-excise-duty-rates/9001>

Example of calculation of excise duty: Eurosuper 95 fuel:

The amount of excise duty on the example of Eurosuper fuel that costs 1,54 euros per liter

Excise duty rate for Unleaded petrol 406, 00 EUR/1000 l

$406/1000 \times 1 = 0,406$ euro for liter.

$0,406/1,54 \times 100 = 26,36\%$

Excise duty for euro super 95 is 26,36% of total price.

3. Amount of tax revenue collected from excise duties

Excise duty, as a form of sales tax applied to several products, represents a significant income for the state budget of each member of the European Union, including Croatia. Therefore, in order to see the importance of excise tax revenues, the amounts collected from excise taxes in 2021 and 2022 will be given.

Table 4. Share of revenue from Excise duties

SHARE OF REVENUE FROM EXCISE DUTIES		
	2021	2022
ENERGY PRODUCTS AND ELECTRICITY	8.441.043.011,23	8.103.318.698,70
ALCOHOL AND ALCOHOLIC BEVERAGES	988.614.867,28	1.097.807.636,97
MANUFACTURED TOBACCO AND TOBACCO PRODUCTS	5.765.331.853,71	6.546.693.266,93
TOTAL	15.194.989.732,22	15.747.819.603,60

Source: creation of the author according to <https://carina.gov.hr/UserDocsImages//dokumenti/Trosarine/Propisi/Statistika%20i%20izvje%C5%A1%C4%87a/2021//Financijski%20prikaz%202021%20godina.pdf>

Share of revenue from Excise duties in 2021

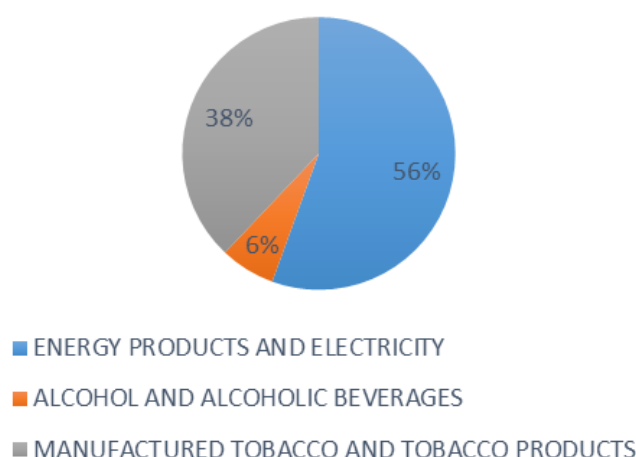


Figure 1 Share of revenue from Excise duties in 2021

Share of revenue from Excise duties in 2022

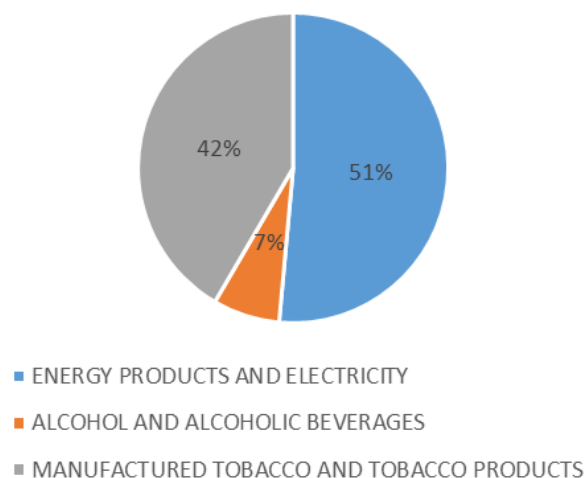


Figure 2 Share of revenue from Excise duties in 2022

Table 5. Share of revenue from Excise duties in total tax revenue

	2021	2022
SHARE OF REVENUE FROM EXCISE DUTIES	15.194.989.732,22 kn	15.747.819.602,60 kn
TOTAL TAX REVENUE	83.651.787.803,00 kn	97.857.296.455,90 kn
% OF REVENUE FROM EXCISE DUTIES IN TOTAL TAX REVENUE	18,16%	16,09%

Source: creation of the author according to the data of the Ministry of Finance

Within the framework of the analyzed years, we can see that the importance of excise tax revenue in the Republic of Croatia is significant. The share of the revenue from excise duties in total tax revenue was 16 and 18 percent. In absolute terms, it increased in 2022 compared to 2021, but in relative terms, it decreased in relation to total revenues.

4. Conclusion

After analyzing excise products and the actual amounts of excise duties in the Republic of Croatia, we can say that within the framework of this work we have succeeded in proving their importance. The importance of excise duties is visible in two aspects: the state revenue and the price of excise products.

Revenues generated from excise duties in the analyzed years were to between 16 and 18 percent of total tax revenues. The relative share of excise duties probably decreased in 2022 due to corrections of excise duties on energy products for the purpose of reducing inflation, which was significant in 2022.

Looking at another aspect, the share of excise duties in the total price of products to which excise duties are applied, we can also state the importance of excise duties as such. It was shown that the share of excise duty is significant in the total price of excise products. In case of alcoholic products, the analyzed drink the amount of the excise duty was about 12% of the total price. It was even more significant in the case of unleaded gasoline, where percentage was 26%. It was especially visible in the case of cigarettes, where it exceeds 50%, and on the analyzed pack of cigarettes, it was about 57% of the total price.

By taking into account the above stated, this paper confirms the importance of excise duties on both state revenues and the prices of excise products.

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COST MANAGING APPROACH TO INFLATIONARY CONDITIONS

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Abstract. Inflation is inevitable phenomenon in the economic society and the companies have to adjust their business to be in line with changing market conditions. Inflation has significant impact on the company business and these impacts can be both, positive and negative. Companies that proactively manage their business in response to inflationary pressures are better positioned to navigate through the challenges associated with rising prices. Inflationary pressures of rising prices affect various aspects of a business, through the increased costs for raw materials, labour, and other inputs what lead to higher operating costs. About many factors depends how the companies will adjust their operations, such as type of industry, type of goods or services, materials and etc., but the most companies put their focus on the cost managing. By the cost managing, companies take the first steps to adapt inflation, striving to have business under control and even thrive in these inflationary circumstances. To adapt inflationary pressures, companies take a proactive and dynamic cost managing approach with which can navigate the challenges posed by inflation. This involves a combination of several ways in which companies can respond to inflation through the effective cost management, such as regularly reviewing and analyzing of all costs and budget, implementing dynamic pricing strategies, efficiency improving, investing in cost effective technology solutions, negotiating with suppliers, optimizing inventory levels and etc. By this cost managing approach the companies ensure flexibility and adaptability to inflationary environment and maintain business prosperity.

Key words: *inflation, cost, cost managing*

1. Introduction

Inflation, an inevitable phenomenon in economic societies, poses significant challenges to businesses, compelling them to adapt to changing market conditions. Inflationary pressures can produce both positive and negative impacts on the companies, those that proactively manage their operations are better prepared to navigate with the inflationary conditions. The effects of inflation a visible through the various facets of a business, driving up costs for raw materials, labour and other inputs, thereby increasing operating expenses. On which way companies will adjust their operations on inflationary conditions depends on several factors including industry type, goods or services offered and available resources. However, many companies prioritize cost management as a primary strategy for mitigating the impacts of inflation. Through proactive and dynamic cost management approaches, company aims are not only to control expenses but also thrive to prosper during inflationary circumstances. This entails implementation of a proactive and dynamic cost managing approach. Proactive and dynamic approach to cost management enables companies to allocate costs more accurately by identifying and analysing activities that drive costs within their operations. By dissecting costs at the activity level, companies gain insights into areas where efficiencies can be improved, resources can be optimized, and

expenditures can be minimized. This approach allows businesses to better understand the true cost drivers behind their products or services, enabling them to make informed decisions to adapt to inflationary pressures. Analysing and understanding the cost structure across each step of entire value chain of a business, from raw material acquisition to the delivery of the final product or service to the customer, companies can identify areas of inefficiency, opportunities for cost reduction and potential areas for innovation. This cost managing approach enables businesses to optimize their operations by reallocating resources to activities that add the most value and by streamlining processes to reduce overall costs. By adopting such cost managing approach, companies bolster their flexibility and adaptability in an inflationary environment, thereby ensuring continued prosperity in their business.

2. Cost management evolution

During the first half of the twentieth century, cost management was tool used by the early industries of the nineteenth century only for inventory valuation and financial reporting with little or no emphasis on decision making. Cost management has evolved significantly over the years, transitioning from a traditional focus on cost reduction to a more strategic approach that considers value, revenue, and overall business performance. In the 20th century, cost management was criticized for its internal focus mainly measuring and controlling product/service costs, producing financial and non-financial information at both short run and long run, reducing costs simultaneously and narrow perspective on value-added activities. However, in the 21st century, strategic cost management has emerged as a vital tool for organizations to navigate a complex and competitive business environment. Cost management bridges the gap between cost and value, emphasizing the importance of understanding both to make informed decisions about customers, markets, and overall business strategy. It involves looking beyond internal operations to consider the entire value chain and external market factors. Strategic cost management is not just about cutting costs but also about using cost information strategically to enhance revenue, improve customer satisfaction, and strengthen the company's strategic position. The evolution of cost management reflects a shift towards a more holistic and forward-thinking approach that considers the long-term viability and success of organizations. This new way of looking at cost management shows that companies need to think long-term and consider how to be successful in the future and how to be in line with changing markets conditions. According to (Dess & Lumpkin, 2003), the main characteristics of strategic management are:

1. Concentrating on general organizational goals.
2. Involving all stakeholders in decision making.
3. Working through one vision to include both short and long perspectives.
4. Recognizing trade-offs between effectiveness and efficiency.

By focusing on above mentioned characteristics and implementing adequate activities, strategic cost management helps companies adapt to changes in the market, meet customer needs, and make more profit in today's turbulent business world. Cost management evolution from the traditional aspect to the strategic aspect can be present by the following table (Kumar & Nagpal, 2011):

Table 1 Comparison of traditional cost management and strategic cost management

	Traditional cost management	Strategic cost management
Focus	Internal	External
Perspective	Value added	Value chain
Cost analysis way	In term of: product, customer, and function With a strongly internal focus Value added is a key concept	In terms of the various stages of the overall value chain of which the firm is apart With a strongly external focus Value-added is seen as a dangerously narrow concept
Costs analysis objective	Three objectives all apply, without regard to the strategic context: Score keeping, attention directing and problem solving	Although the three objectives are always present, the design of cost management system changes dramatically depending on the basic strategic positioning of the firm: either under a cost leadership strategy, or under a product differentiation strategy
Cost driver concept	A single fundamental cost driver pervades literature - cost is a function of volume. Applied too often only at the overall firm level	Multiple cost drivers such as: Structural drivers (e.g. scale, scope, experience, technology, complexity) Executional drivers (e.g. participative management, total quality management)
Cost containment philosophy	Cost reduction approached via responsibility centres or product cost issues	Cost containment is a function of the cost driver(s) regulating each value activity
Primary concern	Cost impact	Cost / Value / Revenue
Key disciplines	Finance / Accounting	Marketing / Economics
Primary role	Scorekeeper	Analyst and consultant
Management responsibilities	Follower/reactive Risk-averse	Leader/proactive Comfortable with ambiguity

Source: Kumar & Nagpal, 2011.

From the table above, it can be concluded that strategic cost management is not limited and focused exclusively on the costs as traditional cost management. Strategic cost management includes all available resources which are used in the company value chain. Therefore, strategic cost management should consider costs, value, revenue, productivity and at the same time the company's strategic position.

3. Economics consequences of inflation

Inflation, as inevitable phenomenon with significant impact on general level of prices, has been a subject of extensive research in economics. In economics literature we found a lot of different definition but mainly all together agree that inflation measures how quickly money loses its purchasing power (Fernando, 2024). This loss of purchasing power impacts the cost of living for the common public which ultimately leads to a deceleration in economic growth. Inflation have various economic consequences, which can be both positive and negative depending on the context and severity. Here are some of the key economic consequences of inflation:

1. Inflation erodes the purchasing power of money, meaning that the same amount of currency can buy fewer goods and services over time.
2. High or unpredictable inflation rates can create uncertainty for businesses and consumers. Businesses may struggle to plan and invest effectively, while consumers may delay purchases in anticipation of further price increases.
3. Central banks often respond to inflationary pressures by raising interest rates to curb spending and investment. Higher interest rates can increase the cost of borrowing for businesses and consumers, leading to reduced investment and consumption, which can potentially slow economic growth.
4. Inflation can impose additional costs on businesses, known as menu costs, associated with changing prices frequently to keep pace with inflation. These costs include updating price lists, re-labelling products, and adjusting marketing materials.
5. Inflation can impact a international competitiveness. If domestic prices rise faster than those in other countries, exports may become less competitive in foreign markets, while imports may become more attractive to domestic consumers.
6. High inflation rates can discourage saving and long-term investment. When the value of money is eroded quickly, individuals and businesses may prefer to hold assets with more stable real values, such as real estate or commodities, rather than savings accounts or bonds.
7. Persistent high inflation can lead to social unrest and political instability. It can erode public confidence in the government's ability to manage the economy and exacerbate social inequalities, particularly if certain groups are disproportionately affected by inflation.

As noted above, inflation has significant impact on various aspects of the economy, from individual purchasing power to overall economic stability. Inflation erodes the value of money, creates uncertainty for businesses and consumers, and can lead to higher interest rates and additional costs for companies. Companies have to adapt to inflationary pressures by adequately costs managing, pricing strategies and investment decisions.

4. Costs managing approach to inflationary conditions

Starting from the fact that inflation essentially means that the prices of goods and services are rising over the time, what affects the costs of inputs (like raw materials, labour, and utilities) and the prices of outputs (the goods or services a company sells), we can point out that inflation create a significant challenge for companies in business managing. These challenges demand adopting a proactive and dynamic approach cost management approach, what involves constant evaluation, strategic decision making and commitment to the efficiency with which companies can curb the effects of inflation. To curb the effects of inflation and ensure prosperity in inflationary environment the companies should apply some of the following activities:

- constantly reviewing and analyzing all costs associated with the business and identify areas where costs are increasing and assess the impact on overall expenses.
- constantly reviewing the output prices and correct them to anticipate changes in input costs of goods and services and pass them on to customers.
- focusing on business efficiency to reduce waste and optimize the use of resources and adoption of new technology solutions.
- proactively negotiating with suppliers to secure favorable terms and prices using long-term contracts, bulk procurement and developing strategic partnerships with suppliers.

- investing in technology solution, automation, data analytics and other digital tools that enhance efficiency and reduce costs.
- managing with the labor costs including performance-based incentives, employee training and implementing flexible work arrangements.
- constantly reviewing and adjusting budgets in line with inflationary pressures.
- optimizing the inventory levels to prevent excess holding costs and avoid overstocking.
- analyzing customer segments to identify those less sensitive to price increases and undertaking marketing efforts and pricing adjustments to minimize the impact on price-sensitive customer segments.
- educating employees on the importance of cost management and involve them in identifying cost-saving opportunities.
- constantly monitoring and management of cash flow to ensure adequate liquidity to cover increased costs and meet financial obligations.

The inclusion of these activities in cost management will upgrade it to a new dimension and a new level of cost management, i.e. strategic cost management. Strategic cost management contributes to the success of companies in the 21st century in several ways (Kumar & Nagpal, 2011):

- Focus on Value and Revenue: Strategic cost management goes beyond just cost reduction and control. It emphasizes the importance of considering value and revenue as critical factors in the success of companies. By focusing on increasing revenue and improving productivity, strategic cost management helps companies enhance their financial performance and competitiveness
- Enhanced Strategic Position: Strategic cost management aims to improve the strategic position of a firm while reducing costs. It helps organizations compete in areas such as cost, quality, customer service, and flexibility, ultimately leading to an improved strategic position in the market
- Long-Term Cost Determinants Analysis: Strategic cost management involves analyzing long-term cost determinants such as economies of scale and experience to understand their influence on costs. By considering these factors, companies can make informed decisions that contribute to long-term success
- Integration with Strategic Management: Strategic cost management is an integrated and proactive part of strategic management. It aligns cost management practices with overall strategic goals, satisfying all key stakeholders and contributing to the long-term value of the company
- Adaptability to Changing Business Environment: In the face of global competition, demanding customers, and rapid technological advances, traditional cost management may not be adaptable. Strategic cost management, with its focus on value creation and revenue enhancement, helps companies navigate these challenges and shape their future effectively.

The suggested framework for strategic cost management in the 21st century includes a variety of techniques and strategies aimed at improving cost and revenue management, enhancing productivity, maximizing profit, and improving customer satisfaction. This, new accounting approach – strategic cost management, has become a crucial tool for mitigate business instabilities arises from environment. One of these instabilities which confront the companies is inflation, which stress business by higher expenses and increased debt. As we already noted, inflation is inevitable in business and companies should adjust to inflation by taking appropriate steps to manage the high costs of inflation and keep debt under control. By taking proactive steps such as reviewing costs, renegotiating contracts with suppliers and

adjusting pricing strategies, companies can maintain control of their finances even in the face of inflation. (Houston, 2023) The five ways that business owners can manage the high cost of inflation to keep debt under control:

- Monitor expenses closely - this involves reviewing variable expenses like supplies, utilities, and labor costs. Through this practice, you can pinpoint areas for potential cost reduction, thereby alleviating your overall debt burden.
- Create a long-term budget - this budget should anticipate potential price hikes over the time and incorporate anticipated revenue growth. This approach ensures that you consistently operate within your financial capabilities and maintain a clear understanding of your financial status.
- Diversify your customer base - expanding the customer base allows you to mitigate risk and decrease dependency on any single customer.
- Invest in efficiency - by making investments in new technologies and energy-efficient equipment companies have potential to lower expenses and boost profitability in the long run.
- Be proactive about debt management - this entails consistently evaluating debts and pinpointing opportunities to reduce or eliminate them, as well as negotiating favorable terms with lenders and creditors for lower interest rates and fees.

In essence, understanding the theoretical concepts of inflation and its impact on cost management is critical for businesses to effectively navigate through the dynamic economic environment. By integrating these methods and tactics into a cost management approach, companies can strengthen competitiveness, improve financial results and achieve sustained success in an inflationary business environment.

5. Conclusion

The challenges posed by inflation demand a proactive and dynamic cost management approach for businesses to survive and thrive in turbulent market conditions. By embracing the cost management strategies such as constant evaluation of costs, dynamic pricing adjustments, investment in efficiency, and proactive debt management, companies can effectively navigate the business under complexities of inflationary environments. Strategic cost management emerges as a vital tool, emphasizing the importance of considering costs and revenue alongside cost reduction. Through these costs managing approach, companies not only mitigate the impacts of inflation but also enhance their competitiveness and ensure long-term prosperity. Therefore, understanding the theoretical implications of inflation and integrating effective cost management practices are essential for businesses to succeed in the dynamic economic environments.

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ACCOUNTING AND LEGAL ASPECTS OF SMART CONTRACTS

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Abstract. Since the introduction of cryptocurrencies approximately a decade and a half ago, the application of the Blockchain has spread to different areas of business. Among other uses, mentioned technological progress has also laid the foundation for smart contracts, which significantly affect the behaviour of entities in the corporate environment and contribute to accuracy, transparency and economization of resources. Smart contracts have the potential to revolutionize international trade by reducing paperwork and facilitating collaboration between traders. The use of this technology simplifies processes, reduces administrative burdens and improves efficiency. In addition, smart contracts contribute to transparency by reducing fraud and supply chain errors, thereby innovating global trade. This paper shows the evolution of smart contracts since its introduction, provides an overview of regulative framework of smart contracts in European Union, as well as the insight in examples of regulation in other countries, and covers accounting and financial aspects regarding smart contracts. The differences between the smart contracts using centralized, semi-centralized and decentralized systems are shown with a special emphasis on the legal framework and responsibility. Although the European Union (EU) recently regulated the segment of cryptoassets, smart contracts are still not subject to a specific legislative framework, and it is necessary to apply the existing (general) legislative framework, which becomes challenging since the application of smart contracts is constantly expanding in different sectors of the market and society.

Key words: *accounting; Blockchain; European Union; regulation; smart contracts*

1. Introduction

From a legal perspective, a contract is an accord between parties that establishes a legally binding relationship or other legal effect (Kölvart, Poola & Rull, 2016). Smart contracts are viewed as novel types of agreements akin to contracts, that are written in source code (Kölvart, Poola & Rull, 2016). A software program carries out the stipulations of a contract (Kölvart, Poola & Rull, 2016). For lawyers, smart contracts are seen as automated agreements that exist alongside traditional legal contracts, as jurisdiction cannot be bypassed. Jurisdiction ensures the right to justice, which is a fundamental human right and forms the basis of the rule of law (Francioni, 2007). Nick Szabo, a Computer Science graduate of University of Washington and a legal scholar, introduced the concept of digital and self-enforcing “smart contracts” in 1993 (Szabo, 1997; Omohundro, 2014). Szabo defines a smart contract as a digital transaction protocol that executes the conditions of the contract (Babbitt & Dietz, 2014). He proposed a decentralized framework where transactions could occur between two parties without the need

for intermediaries. Szabo was convinced that this innovation could transform conventional contract agreements by automating their fulfillment and reducing the risks involved (Urquhart, 2003). However, the economic and communications systems in place at that time were insufficient to facilitate their immediate implementation (Omohundro, 2014).

Despite being a futuristic concept at the time, smart contracts set the groundwork for the evolution of decentralized systems. In the realm of smart contracts' growth and evolution, the significant contributions of Hal Finney, a renowned cryptographer and programmer, cannot be ignored (Urquhart, 2003). In collaboration with Nick Szabo, Finney saw the transformative potential of this technology and was pivotal in investigating its uses beyond the financial sector (Urquhart, 2003). He realized that smart contracts could bring about a revolution in various industries by simplifying processes, cutting costs, and doing away with intermediaries (Urquhart, 2003).

The prospect of bypassing banks, lawyers, consultants, and other intermediaries is undoubtedly attractive as it reduces transaction costs and enhances the efficiency of the contracting process (Kölvart, Poola & Rull, 2016). The goal is to make a transaction as straightforward and manageable as possible (Kölvart, Poola & Rull, 2016). A computer program oversees the entire contracting cycle, finalizes a contract, and then automatically executes the terms of the contract (Kölvart, Poola & Rull, 2016).

One of Finney's significant contributions to the evolution of smart contracts was his work on the concept of reusable proof-of-work (RPOW) tokens, which allowed individuals to demonstrate ownership of computational work, ensured the authenticity and integrity of digital assets, and served as a forerunner to the blockchain technology that underpins smart contracts (Urquhart, 2003). It was only with the advent of Bitcoin that the idea of smart contracts started to garner substantial interest. Bitcoin brought forth the blockchain, a decentralized and unalterable record, facilitating secure transaction execution without the need for intermediaries (Urquhart, 2003), and it laid down the foundations for Ethereum platform which introduced the concept of smart contracts widely known in contemporary business environment.

2. Legal aspects of smart contracts

Since the appearance of Ethereum platform that allowed everyone to gain access and use smart contracts,¹ the interest for smart contracts has been rapidly growing and new possibilities of its application are constantly being introduced. For this reason, it would be expected that smart contracts are now regulated and that all the rights and obligations of the contracting parties associated with smart contracts are now known, but that it is not the case. European Union (EU) recently regulated a segment on markets in crypto-assets (L 150/40, 2023), but in that process EU did not set the basis for the legislative framework on smart contracts. Although smart contracts are only partially connected with crypto-assets, and both can function separately from each other, we believe that the basis of legal regulation for smart contracts could have been laid together with crypto-assets. As another option for regulating smart contracts in EU, we can point out the possibility of regulation smart contracts through international private law on contracts. In that case, the basis for that kind of regulation could be found in the rules of the Rome 1 regulation (L 177/6, 2008). Therefore, it is still up to legal science, jurisprudence and customary law to determine what smart contracts are, how they should be used and which existing legal regulations could be applied to them.

¹ See in more detail: Vitalik Buterin, „Ethereum: A Next-Generation Smart Contract and Decentralized Application Platform“ (Ethereum White Paper, 2014.) <<https://ethereum.org/en/whitepaper/>> (accessed 10. 4. 2024.).

2.1. Definition of smart contracts

There are many definitions of smart contracts that look at them from various aspects (Werbach. & Cornell, 2017). As an example we can point out definition that describes smart contract as self-executing contract that has terms of contract written into lines of code that exist in a distributed/decentralized blockchain network and it controls execution with traceable and irreversible transactions (Frankenfield, 2021). We consider the above definition to be correct from a technical point of view, with regard to smart contracts used on the Ethereum platform, but we cannot agree with the statement that smart contracts are actually contracts. We also think that from a technical point of view, the above definition should be broader, since smart contracts can also be used in a centralized way that allows greater flexibility for its users. Therefore, we believe that from a legal point of view, smart contracts can be described as “a way of executing predefined criteria and conditions that two or more parties agree to be executed independently using computer code located on the blockchain” (Perkušić et al., 2022, p. 671). From said definition, it is evident that smart contracts are primarily not a form or type of contract, but a way of implementing the contract.

2.2. Types of smart contracts

There are various divisions of smart contracts, and with its further development, that number will constantly grow, but we believe that, from a legal point of view, two divisions of smart contracts are especially important to us. The first division refers to the type of blockchain system that is used, while the second division refers to the possibility of impacting on the execution of a smart contract.

Concerning the type of blockchain that is used, smart contracts can be divided into centralized (private systems), semi-centralized (hybrid or consortium systems) and decentralized systems (public systems) (Perkušić et al., 2022). Public systems are often connected to some type of cryptocurrency and there is no central body that is responsible for the functioning of the system itself. Therefore, the users of such a system are often left unprotected and states have problems with regulating this type of system, because there is no responsible body to which they would apply their regulations. For other two types of blockchain system we can find responsible parties and they can easily function without some type of cryptocurrency that would be paid as a reward for mining services that are needed for decentralized systems in order to keep the records in the general ledger.² Smart contracts that are based on such systems are being used in construction, insurance and many other areas, and could be ideal starting ground for regulating smart contracts.

Other division of smart contracts is based on the difference between the so-called “strong” and “weak” smart contracts. The difference between them is based on the ability to influence the code, that is, on the ability to stop or change the execution method of the smart contract. In the case of strong smart contracts, changes are not possible even if all contracting parties agree to it. Such changes would not be possible even if they wanted to stop execution of the smart contract because they noticed the bug in the code of smart contract. On the other hand, weak smart contracts are open for changes and the outcome of that kind of smart contract can be different than it was originally designed in the code of a smart contract (Perkušić et al., 2022). Therefore, the contracting parties in these cases choose between being sure that the smart contract will be implemented, which leaves no room for later refinement of the smart contract, or they can go in the direction of a weak smart contract that allows them to make subsequent changes, but thereby lose one of the main characteristics of smart contracts, which is security in the implementation of the contract itself.

² See Perkušić, M. (2020), p. 274-340.

3. Blockchain and smart contracts in accounting and auditing

Blockchain, which has been already applied in wide range of industries (Kokina et al., 2017, in Zhang et al., 2021), has been highlighted as a technology capable to profoundly transform numerous professional areas in the near future (Hamilton, 2020) and that it “will do to accounting, finance, and legal what the Internet did for communications, advertising, and media” (Hamilton, 2020, p. 10 and 11). Professional areas in finance and accounting such as banking, payment systems, cash management, inventories, accounts payable and receivables are subject to significant changes (Hamilton, 2020). It is often stated that mentioned technology has the potential “to reduce transaction errors and enhance the quality of reporting significantly” (Zhang et al., 2021, p. 147), as well as “break through organisational boundaries” (Moll & Yigitbasioglu, 2019, in Garanina et al., 2021, p. 5131).

Considerable integrative potential of Blockchain and accounting emerges from “their similarities in information recording functions and their differences in information storage and verification mechanisms” (Zhang et al., 2021, p. 148). From that standpoint, “tamper-resistant recording of data based on the consensus of network participants” is emphasized as one of the most important characteristics of blockchain technology (Zhang et al., 2021, p. 148). Thus, “accounting information verification can be objective and not biased in favor of the information provider – the company” (Fuller & Markelevich, 2020, in Zhang et al., 2021, p. 148). For example, “the immutable ledger will allow vendors and customers to exist and share one ledger – one company’s account payable becomes another company’s account receivable” (Hamilton, 2020, p. 10).

Besides carrying “transactional data in real time”, blockchain technology “can also carry a programmed version of human action” (Schmitz & Leoni, 2019, p. 336) in “the form of so-called smart contracts, which encode relevant terms into a blockchain and execute automatically when predefined conditions are met” (Coyne & McMickle, 2017; Ølnes et al., 2017; KPMG, 2018; Rozario & Vasarhelyi, 2018, in Schmitz & Leoni, 2019, p. 336). They have potential to “significantly influence financial statement audits’ nature and outcomes” (Rozario & Vasarhelyi, 2018, in Barr-Pulliam et al., 2022, p. 363), as well as the field of accounting given that they provide “the autonomous recording of transactions in compliance with agreed terms” (ACCA, 2017; CPA & AICPA, 2017; Dai & Vasarhelyi, 2017; ICAEW, 2017; Yermack, 2017; Kozłowski, 2018; O’Leary, 2018, in Schmitz & Leoni, 2019, p. 337). These contracts, as “the main technology behind smart accounting”, possess the capacity “to build a digitalized accounting ecosystem” (Desplebin et al., 2021, p. 751).

3.1. The application of smart contracts in accounting

Smart accounting implies automation of certain activities and easier reporting procedure (Desplebin et al., 2021), in terms of reducing duration of engagement in time-consuming activities, as well as reducing the likelihood of accounting error (Rozario & Vasarhelyi, 2018, in Desplebin et al., 2021). Financial reporting will profit from utilization of smart contracts in terms of transparency and accuracy of data (Hamilton, 2020). Among other uses, smart contracts in accounting could be applied (Desplebin et al., 2021, p. 751):

- for “the execution of simple contracts”
- “to carry out a set of operations under specific conditions”
- “as an automated control tool that monitors accounting operations based on standardized procedures” in order to check “that the accounting entry complies with predefined conditions and standards”
- “to initiate specific accounting procedures when certain criteria are met”.

For instance, smart contracts could include “rules such as *record sales after shipment of goods*” and, in that case, “the system automatically reviews and verifies the shipment date before recording sales onto the blockchain” (Dai & Vasarhelyi, 2017, in Schmitz & Leoni, 2019, p. 337).

The significant impetus contributing to wider application of smart accounting is the environment of virtual connectivity of objects (Desplebin et al., 2021), i.e. the concept of the Internet of Things (IoT), which implies “the connectivity of many physical objects within a virtual environment through the use of radio frequency identification (RFID) markers, sensors, or other elements allowing a connection within a network” (Atzori et al., 2010, in Desplebin et al., 2021, p. 752). More advanced use of this concept implies real-time accounting which “would allow instantaneous accounting information to be disseminated to interested stakeholders such as managers, auditors, accountants, and the organization’s shareholders” (Alarcon & Ng, 2018, in Desplebin et al., 2021, p. 752).

3.2. The application of smart contracts in auditing

The idea of integration of auditing and smart contracts in order to reduce extensive paperwork dates from the end of preceding millennium (Szabo, 1997, in Parmoodeh et al., 2023). When considering benefits of smart contracts for auditing, they can minimise temporal costs as well as likelihood of human error (Kokina et al. 2017; Rozario & Vasarhelyi 2018, in Schmitz & Leoni, 2019) “by automating the transaction reconciliation procedure while providing more transparency to stakeholders through close to real-time audit reporting” (Rozario & Vasarhelyi, 2018, in Schmitz & Leoni, 2019, p. 337).

Smart contracts allow auditors to implement “more intelligent controls, especially with the integration of data analytics, continuous auditing and big data models” (Parmoodeh et al., 2023, p. 28), such as cancelation of “a transaction if they detected a violation of the internal business rules or agreements” (Jans et al., 2014, in Parmoodeh et al., 2023, p. 28). On the other side, not all of the transactions are encompassed by these procedures and, thus, some of the accounting entries (e.g. assessment of fair value) have to be examined by accounting experts (Schmitz & Leoni, 2019), creating a need for the holistic audit approach (Rozario & Vasarhelyi, 2018, in Schmitz & Leoni, 2019).

3.3. Reflections on the future of accounting and auditing in the context of technological advancements

The question that arises after above mentioned facts regarding accounting and auditing profession is following – does the technological development render the accounting and auditing experts unnecessary?

Despite significant number of academics predicting severe repercussions for these industries (Peters & Panayi, 2016; O’Leary, 2017; Yermack, 2017; Casey & Vigna, 2018, in Schmitz & Leoni, 2019), “blockchains do not provide a guarantee for transactions taking place in the real world” and “even if they are recorded onto blockchains, transactions may still be fraudulent, illegal or unauthorised” (Schmitz & Leoni, 2019, p. 337). They “might be executed between related parties, linked to a side agreement or incorrectly classified” (CPA & AICPA, 2017, in Schmitz & Leoni, 2019, p. 337).

Because of “extensive accounting knowledge required to determine whether ledger entries have been made correctly” (Coyne & McMickle, 2017, in Schmitz & Leoni, 2019, p. 337) (e.g.

incapability “of preventing asset misappropriation, erroneous measurement or estimation of valid transactions” [EY, 2016; ACCA, 2017; CPA & AICPA, 2017; ICAEW, 2017, in Schmitz & Leoni, 2019, p. 337]) and probability that business entities will not “store all their transactions on blockchains” (Schmitz & Leoni, 2019, p. 338), academics and professionals, including the largest audit companies in the world, do not agree with forecast of redundancy of employees in these industries (e.g., Coyne & McMickle, 2017; Dai & Vasarhelyi, 2017; Kokina et al., 2017; Kozłowski, 2018; Rozario & Vasarhelyi, 2018; EY, 2016; ACCA, 2017; CA ANZ, 2017; CPA & AICPA, 2017; KPMG, 2018, in Schmitz & Leoni, 2019).

Finally, the potential of this technology relies on the premise of unhackability which was undermined by “increasing evidence that blockchain, like any traditional database or data sharing arrangement, is vulnerable to hacks and attacks”, such as the case of decentralized investment fund named Decentralized Autonomous Organization which occurred in 2016 because of the flaw in smart contract (Castonguay & Smith, 2020, p. 367 and 368) that resulted in a loss of 50 mil. dollars during several hours (Eha & Macheel, 2016, in Castonguay & Smith, 2020).

4. Conclusion

Smart contracts are not synonymous with legal contracts – they are primarily a method of application of legal contracts. Smart contracts, which are essentially computerized transaction protocols that execute the terms of a contract, are poised to revolutionize various aspects of our society. They offer a unique way to automate the fulfilment of agreements, providing immediate assurance of results without the need for an intermediary. This paper indicates that regulation of smart contracts is needed so that they can be used efficiently and safely. At the same time, we believe that it is necessary to start with the regulation of centralized smart contracts and that the EU should not leave the regulation of smart contracts entirely to the member states, but should offer guidelines for the creation of a legislative framework at the level of the member states in order to standardize the regulation of smart contracts at the same level.

Smart contracts could potentially contribute to making AI systems advantageous for human society. In the forthcoming decades, it will be necessary to expand numerous laws and ethical standards to automated intelligent systems.

Although blockchain has an enormous potential to enhance the productivity of accounting and auditing industry, it is probable that these industries will not be threatened by these technological advancements. It is most likely that it will transform these industries in sense of providing additional time to auditors and accountants, for other, more productive tasks.

However, the adoption of smart contracts is not without its challenges. Issues related to security, potential vulnerabilities, and legal implications are some of the hurdles that need to be addressed. Future research should therefore focus on these areas to ensure that the full potential of smart contracts can be realized. This underscores the importance of continued exploration and understanding of smart contracts and their implications for our modern digital world.

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FINANCIAL ANALYSIS OF FACTORING COMPANIES IN THE REPUBLIC OF CROATIA

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Abstract. In order to secure funds necessary for financing their operations, companies usually resort to traditional financing sources such as personal savings and bank loans. Besides mentioned sources, there are alternatives for acquiring additional monetary assets such as factoring. The importance of factoring is often highlighted during financial crises, when companies utilize it for boosting their cash flows. Despite being the entity responsible for approving financing for other companies, factoring companies also have to secure their market survival through positive financial results and viable financing sources. The objective of this paper is to provide an insight into factoring market in the Republic of Croatia regarding number, financial position and financial performance of factoring companies, as well as thoughts on their future prospects.

Key words: *factoring; factoring companies; financial performance; Republic of Croatia*

1. Introduction

When traditional financing sources (e.g. bank loans) are not easily available, companies seek alternative modalities of financing their operations. One of financing sources that could be classified in mentioned category is factoring whose legal definition is as following (Official Gazette, 2014, art. 4): “Factoring is a legal arrangement in which the factoring service provider, based on and in accordance with the factoring contract concluded with the supplier and/or customer, purchases factoring object with or without the right of recourse”. “The object of factoring are existing and/or future, overdue, full or partial monetary claims arising from the delivery of goods and/or provision of services by business entities in the country or abroad” (Official Gazette, 2014, art. 2).

This legal arrangement offers an opportunity to companies, which require cash and are not in a position to wait for the maturity of their receivables, to sell their receivables and obtain funds necessary for financing their operations. The importance of factoring is often apparent during the financial crises, when the access to the traditional forms of financing is highly restricted. This increase in demand is usually accompanied by the expansion of the factoring industry, which is inversely related to financial performance of majority of other industries.

The objective of this paper was to provide an insight into factoring market in the Republic of Croatia regarding number, financial position and financial performance of factoring companies, as well as thoughts on their future prospects. The analysis of the industry has shown that the factoring industry collapsed in the last decade, giving them limited prospects for a turnaround in future.

2. Factoring market in the Republic of Croatia

As apparent from the Figure 1 which shows the number of factoring companies at the end of a year during the time period from 2007 to 2023, the steady growth of the number of mentioned companies during the period from 2007 to 2009 culminated in the highest number of factoring companies at the end of the 2010. From that timepoint, with the exception of 2014, the number of factoring companies had a downward trend which could be characterised as a sharp decrease. Within the three-year period from 2014 to 2017 their number decreased by 47% (from 17 to 9 companies) and in the following three-year time period from 2017 to 2020 it decreased by 56% (from 9 to 4 companies). Ultimately, there were only three factoring companies operating in the Republic of Croatia at the end of the observed period (in 2023).

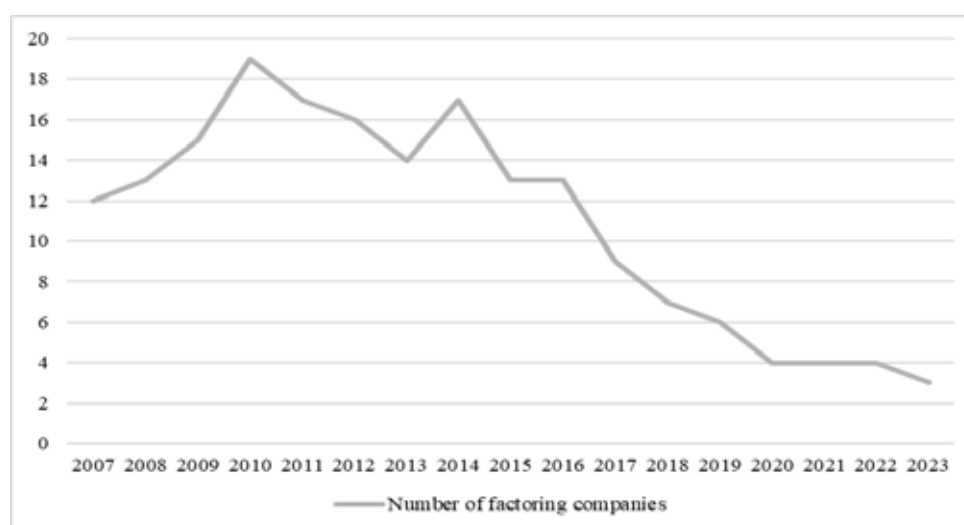


Figure 1 Number of factoring companies from 2007 to 2023

Source: Croatian Financial Services Supervisory Agency, Faktoring društva (eng. *Factoring companies*), available at: <https://www.hanfa.hr/statistika/faktoring-drustva/> [accessed: 8th April 2024]

Having in mind that the importance of factoring usually increases during financial crises due to the need for alternative sources of financing, the movement of the number of factoring companies in the Republic of Croatia approximately matches the years of financial crisis which started worldwide in 2007 and in the Republic of Croatia a bit later. As apparent from the Figure 2 which exhibits the data for the time period from 2007 to 2022, the real GDP growth rate in the Republic of Croatia was negative from 2009 to 2014, in the years of accelerated financial crisis. Subsequently, the growth rate was positive in all years since 2015, with the exception of the COVID-19 induced crisis in 2020 when GDP growth rate plummeted to the record low during the observed period, after which the Republic of Croatia rapidly recovered and achieved GDP growth rate records in 2021 and 2022 during the fifteen-year period.

Besides the effects of the new legal framework in the Republic of Croatia, which introduced higher demands for factoring companies in 2014 with the implementation delay (Klepo, 2018), as well as the epilogue of the financial crisis which lasted for several years, financial year 2017 was the turning point regarding the financial prosperity of factoring companies because of the collapse of “the conglomerate Agrokor, the biggest privately-owned company in Croatia and the Balkans” which accounted “for 15% of the country’s economy”, making “the situation (...) particularly alarming for the government, which decided to intervene by starting the bailout process” (Zubovic, 2019, p. 430). Due to its complexity, the Agrokor case included many aspects of business economics and corporate law, such as business transactions with the bills of exchange which were highly important in the context of the factoring industry.

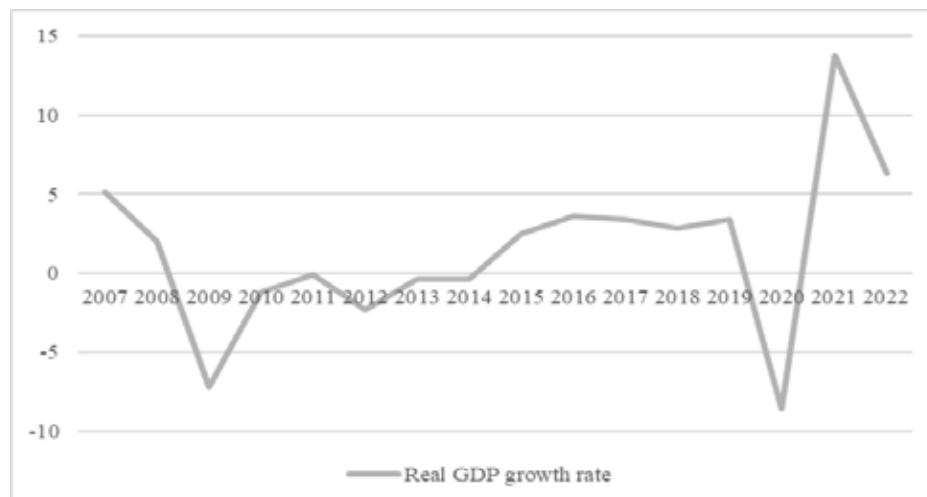


Figure 2 Real GDP growth in the Republic of Croatia from 2007 to 2022

Source: Croatian Bureau of Statistics, Godišnji bruto domaći proizvod za razdoblje 1995. – 2022., revidirani podaci (eng. *Annual gross domestic product for the period 1995-2022, revised data*), available at: <https://podaci.dzs.hr/2023/hr/58253> [accessed: 8th April 2024]

Agrokor utilized shadow banking with its business partners from distribution chain who “agreed to covert financing by taking out loans from banks themselves or lending it their own money” in exchange for bills of exchange issued by Agrokor (Klepo et al., 2017, p. 6). In order to secure steady cash flow, “they would sell these bills of exchange to factoring companies, with a certain discount” (Klepo et al., 2017, p. 6). Given that these bills of exchange included right of recourse, factoring companies and group’s suppliers experienced difficulties because the value of these written orders was approximately HRK 3.5 billion (Klepo et al., 2017). After the prosperous six-year period for the factoring industry, the demise of Agrokor in 2017 led to a decline of the market of bills of exchange, resulting in negative financial results (Klepo, 2018). This situation was reflected in the increase of provisions in accounting records (Klepo, 2018).

3. Financial position and financial performance of factoring companies in Croatia

Probably the best indicator of the scale of factoring industry demise in the Republic of Croatia are the amounts of total assets. The aggregate value of total assets in 2013 was at its record high of 1.060.001.000 €. After that timepoint, factoring companies have lost most of their asset and the highest decline in absolute terms was in 2017, in the dawn of the Agrokor crisis, when total assets declined by 470.810.000 € or, in the relative terms, by approximately 60%.

Table 1 Value of total assets of factoring companies in the Republic of Croatia from 2007 to 2023 (in 000 €)

Year	Total Assets	Relative change	Absolute change
2007	559.993	-	-
2008	841.846	50,33%	281.853
2009	929.966	10,47%	88.120
2010	762.908	-17,96%	-167.058
2011	769.961	0,92%	7.053
2012	957.219	24,32%	187.258
2013	1.060.001	10,74%	102.783
2014	1.057.874	-0,20%	-2.127
2015	874.274	-17,36%	-183.600
2016	783.072	-10,43%	-91.202

2017	312.263	-60,12%	-470.810
2018	187.282	-40,02%	-124.980
2019	180.903	-3,41%	-6.379
2020	42.997	-76,23%	-137.907
2021	48.143	11,97%	5.146
2022	31.632	-34,30%	-16.511
2023	17.120	-45,88%	-14.512

Source: Croatian Financial Services Supervisory Agency, Faktoring društva (eng. *Factoring companies*), available at: <https://www.hanfa.hr/statistika/faktoring-drustva/> [accessed: 8th April 2024]



Figure 3 Total assets of factoring companies from 2007 to 2023

Source: Croatian Financial Services Supervisory Agency, Faktoring društva (eng. *Factoring companies*), available at: <https://www.hanfa.hr/statistika/faktoring-drustva/> [accessed: 8th April 2024]

The tendency of decline continued through the following years – in the last observed year (2023) the value of their total assets was 17.120.000 €, which was only 1.62% of value of total assets at their peak ten years ago (2013). This is probably the most obvious indication of their economic situation which does not appear promising at all.

Financial analyses of factoring companies were previously conducted by Kaur & Dhaliwal (2014), Khan & Sultana (2016) and Alper & Başdar (2017).

Financial indicators utilized for the financial analysis of the factoring industry in the Republic of Croatia are *current ratio*, classified in the liquidity ratios that “measure the ability of a firm to fulfil short-term liabilities”, *leverage ratio* which belongs to the financial leverage ratios that “are used to determine whether the business equity is sufficient, the balance between liabilities and equity within the asset structure and whether the equity funds were invested in liquid or fixed assets” and *asset profitability* which belongs to the profitability ratios “that are used to measure the success of a business’ operations” (Alper & Başdar, 2017, p. 633).

Table 2 Financial analysis of factoring companies in the Republic of Croatia from 2007 to 2023

Financial indicator	Calculation
Current Ratio	Current Assets / Current Liabilities
Leverage Ratio	(Current Liabilities + Long Term Liabilities) / Total Assets
Asset Profitability	Net Profit / Total Assets

Source: Alper & Başdar (2017).

As apparent from Table 2, current ratio increased in the first years of financial crisis from 2007 to 2009, reaching the highest value of 1.72 in 2009. In the period from 2010 to 2021 it fluctuated between 1.03 and 1.25 and in 2023 it reached the highest value over the observed period (2.02), meaning that current assets were slightly more than twice higher in comparison with current liabilities.

The values of leverage ratios have a trend of decrease which accelerated from 2021 and culminated in the highest decline of approximately 28 p.p. in 2023 compared to the preceding year, indicating the trend of deleveraging in the factoring industry.

Table 3 Financial analysis of factoring companies in the Republic of Croatia from 2007 to 2023

Year	Current Ratio	Leverage Ratio	Asset Profitability
2007	1,393364159	0,976943323	0,009010566
2008	1,638961072	0,973983039	0,010703267
2009	1,716810066	0,973267358	0,00551191
2010	1,093720918	0,955565993	0,016766068
2011	1,092569611	0,952036722	0,014874862
2012	1,180358678	0,956205904	0,011142247
2013	1,048014245	0,942285387	0,02236662
2014	1,190142606	0,926849026	0,027202858
2015	1,164875025	0,887518486	0,032253727
2016	1,253291018	0,850830777	0,02856747
2017	1,044528167	0,938200245	-0,374443321
2018	1,103688511	0,86624331	-0,072727703
2019	1,031581095	0,90359384	0,008086866
2020	1,197866468	0,805897017	0,021598867
2021	1,164447289	0,811144192	0,017166857
2022	1,472187392	0,730164042	-0,012734813
2023	2,016929318	0,454650573	0,058747212

Source: Croatian Financial Services Supervisory Agency, Faktoring društva (eng. *Factoring companies*), available at: <https://www.hanfa.hr/statistika/faktoring-drustva/> [accessed: 8th April 2024]

During the years of financial crisis, factoring companies were profitable, but after the crisis two years of losses followed and resulted in the decrease of the number of factoring companies from 13 to 7. After that period, profitability has improved, but insufficiently to maintain the same number of factoring companies in the industry. In 2023, the profitability amounted to approximately 5.9%, which was the highest value over the observed period.

4. Conclusion

The objective of this paper was to provide an insight into factoring market in the Republic of Croatia. After their heyday during the 2007 financial crisis, the number of factoring companies sharply decreased and there were only three factoring companies operating in the Republic of Croatia at the end of the observed period. The best indicator of the scale of demise of factoring industry in the Republic of Croatia are the amounts of total assets which in 2023 amounted only 1.62% of the value of total assets at the peak of financial prosperity of the industry ten years ago. These numbers are caused by the combined effect of the economic recovery after 2007 financial crisis, new legal regulation of the factoring industry, as well as the demise of Agrokor group, which had a devastating effect on the industry. The factoring industry in the Republic of Croatia underwent the path from lucrative to marginal, and the prospects for regaining its economic power are unfavourable.

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CODE OF BUSINESS CONDUCT AS A FORM OF ANTI-FRAUD CONTROL

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Abstract The recent global research on the effects of occupational fraud, published in 2022 and based on data collected from January 2020 to September 2021, revealed that total losses for businesses due to fraud amounted to 3.6 billion USD. On average, this represented 5% of the revenue of the organizations in question. Given the substantial losses, companies worldwide are increasingly investing in fraud prevention and detection measures. The most cost-effective approach to mitigating fraud losses is by preventing fraud from occurring in the first place. This effort typically begins with the establishment of a Code of Business Conduct (furthermore: COBC) that all employees of the organization are expected to adhere to. Furthermore, companies extend the COBC to encompass volunteers, temporary workers, consultants, and third parties associated with the company. Some companies have also developed an abbreviated version of the COBC specifically tailored for third parties such as customers, vendors, and contractors. An emerging trend involves initiating cooperation with third parties only after formal acceptance of the COBC. This ensures that partners are aware of the company's commitment to compliance and ethics. Importantly, if the COBC is integrated into business contracts, if worded properly, it can provide the company with the ability to terminate any contract in the event of noncompliance by the contractor. However, despite the compelling evidence supporting the adoption of a formal COBC, a national-level research study conducted in Croatia revealed that only 33% of companies have established a formal COBC. This is significantly lower compared to the global average of 82% among companies worldwide. The absence of proper anti-fraud measures leaves Croatian companies more vulnerable to experiencing occupational fraud. Therefore, the primary objective of this paper is to delve into the development, implementation, and enforcement of a robust COBC, as well as to outline role of COBC in fraud prevention and detection.

Key words: *occupational fraud, fraud prevention, Code of Business Conduct, anti-fraud controls*

1. Introduction

It is known that social groups form around a set of values that serve as the basis on which group members act and behave. While individual beliefs and morals may vary, the group values highly influence the attitudes and actions of its members. This collective of beliefs and morals constitutes a framework known as ethics. Ethics provides individuals with a guide for distinguishing right from wrong. At an organizational level, the above-described set of values shapes the culture of a company. When employees choose to engage in activities contrary to the set values, they act against the organization's interests. In cases where these activities include deceiving others to gain personal benefit, they are categorized as fraudulent activities, posing significant financial and reputational risks to businesses.

To prevent fraud and maintain ethical standards, organizations implement policies and procedures, one of which is the Code of Business Conduct (furthermore: COBC). The COBC serves as a set of rules to be followed within the organization, setting the expectations for employees and guiding decision-making processes. Additionally, some companies even share their COBC publicly to emphasize their commitment to ethics. It is worth noting that the set of values will differ among the COBCs based on the company's size, industry, whether it is for-profit or nonprofit, and national or international.

The latest Occupational Fraud 2024: A Report to the Nations research (ACFE, 2024), covering 1921 cases across 138 countries, revealed that losses from reported fraud cases exceeded \$3.1 billion. These significant losses highlight the importance of detecting fraud as soon as possible, or even better, preventing fraud before it occurs. Active fraud prevention is thus a critical component of anti-fraud strategies for organizations of any size. Fraud detection and prevention strategies may include components such as fostering a zero-tolerance to fraud among all employees, a communication strategy, control mechanisms and culture change within the company (Krummreck, 2002). Statistics indicated that companies with established COBCs, affected by fraud, faced the fraud case that would on average last for 12 months, while companies without COBCs suffered from case spanning over 20 months, meaning that COBCs reduced the duration of fraud case by 40%. Consequently, the research showed that companies with COBCs experienced a median loss of \$121,000 due to fraud case, while companies without COBCs experienced a median loss of \$200,000. These statistics clearly demonstrate the benefits of establishing COBCs. Also, the companies employing less than 100 employees were less prone to have COBCs established (only 56%) opposite the companies employing more than 100 employees.

This paper aims to inspire and encourage all companies without COBCs to implement one. The paper will present a few examples of COBCs from well-established international companies, discuss how companies introduce COBCs to employees, and outline the role of COBC in fraud prevention and detection. The paper is structured as follows. After first, introductory part, in the second part of the paper role of COBS in fraud prevention is presented as well as structure of COBC with practical examples. Next part of the paper is dealing with COBCs implementation and communicating COBs to relevant stakeholders while the final part of the paper brings concluding remarks.

2. Code of Business Conduct – role in fraud prevention and detection

2.1. Code of Business Conduct as anti-fraud control

In his paper, Biegelman (2004) presented a study commissioned by the Fraud Task Force of the American Institute of Certified Public Accountants (AICPA), following significant corporate fraud incidents in the early 2000s. According to the study, the COBC should reflect the company's core values and guide employees in making appropriate decisions. It should also contain standards designed to deter fraudulent practices and promote honest and ethical behaviour among all employees, regardless of their positions. The COBC should clearly outline what employees can and cannot do, emphasizing compliance with laws, rules, and regulations as a negative work environment can create incentives for fraud, highlighting the importance of management's care for employees, realistic goal-setting, and fair advancement opportunities. Ethical behaviour within the organization should leave no ambiguity about expectations, with zero tolerance for business misconduct or fraudulent practices. Discipline should be fair, appropriate and consistent for all employees. To encourage reporting of

inappropriate behaviour, mechanisms for safe and anonymous reporting should be established. COBC provides all employees with basic guidelines to conduct ethically and lawfully on a daily basis. It is often stated how COBC is a cornerstone in fraud prevention and detection and one of the most effective controls in reducing fraud losses. ACFE research on global level shows how COBC is one of the most common anti-fraud controls and was present in 85% of victim organizations (ACFE, 2024, 38). First fraud research in Croatia, conducted according to ACFE methodology revealed that Croatian companies significantly lag behind global trends in integrating controls to prevent fraudulent actions. In that sense, when analyzing COBC only 33% of Croatian companies had implemented COBC in the time of fraud occurrence. Moreover, among the 18 anti-fraud controls analysed, the formal COBC was ranked fifth and more than half of the organizations that participated in the survey did not have any established formal form of internal controls (ACFE Croatia, 2022). Such information is truly worrying and shows that Croatian companies are quite slow in the fight against fraud. By researching the COBCs of different Croatian companies, a significant difference in appearance and content can be noticed. This can be partly attributed to different branches of activity. Some of the common characteristic in COBCs in Croatia are the invitation to respect ethical principles, principles of social values, compliance with the law, clauses on human rights, guidelines for anti-corruption activities, instruction on how to deal with violations of the COBC, etc.

2.2. Structure of Code of Business Conduct

While combating fraud within the companies usually falls under internal or external auditors and board of directors, the prevention and detection of fraud is ultimate management's responsibility. In that light, the management sets the organization's ethical tone and reinforces anti-fraud culture, part of which is developing COBC that is in line with the company's values and mission.

When developing COBC, the following should be taken into the consideration:

- Applicable industry and practice – COBC should follow industry practices and standards, especially any governmental regulations (such as competition law, labor law, environmental protection laws, etc.)
- Size of organization – large organizations will have more formal operations and greater resources to meet the requirements than smaller organizations (for example, smaller organizations may use available personnel rather than employ separate staff to carry out ethics).
- Misconduct that already happened (if any) – the company can add such clause that would prevent similar misconduct from happening (for example, if there were instances of official document forgery, the clause on how to keep documents should be added).

The COBC should set forth in detail what is expected in the ethical climate of the company. Under each ethical principle that employees need to adhere to, simple explanations of what would be breach of the standard can be given. In general, COBC should be written in simple manner so it can be clearly understood by all employees, regardless of their positions. The ethical standards (clauses) will differ from company to company.

The Association of Fraud Examiners (ACFE) gives guidelines on how to develop COBC and the following is proposal on what can be included in COBC according to ACFE framework. In companies COBS following sections should be included (ACFE, 2017): Introduction; Most common ethical standards; Compliance with laws; Conflicts of interest; Gifts and entertainment; Outside Employment; Relationships with suppliers and customers; Confidential information;

Company assets; Political Contributions; Employee Conduct; Reporting Violations; and Discipline. In the next part of this paper each of these part if briefly elaborated and a short example is provided.

- **Introduction:** this part of COBC explains what COBC is, why adherence to COBC is vital for the company, who needs to follow COBC and who to contact in case of any questions regarding COBC. This section of COBC outlines the importance of high standards of business conduct and promotes COBC as a working guide for all stakeholders in the company. However it is also stated how “each employee should apply code with common sense” and “there is no substitute for common sense” (ACFE, 2017, 4.628).

As example of introductory part from JPMorgan Chase&Co can be specified: “The Code of Conduct (“Code”) sets forth the expectation that employees conduct themselves with integrity, at all times. It provides employees with the principles to help govern their conduct with clients, customers, suppliers, vendors, shareholders, fellow employees, regulators, markets, and the communities in which we operate. The Code applies to the employees and directors of JPMorgan Chase & Co. (“firm” or “JPMorgan Chase”) and its direct and indirect subsidiaries.” (JPMorgan Chase & Co., 2023).

- **Most common ethical standards:** within part of the COBC applied ethical standards are outlined and as one of commonly mentioned standards fair Competition can be pointed out. In this sense companies should promote honest, direct, and fair competition, compliance with antitrust laws and avoiding price fixing or market allocation agreements with competitors.

For this part of the COBCs an example from Johnson & Johnson can be outlined: “Antitrust and competition laws promote fair competition and protect consumers from unfair business practices. These laws frequently address illegal agreements between companies, such as price fixing, as well as other unfair trade practices that restrict competition. We comply fully with all applicable antitrust and competition laws. We are responsible for dealing fairly with customers, suppliers, competitors and other third parties. This means our employees avoid taking unfair advantage through manipulation, concealment or misrepresentation of key facts, or other unfair practices.” (Johnson & Johnson, 2019, 13).

- **Compliance with laws:** this section refers to compliance with all applicable laws and regulations and adherence to the highest ethical standards. It should be emphasized how company should adhere to all applicable laws and regulators framework of country in which it operates as well as with all international relevant regulations.
- **Conflicts of interest:** this part of COBC gives direction how to act in situations where personal interests conflict with company duties. As situations which give rise on this issue gifts from suppliers, close or family relationship with outside suppliers, ownership in another company etc. may be pointed out.

This part of COBCs is shown on example of Mueller Water Products: “You have a responsibility to make decisions based on the interests of the Company without regard to how they might personally benefit you. A conflict may occur when your private or professional interests interfere in any way — or even appear to interfere — with the interests of the Company. Even if you did not intend for your actions to create a conflict of interest, the perception of a conflict by others can be just as damaging.” (Mueller Water Products, 2019, 11).

- **Gifts and entertainment:** prohibition of soliciting or accepting gifts or entertainment of more than token value that could influence their judgment or favor certain suppliers is emphasized through this part COBCs.

Example from Roche can be stated: “Gifts or entertainment may be given only where appropriate and where there is no risk of creating the perception of influencing the recipient in his/her decision. Gifts must be of minimal value and entertainment must not go beyond what is reasonable. Lavish or inappropriate gifts or entertainment are strictly prohibited. Demanding or soliciting gifts or entertainment of any kind is prohibited. This includes not only items but all kinds of advantages. Unsolicited gifts or entertainment may only be accepted if they do not go beyond common courtesy and are an accepted local business practice. Offers of entertainment may only be accepted if they arise out of the normal course of business, cannot be seen as lavish and take place in settings that are appropriate.” (Roche, 2022, 42)

- **Outside Employment:** prohibition of engaging in outside employment that competes with the company or affects their objectivity in carrying out their responsibilities is emphasized through this section of COBC.
- **Relationships with suppliers and customers:** this part of COBC gives guidelines how to treat business partners fairly and with integrity. It should be emphasized that business transactions should be performed in the best interest of a company and all situations involving conflict or the appearance of conflict between duty to the company and personal interest should be avoided (ACFE, 2017).

As example a part of this section from the COBC of Inter IKEA Group is presented: “The way we deal with our business partners shall be characterised by honesty, respect, fairness and integrity. Inter IKEA Group companies shall comply with the laws and regulations in all jurisdictions where we do business. We shall not offer or accept from customers and other business partners, official institutions, or representatives of such entities any rewards or benefits that violate any applicable laws or this Code. We will ensure that our business partners (franchisees, suppliers, customers, and sub-contractors, etc.), as well as companies in which we directly invest, are aware of our Code and our values.” (Inter Ikea Group, 2016, 6).

- **Confidential information:** this section gives directions related to protection of confidential company information and avoidance of disclosing it without proper authorization. Some examples of forbidden conduct in this area include misuse (selling, transmitting etc.) of confidential company information or trading with company stock based on information that are not publicly available.

Practical example can be shown at part of COBCs from Apple company: “One of our greatest assets is information about our products and services, including future product offerings. Never disclose confidential, operational, financial, trade-secret, or other business information without verifying with your manager whether such disclosure is appropriate. We are very selective when disclosing this type of information to vendors, suppliers, or other third parties, and only do so once a non-disclosure agreement is in place. Even within Apple, confidential information should only be shared on a need-to-know basis.” (Apple, 2024, 7).

- **Company assets:** this part of COBC is dealing with managing company assets with integrity. It gives directions related to handling cash and bank accounts, compliance with all relevant accounting procedures, recording transactions in a timely manner, control procedures that should be in place in order of safeguarding assets, procedures related to expense reimbursement etc.

Example from company Sony Group Corporation can be stated: “Sony protects its assets from any types of loss or misuse. Sony’s assets are to be used only for legitimate business purposes and only by authorized Sony employees or their designees. We must not pursue personal benefits using Sony’s assets. Sony reserves the right to monitor and inspect Sony’s assets, including e-mail, data and files kept on Sony computers or other devices, in accordance with applicable laws.” (Sony Group Corporation, 2024, 33)

- **Political Contributions:** this part of the COBC is related to participating in political contributions. Usually, it is defined how contributions should be in line with applicable laws and contribution should be made from funds that are allocated for such purposes and approved from highest levels of management.
- **Employee Conduct:** guidelines related to employee conduct in company premises or while on company business are outlined under this section. As activities not allowed in company premises and during working hours following can be stated: consumption of alcoholic beverages, use of drugs, driving under the influence of drugs or alcohol, betting or gambling, carrying weapons etc.

This part of COBCs is shown on example of company Meta: “Whether working in an office, commuting to or traveling for work, at home, in labs, at data centers or out in the world, nothing is more important than staying safe and healthy. We care about each other’s well-being; we want to create conditions in which we are free from harm and free to do our best work...Do not work under the influence of illegal drugs, controlled substances, or any other substance that could compromise safety or performance...Do not feel pressured or pressure others to consume alcohol at work events or with work colleagues; if you do consume alcohol at a work event, please do so responsibly.” (Meta, 2024, 15)

- **Reporting Violations:** Through this part of COBC employees are encouraged to report any violations of COBC promptly and the company guarantees protection of whistleblowers from reprisal. All employees should act according to rules, acts and principles adopted within company and each employee has obligation of reporting all the issues that represent violations of COBC.
- **Discipline:** Violations of the code can result in disciplinary action, including dismissal and supervisors or executives who condone or permit unethical conduct may also face disciplinary action. Different disciplinary actions can be undertaken when violations of COBC occurs and some include work suspension, reduction in salary, reprimand etc.

As example of this section part of Ryanair Holdings PLC is shown: “Disciplinary action will be taken against any employee who violates or encourages / requests others to violate this Code. Certain violations (e.g. breaches of law) could also subject the individual who committed the violation to civil or criminal penalties, including fines and/or imprisonment.” (Ryanair Holdings PLC, 2013, 9).

3. Implementation of Code of Business Conduct

3.1. Communication of Code of Business Conduct with employees

After establishing the COBC, effective communication with all employees becomes essential. Each organization should create a clear policy for educating employees, managers, and executives about the COBC’s principles. This education can be facilitated through various means such as emails, memos, and formal COBC training sessions. Employees should attend these sessions when they start their employment and as a refresher annually or upon any changes in the COBC. The human resources department usually keeps records of training attendance, with employees confirming their understanding of the COBC through signed statements in their human resources files. COBC training should be inclusive, covering employees at all levels; no exemptions in receiving initial orientation nor ongoing training should be granted. Like any educational effort, frequent exposure seems to be key for absorbing and applying the information provided. The latest Occupational Fraud 2024: A Report to the Nations research, showed that organizations that did not have trainings of this sort established for employees and managers suffered almost twice of lost than the companies that had awareness trainings (ACFE, 2024).

Training sessions should explain each COBC section and why it's important for the organization and its employees. Examples of potential COBC breaches should be provided for clarity. Training sessions should be interactive, allowing employees to discuss appropriate actions in different scenarios. The employees should be made aware of how breaches of COBC hurt them and the company through lost resources, decreased productivity, damage to the company's reputation, and consequently, loss of bonuses, layoffs, increased scrutiny. It is crucial to let the employees know how they can report any suspicions of breach of COBC and how the same breaches will be investigated. Also, the disciplinary measures for each breach should be explained. In addition to company wide COBC training, specialized sessions should be provided for managers and executives. These sessions should focus on fraud prevention and detection relevant to their roles. For example, managers may learn to recognize warning signs specific to their departments, such as procurement manipulation or payroll fraud.

Some companies integrate parts of the COBC into employment contracts, depending on local regulations and industry norms. These may include clauses on confidentiality, conflict of interest, antibribery, and disclosing the information to the competition.

3.2. Communication of Code of Business Conduct with the partners

Efforts to commit to the values and ethics should not be limited to the company's employees alone. Therefore, a number of companies have developed shortened and specialized COBCs for third parties they work with. Partners are required to acknowledge receipt of the COBC either online or by signing and stamping it. These partners typically include consultants, government agencies, and most commonly, suppliers. COBCs shared with suppliers are often referred to as Supplier Guiding Principles (further: SGPs). The acknowledgments are stored in partner's files along with the contracts. In larger companies, the Internal Audit department periodically reviews the completeness of these files, particularly for partners that interact with government entities such as customs offices, construction firms, and license providers.

Aligned with the company's overall COBC, SGPs are tailored to accommodate the unique dynamics of each business sector. While specific sections may vary, a core component typically addresses compliance with local laws, human rights, and labour standards and for suppliers interacting with the government, especially important antibribery and corruption policies. Additionally, companies operating within distinct market segments may include specialized provisions in their SGPs such as animal welfare, bans to use certain minerals in production, carbon footprint, fair competition and similar.

For instance, Roche, medical innovations company, is committed to protecting their intellectual property as the following: "As business partners supporting Roche's efforts, suppliers shall respect Roche's intellectual property rights, protect Roche's trade secrets and confidential information, and safeguard customer information. Suppliers shall manage technology and know-how in a manner that protects intellectual property rights." (Roche, 2022, 14)

Efforts to align partners with the company's values typically extend beyond merely documenting them on paper and distributing them to partners. There is an emerging trend within international companies, particularly those operating in developing countries, of organizing ethics and compliance training sessions for suppliers. During these sessions, each section of the SGP is elaborated upon and discussed with the suppliers. Some companies even require suppliers to complete specially designed questionnaires to assess their commitment to ethics and compliance. If the scores are unsatisfactory, companies may choose not to engage with such suppliers.

One of the most common measures that companies impose to ensure that partners are following their COBCs is the monitoring clause. This clause is typically included in contracts or SGPs, granting companies the authority to audit third-party compliance with shared values.

Provisions for contract termination in cases of non-compliance underscore the importance companies place on ethical standards.

By sharing SGPs with third parties, particularly those with significant market presence and revenue, companies have a notable influence on industry standards and global ethics. They ensure that their business partners, many of whom rely on their patronage, align with established values, even in the absence of their own formal COBCs. This underscores the influential role large companies play in shaping ethical norms and market practices on a global scale.

4. Conclusion

Effective system of anti-fraud controls is crucial for fraud prevention and detection. Strong system of anti-fraud controls based on Code of Business Conduct (COBC), Anti-fraud policies and Fraud training can contribute to fraud prevention and finally increase fraud detection. The latest research performed by Association of Certified Fraud Examiners shows that implementing a COBC reduces the occurrence, duration, and financial impact of fraud cases within organizations (ACFE, 2024). It is evident that companies should establish the practice of having a COBC and ensure that employees commit to it. One of the main advantages of having a COBC is cost-effectiveness, as it does not incur significant expenses to develop. COBC is a foundation for creating corporate culture which promotes highest ethical values and helps everyone who works in the company to understand responsibilities and commitment to ethical behaviour. It has positive impact on behaviour and attitudes of all employees and sends message on “tone at the top” of the company.

The paper presented the most common ethical standards included in COBCs and provided examples from some of the well-known international companies. Additionally, it outlined how to properly communicate the COBC with employees to ensure their understanding and adherence to it. By offering training sessions and incorporating COBC principles into employment contracts, companies can emphasize the importance of ethical behaviour at all levels of the organization. Moreover, extending COBC principles to third parties through Supplier Codes of Conduct further reinforces ethical standards globally.

COBC is one of the essential anti-fraud controls and companies who adopt it show that they promote the highest standards of business conduct and ethics as well as zero tolerance to fraudulent behaviour. It has a major role in fraud prevention and detection and therefore its function in fraud fighting should even be more emphasized and communicated to all relevant stakeholders of the company.

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BENEISH M-SCORE AS A TOOL FOR FRAUD DETECTION

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Abstract. Fraud, in all forms and instances is becoming a bigger and bigger problem, especially in the post-COVID era of rising inflation and fast paced business. With the addition of governments subsidizing a wide variety of activities, it is clear there is a need for a quick and efficient method to predetermine which companies present a “good fit” for such activities. The main objective of this paper is to suggest using the Beneish model as a first step to determining the eligibility of potential recipients. Additionally, the suggested model can also be used as a tool (one of many) in making investment decisions, as it is used by many professional investment firms. The Beneish model is a mathematical model that uses financial ratios and eight variables to identify whether a company has manipulated its earnings. In this paper we have taken the available public financial statements of a large company, which during a longer period of time was the beneficiary of substantial grants from public sources and calculated the Beneish M-score for said company for 3 consecutive years. The paper shows that applying a simple but effective method could potentially save the taxpayers money from those trying to use it dishonestly.

Key words: occupational frauds, fraud detection, Beneish M-score.

1. Introduction

Business frauds are a global problem and they cause significant losses at the level of companies, countries, and at the global level. The fight against fraud is gaining more and more importance every year. Fraud investigations are challenging and demanding due to the fact that perpetrators try to cover up their crimes, and forensic experts use different methods and techniques in their fraud investigations to spot potential areas of fraud. Although perpetrators try to cover up fraud in various ways, the fact is that the application of various analytical techniques such as horizontal analysis, vertical analysis and relationship analysis can be of a great help to the forensic expert in fraud investigations and guide his further work. In the preliminary phase of forensic analysis, when it is necessary to detect possible manipulations, in addition to analytical techniques, different forensic models are used. Some of the models that are often used in forensic research are Benford's model, Altman's model and Beneish model. In the framework of this paper, the authors will present the basic determinants of the Beneish model as a tool for detecting potential fraud in financial statements. Also, the calculation of individual parameters and the final M-score, as well as the role of the Beneish model in forensic analysis, will be presented on an actual example. The paper is structured as follows. After the introductory chapter of the paper, the second part of the paper presents the fundamental determinants of the Beneish model as one of the potential tools for fraud detection. In the third chapter, the application of the Beneish model is presented on a practical example, and the last part of the paper brings concluding considerations.

2. Beneish model – role in fraud detection

Forensic experts use various methods and techniques in their investigations to detect areas of possible irregularities and narrow down the area of further fraud investigation. One of the models often used to identify financial manipulations is the Beneish model. This model uses data published in the financial statements of companies and was developed by prof. M.D. Beneish from the Kelley School of Business at Indiana University. In the paper “The Detection of Earnings Manipulation” from 1999, he presented a model intended to expose companies that manipulated earnings (Beneish, 1999). The goal of his research was to develop a model that would distinguish between manipulated and non-manipulated financial statements based on selected financial variables.

The experimental sample consisted of 74 companies that were either condemned by the regulatory agency for non-compliance with accounting standards or were identified by the media as potential manipulators, and the control sample consisted of companies from the same industry for which there were no indications of manipulation of financial statements. By applying various statistical methods, Beneish developed a model with 5 variables intended to predict manipulations in financial statements, and in subsequent research he added three more variables. Today two versions of the model are most often used - the version with 8 or the version with 5 variables.

Beneish model is used as a fraud detection tool, and it is interesting to point out how model exactly detected manipulations in the earnings of Enron, which became known as one of the biggest corporate scandals and failures caused by manipulating financial statements. Also, it is interesting to point out how calculated the M-score for the company ZZZZ Best, which is also known as one of the anthological corporate scandals, also exceeded the reference values several times and clearly indicated possible manipulations in this company (Belak, 2011). Wells (2001) points out that all contradictions in financial statements, such as significant overestimation of assets or income “will show up over time” and the application of analytical procedures and different models in forensic analysis will certainly make sense and may indicate certain irregularities in financial statements. Beneish model known as M-score consists of eight variables that are calculated based on data from financial statements. The variables included in the Beneish model and the method of calculation are presented below.

Variables included in Beneish model.

- Days' sales in a receivable index (DSRI)

$$DSRI = \frac{\text{Receivables (t) / Revenue (t)}}{\text{Receivables (t-1) / Revenue (t-1)}} \quad (1)$$

- Gross margin index (GMI)

$$GMI = \frac{\text{Gross profit (t-1) / Revenue (t-1)}}{\text{Gross profit (t) / Revenue (t)}} \quad (2)$$

- Asset quality index (AQI)

$$AQI = \frac{1 - (\text{CA(t)} + \text{PPE(t)} / \text{TA(t)})}{1 - (\text{CA(t-1)} + \text{PPE(t-1)} / \text{TA(t-1)})} \quad (3)$$

- Sales growth index (SGI)

$$SGI = \frac{\text{Revenue (t)}}{\text{Revenue (t-1)}} \quad (4)$$

- Depreciation index (DEPI)

$$DEPI = \frac{\text{Depr(t-1)} / (\text{Depr(t-1)} + \text{PPE(t-1)})}{\text{Depr(t)} / (\text{Depr(t)} + \text{PPE(t)})} \quad (5)$$

- Sales and general and administrative expenses index (SGAI)

$$SGAI = \frac{\text{GA(t)} / \text{Sales(t)}}{\text{GA(t-1)} / \text{Sales(t-1)}} \quad (6)$$

- Leverage index (LVGI)

$$LVGI = \frac{(\text{LTD(t)} + \text{CL(t)}) / \text{TA(t)}}{(\text{LTD(t-1)} + \text{CL(t-1)}) / \text{TA(t-1)}} \quad (7)$$

- Total accruals to total assets (TATA)

$$TATA = \frac{\text{Working capital} - \text{Cash} - \text{Depr}}{\text{Total assets}} \quad (8)$$

where:

- PPE – Property, plant, and equipment
- CA – Current assets
- TA – Total assets
- LTD - Long-term debt
- CL - Current liabilities
- GA - General expenses
- Depr – Depreciation

Each of the previously presented variables is, as stated in the formulas, calculated on the basis of the data presented in the financial statements, and table 1 shows the arithmetic means for manipulated and non-manipulated statements as well as instructions for assessing possible manipulations.

Table 1 Arithmetic means of the variables included in the Beneish model

Variable	Manipulated	Not manipulated	Assessment of possible manipulations
DSRI	1.465	1.031	Index greater than 1.031 – possible manipulations
GMI	1.193	1.014	Index greater than 1.014 – possible manipulations
AQI	1.254	1.039	Index greater than 1.039 – possible manipulations
SGI	1.607	1.134	Index greater than 1.134 – possible manipulations
DEPI	-	1.000	Index greater than 1.000 – possible manipulations
SGAI	-	1.000	Index greater than 1.000 – possible manipulations
LVGI	-	1.000	Index greater than 1.000 – possible manipulations
TATA	0.031	0.018	Index greater than 0.018 – possible manipulations

Source: Belak, 2011.

According to the results, if the values of individual variables exceed the critical values for non-manipulated reports, then the conclusion is made that there is a possibility of manipulation of that variable. For example, if days' sales in a receivable index exceeds the value of 1.031, it is concluded that there is a possibility of manipulation. In order to simplify the interpretation of individual indicators, a unique control measure of 1.08 was set for the variables DSRI, GMI, AQI and SGI. Therefore, if the determined values for these parameters exceed the control value of 1.08, it is concluded that there is a possibility of manipulation. The critical value for the variables DEPI, SGAI and LVGI is 1.00, while for the last variable of the model, TATA, the threshold value is 0.02, which means that if the determined value of the indicator indicates an excess of more than 2%, there is an indication of manipulations in financial statements.

After calculating individual variables included in the model are calculated, the M-score is estimated and the final result is determined. After determining M-score an assessment of possible manipulation and fraud in the financial statements is given. The model for calculating the M-score has the following form:

$$M = -4.84 + 0.92 * DSRI + 0.528 * GMI + 0.404 * AQI + 0.892 * SGI + 0.115 * DEPI - 0.172 * SGAI + 4.679 * TATA - 0.327 * LVGI \quad (9)$$

If the M-score result is less than -1.78, it is concluded that the company did not manipulate earnings, and in situations where the obtained result is higher than -1.78, it is concluded that there is a possibility of earnings manipulation and further and more detailed forensic analysis is required. For example, a determined M-score in the amount of -2.5 indicates a low probability of manipulation of financial statements, while a determined M-score in the amount of -1.6 indicates potential manipulations of financial statements. It is interesting to point out that some authors (for example, Belak, 2011, Valaskova & Fedorko, 2021, Fenyves, Pisula & Tarnoczi, 2023) take -2.22 as the reference value of the M-score, that is, draw a conclusion about possible manipulations when the calculated M-score is higher than -2.22. It is important to point out that the model is used as a tool for detecting possible fraud and manipulation of earnings, and that making more specific conclusions requires a more detailed forensic analysis.

The five-variable version of the model has the following form:

$$M = -6,065 + 0.823 * DSRI + 0.906 * GMI + 0.593 * AQI + 0.717 * SGI + 0.107 * DEPI \quad (10)$$

Application of Beneish model, requires data from financial statements for two consecutive years, and when applying it, it is necessary to take into account the limitations of the model. Belak (2011) cites the fact that the model was developed on the basis of American accounting standards as a potential limitation of the model, and its application to companies that have prepared reports in accordance with International Financial Reporting Standards may give different results. Furthermore, data for two consecutive years are included in the model, and the model will not be successful in detecting manipulations if the reports have been manipulated for several consecutive years. Despite the aforementioned limitations, the model has been widely used, and below is a practical example and assessment of possible manipulations based on the example of a Croatian company.

3. Calculation of the Beneish M-score model

In this chapter of the paper practical application of Beneish M-score model is shown. In order to apply model on a real-life example public financial statements of a large company (for four consecutive years) have been taken. Data required for the analysis have been slightly altered as to keep the company anonymous but without affecting calculation results. In our calculations we used both versions of the Beneish M-score model: full 8-variable Beneish

model and also a shorter 5-variable version of the model which is commonly used in forensic analysis. In analysis data from publicly available financial statements of a large company for the years 2018, 2019, 2020 and 2021 were used. A company which has a full set of financial statements was used due to fact that short format of financial statements would not be sufficient to calculate the necessary elements for an M-score (Beneish model) calculation.

In order to calculate different variables from the Beneish M-score models following data were extracted from company's financial statements:

- PPE – Property, plant, and equipment
- CA – Current assets
- TA – Total assets
- Receivables
- Cash
- Long-term debt
- Current liabilities
- Working capital
- General expenses
- Depreciation
- Revenue
- Gross profit

For the specific company used, data are presented in the following table.

Table 2 Anonymised specific company financials

Results	2021	2020	2019	2018
PPE	248.244	139.730	60.119	51.524
Current assets	371.468	303.485	402.850	83.253
Total assets	2.233.744	963.498	801.473	281.100
Receivables	88.323	100.795	87.481	36.667
Cash	84.375	48.895	224.814	13.383
LT debt	28.634	122.440	80.638	16.221
Current liabilities	348.758	205.787	86.618	44.884
Working capital	22.711	97.698	316.232	38.370
General expenses	440.088	184.526	110.969	68.924
Depreciation	29.478	12.201	10.714	5.755
Revenue	1.021.034	167.405	119.907	45.136
Gross profit	123.735	135.586	110.283	41.332

All amounts in Table 2 are expressed in Croatian Kuna as it was the official currency for those years. Also, all amounts are anonymised in a way not to affect final M-score calculations. In the next step of the analysis each element of Beneish M-score was calculated and the results are presented hereafter.

- Days' sales in a receivable index - DSRI

A significant increase in the ratio ($DSRI > 1$) may indicate the likelihood of overestimating earnings through accelerated recognition of revenue or a change in credit policy to boost sales by providing additional deferred payment. In our example the results were as follows:

Table 3 DSRI calculated values

	2021	2020	2019
DSRI	0.1437	0.8253	0.8981
Indication	Ok	Ok	Ok

As seen in Table 3, the DSRI is below the threshold of 1 for all three observed periods, with a declining trend indicating no issues of manipulations when observing only this variable.

- Gross margin index - GMI

A gross margin over 1 ($GMI > 1$) can indicate a deterioration of gross margin as well as negative outlook for a company. A high gross margin index indicates high probability of earnings manipulations and misleading financial reports creation. Calculated results were as follows:

Table 4 GMI calculated values

	2021	2020	2019
GMI	6.6833	1.1356	0.9956
Indication	Look into	Look into	Ok

As seen in Table 4, the Gross Margin Index is only marginally below threshold in 2019, over it in 2020 and significantly over it in 2021. Given the rising trajectory and although the calculated value for 2019 is below the threshold, all three observed periods should be treated with caution and looked into, with a specific focus on 2021.

- Asset quality indeks - AQI

A high Asset Quality Index ($AQI > 1$) is an indicator of probable profit and earnings manipulation. It can indicate that a company has increased its cost deferral (improper, illegal, or excessive capitalization of expenses) or increased its intangible assets. In our example the results were as follows:

Table 5 AQI calculated values

	2021	2020	2019
AQI	1.3381	1.2785	0.8114
Indication	Look into	Look into	Ok

As seen in Table 5, the Asset Quality Index is above its threshold value for 2021 and 2020, while relatively close to its threshold value in 2019. The upward trajectory warrants a cautious approach for all observed periods.

- Sales growth index - SGI

High sales growth itself does not mean of earnings manipulation, however, high growth companies are more likely to commit financial fraud in order to keep up the appearance of high sales. A Sales Growth Index of above 1 ($SGI > 1$) usually indicates it should be investigated. Calculated results were as follows:

Table 6 SGI calculated values

	2021	2020	2019
SGI	6.0992	1.3961	2.6566
Indication	Look into	Look into	Look into

As seen in Table 6, the Sales Growth Index is well above its threshold value for all three observed periods. Furthermore, its movement is not linear and exhibits and extraordinary increase from 2020 to 2021, warranting a serious looking into in order to identify the root cause.

- Depreciation index - DEPI

Manipulation with depreciation rates also lead to earnings misrepresentation. Income increases due to adjusting depreciation methods, i.e., the company revises upwards the estimates of assets useful lives. In such a way, a company may increase income by cutting expenses. Usual threshold for the Depreciation Index is 1. In our example the results were as follows:

Table 7 DEPI calculated values

	2021	2020	2019
DEPI	0.7566	1.8834	0.6643
Indication	Ok	Look into	Ok

As seen in Table 7, the Depreciation Index is above its threshold value only in 2020. Given the nature of this index and despite its value in 2019 and 2021 being below threshold, an investigation into company long-term assets acquisitions and disposals in those years is warranted in order to explain the high index value in 2020.

- Sales and general and administrative expenses index - SGAI

The Sales General and Administrative Expenses puts these expenses in a ratio with sales where a potential problem is indicated if these kinds of expenses were growing faster than sales did. The increase in expenditures compared to sales is interpreted as a negative sign concerning the company's prospects i.e. management is not successful in controlling expenses, decrease in administrative and marketing efficiency. Also, it is an indicator of financial statement fraud. In our example the results were as follows:

Table 8 SGAI calculated values

	2021	2020	2019
SGAI	0.3910	1.1911	0.6061
Indication	Ok	Look into	Ok

As seen in Table 8, the Sales General and Administrative Expenses Index almost doubles in year 2020 warranting an investigation into these kind of expenses for at least year 2020, even though it would be beneficial to look into 2019 and 2021 as well to better understand the movements in these expenses.

- Leverage index - LVGI

Leverage Index indicates an increase in financial leverage and with a value of more than 1 ($LVGI > 1$) represents a high risk of financial statement manipulation. It also presents an incentive for earnings manipulations in order to meet debt covenants. Calculated results were as follows:

Table 9 LVGI calculated values

	2021	2020	2019
LVGI	0.4959	1.6324	0.9600
Indication	Ok	Look into	Ok

As seen in Table 9, the Leverage Index increased from a marginal value of 0,9600 in 2019 to an above threshold value of 1,6324 in 2020, only to decrease to 0,4959 in 2021. Such movement warrants an investigation into the debt movement of the company, including new debts, debt payments and interest recognized.

- Total accruals to total assets - TATA

The Total Accruals to Total Assets Index is an earnings manipulation indicator putting into relation the increasing accruals values compared to total assets. The greater the level of accruals (less cash), the higher the likelihood of profit manipulation. It indicates a company's possible accounting aggressiveness policies, which have a more positive impact on reported profits. In our example the results were as follows:

Table 10 TATA calculated values

	2021	2020	2019
TATA	-0.0408	0.0380	0.1007
Indication	Ok	Ok	Ok

As seen in Table 10, there is no indication of manipulation when observing the Total Accruals to Total Assets Index. Values of two or more times higher than those in the previous period would warrant an investigation.

After calculating each component of Beneish M-score the full 8-variable Beneish M-score model was calculated and full three-year results are presented in the following table.

Table 11 Full 8-variable M-score calculation

Results	2021	2020	2019
DSRI	0.1437	0.8253	0.8981
GMI	6.6833	1.1356	0.9956
AQI	1.3381	1.2785	0.8114
SGI	6.0992	1.3961	2.6566
DEPI	0.7566	1.8834	0.6643
SGAI	0.3910	1.1911	0.6061
LVGI	0.4959	1.6324	0.9600
TATA	-0.0408	0.0380	0.1007
Full M-score	4.4688	-2.0636	-0.6612
Indication	Red flag	Potential problem	Red flag

When calculating the full 8-variable M-score we arrive at a continuation and culmination of problems which were identified during calculation of separate variables of the model.

The reference M-score value is -1.78 with everything higher than this indicating a problem, results between -2.22 and -1.78 indicating a potential problem while results lower than -2.22 not indicating a problem.

Based on this full M-score calculation, the company in question poses a serious red flag and all transfers to it of public funds should be seriously scrutinized and monitored throughout their usage. As mentioned earlier, this company has received significant public funding in the previous years and continues to do so but on the other hand, is very lacking and un-cooperative when it comes to transparency or abiding to simple regulations imposed to all business entities in Croatia. These only fuels suspicion and gives more merit to the results presented in this paper.

A shorter version of M-score was also calculated utilizing only 5 out of 8 elements previously described. The ones left out in this calculation are SGAI, LVGI and TATA. The full three-year results for the 5 variable model are presented in table 12.

Table 12 5-variable M-score calculation

Results	2021	2020	2019
DSRI	0.1437	0.8253	0.8981
GMI	6.6833	1.1356	0.9956
AQI	1.3381	1.2785	0.8114
SGI	6.0992	1.3961	2.6566
DEPI	0.7566	1.8834	0.6643
5 variable M-score	5.3559	-2.3962	-1.9668
Indication	Red flag	Ok	Potential problem

Using only a 5-variable calculation 2020 is showing as ok, but only marginally. When put into context with 2019 and 2021 it is clear that this company's business should be thoroughly revised before any more public funds and granted to it.

4. Conclusion

In this paper, the authors have shown the application of the Beneish model in forensic research using a practical example. The Beneish model is one of the tools of forensic analysis that indicates the possibility of manipulations in financial statements, and by pointing out potential manipulations, directs further forensic investigation. The model consists of 8 (wider version) or 5 (shorter version of the model) variables that are calculated based on the data presented in the financial statements. After calculating the individual variables and then the M-score for an individual company, the result is compared with the critical values and a conclusion is drawn about possible manipulations.

Practical analysis conducted within this paper once more confirmed usefulness of Beneish M-score in forensic analysis. Already during the calculation of the individual variables of the model, certain deviations and red flags for analysed company were observed, which indicated the need for further forensic analysis. The calculation of the M-score for the three analysed years only further confirmed the suspicions and also indicated the possibility of manipulation of the financial statements of the analysed company.

The calculation of the M-score model for the observed company indicates potential manipulations and the need for further investigations. These results gain even more significance if we take into account that in recent years observed company has received significant funds from the state in the form of various grants and is quite non-transparent in terms of disclosures and compliance with legal frameworks in the field of financial reporting. In this sense, the results presented in this paper indicate that Beneish model is a useful tool when conducting forensic analysis, but both state inspectors and decision makers in the public sector could use it as a preventive mechanism for checking and detecting possible manipulators before the allocation of public money. Such an approach would not only reduce fraud and raise the level of awareness of the harmful consequences of fraud, but would also have a positive effect on increasing trust in the work of state bodies and institutions.

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DEVELOPMENT OF THE MUNICIPALITY OF LEČEVICA USING EU FUNDS AND THE ITI MECHANISM

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ABSTRACT. The Mechanism of Integrated Territorial Investments (ITI mechanism) is a new mechanism of the European Union created in the financial period 2014-2020 with the aim of developing large cities recognized as development generators in their environments. Therefore, in the Republic of Croatia at the end of 2015, based on the Regional Development Act, urban agglomerations and urban areas were established, including the Urban Agglomeration of Split, which consists of 13 units of local self-government, namely the City of Split as the lead city of the Urban Agglomeration, the cities of Kaštela, Omiš, Sinj, Solin, Trogir, and the municipalities of Dikmo, Dugi Rat, Dugopolje, Klis, Lečevica, Muć and Podstrana.

The Municipality of Lečevica, as the smallest and least developed unit of local self-government in the Urban Agglomeration of Split, successfully implemented five EU projects funded by the ITI mechanism during the financial period 2014-2020, three from the Operational Program Competitiveness and Cohesion 2014-2020 and two from the Operational Program Efficient Human Resources 2014-2020. This was a great success for Lečevica, resulting in the title of the second most successful municipality in Croatia in terms of EU funds absorption in 2022.

The residents of the Municipality of Lečevica, as end users and target groups of the projects, were maximally involved in project activities, especially in two “soft” projects through which they were able to participate in numerous workshops, education sessions, and social gatherings held in three reconstructed, renovated, and equipped facilities owned by the Municipality, also through ITI projects. Since the residents of Lečevica are mostly elderly, frail, isolated, and scattered across numerous settlements, transportation to project activities was organized and provided to them by an official vehicle procured from the project precisely due to the need for organized transportation of workshop participants.

This paper provides a detailed description of the successfully implemented ITI projects of the Municipality of Lečevica, namely the “Multifunctional Center of Fra Ante Konstantin Matas,” the Arrangement of the Pišteti Well within the project “Open Summer Stages of the Urban Agglomeration of Split,” the Development of Services and Capacities of the Development Agency of the Municipality of Lečevica “Lasta,” “All for Lečevica,” and “Together with Us.”

Keywords: EU funds, ITI mechanism, Urban Agglomeration of Split, Municipality of Lečevica

1. Introduction

During the period from 2014 to 2020, regional policy emerged as one of the key public policies of the European Union, aiming to mitigate social and economic disparities, balance the

quality of life of all member state inhabitants, and address the fact that more than two-thirds of the European population live in cities that are becoming centers of both economic and social development. In order to respond to various economic, social, and environmental challenges, an integrated development strategy became necessary. Thus, the European Union introduced for the first time the Integrated Territorial Investments (hereinafter referred to as the ITI mechanism), designed as an instrument to comprehensively address development challenges, including globalization and associated structural changes, growing inequalities in wealth distribution, climate change and environmental pollution, loss of biodiversity, and the increasing sensitivity of landscapes, natural, and cultural heritage in urban environments. Therefore, the European Union obliged member states to allocate at least 5% of the funds from the European Regional Development Fund for integrated sustainable development measures during the period from 2014 to 2020. For the current financial period from 2021 to 2027, a minimum allocation of 8% has been defined for the implementation of the ITI mechanism.

2. Implementation of the ITI mechanism in the Republic of Croatia

Integrated territorial investments represent a mechanism used for the first time in the European Union during the period 2014-2020, allowing the integration of funds from various European funds and operational programs, and investing these funds in activities to strengthen the role of cities as drivers of economic development. Therefore, the Republic of Croatia, in its program documents for the period 2014-2020, designated the implementation of measures for sustainable urban development through the ITI mechanism within the Operational Program Competitiveness and Cohesion and the Operational Program Efficient Human Resources. For this purpose, funds were allocated from three European funds - the European Regional Development Fund, the Cohesion Fund, and the European Social Fund. During that period, 5.88% of the funds, amounting to 345 million euros, were allocated for the implementation of the ITI mechanism in 8 largest cities (.

Acceptable investment areas for cities under the Operational Programme Competitiveness and Cohesion) through the ITI mechanism include investments in entrepreneurship, district heating, brownfield locations (former military and/or industrial areas), cultural heritage, and public transportation systems in urban areas, all accompanied by complementary investments in human resource development through the Operational Programme for Human Resources Development (OPULJP).

The eligible beneficiaries of the ITU mechanism in the financial period 2014-2020 are 8 urban areas - 4 urban agglomerations: Zagreb, Split, Rijeka, and Osijek, as well as 4 larger urban areas: Zadar, Slavonski Brod, Pula, and Karlovac.

For the financial period from 2021 to 2027, 13.05% of the funds, amounting to 681.275 million euros from the European Regional Development Fund, were allocated for the ITI mechanism's implementation and its implementation in 22 cities.

Acceptable investment areas for cities under the IIT mechanism include investments in entrepreneurship, green, clean, smart, and sustainable urban transport, brownfield locations, cultural heritage and tourism, green infrastructure and natural heritage, multipurpose infrastructure and public spaces, pilot projects at the level of urban settlements and neighborhoods, district heating (for phased projects), and energy efficiency (as a horizontal requirement).

Given the increased allocation for sustainable urban development, the implementation of the ITU mechanism is planned in 22 cities that have established their urban areas in accordance

with the Spatial Planning Act and Guidelines for Establishing Urban Areas and Developing Urban Area Development Strategies for the financial period 2021-2027, namely:

- 4 urban agglomerations: Zagreb, Split, Rijeka, and Osijek
- 10 larger urban areas: Zadar, Slavonski Brod, Pula, Karlovac, Sisak, Varaždin, Šibenik, Dubrovnik, Bjelovar, and Vinkovci
- 8 smaller urban areas that are county seats: Koprivnica, Vukovar, Čakovec, Požega, Virovitica, Krapina, Gospić, and Pazin.

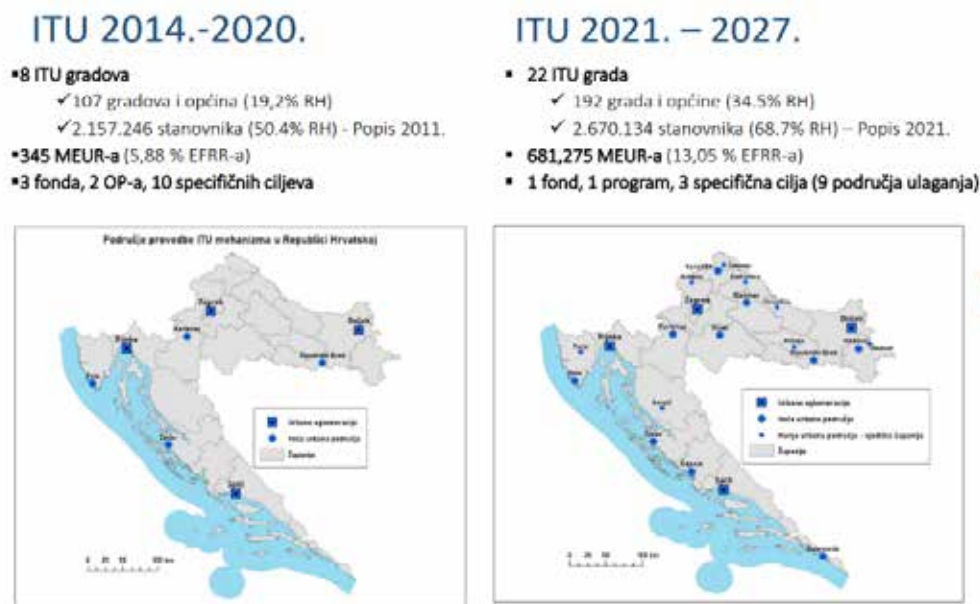


Figure 1 ITU mechanism in Croatia, 2014 - 2020 vs 2021 - 2027.

Source: Ministry of Regional Development and EU Funds, EU Funds 2021 - 2027. New Opportunities, Kaštela

2.1. Urban Agglomeration Split

Urban policy is integrated into the Law on Regional Development of the Republic of Croatia (Law) as one of the important components of regional policy. The Urban Agglomeration Split (UAS) was established on November 30, 2015, at the initiative of the City of Split, as the leading city of the UAS, based on the Law and the decision of the Minister of Regional Development. Its scope includes 6 cities (City of Split, City of Kaštela, City of Sinj, City of Trogir, City of Omiš, and City of Solin) and 7 municipalities (Municipality of Dicmo, Municipality of Dugi Rat, Municipality of Dugopolje, Municipality of Klis, Municipality of Lećeveica, Municipality of Muć, and Municipality of Podstrana). During the period from 2021 to 2027, the scope of the UAS remains unchanged.

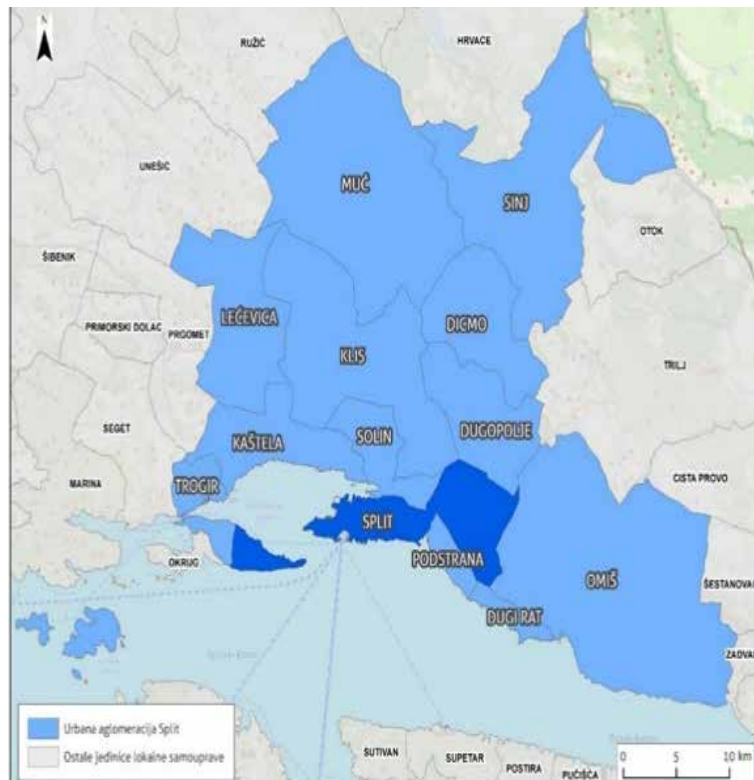


Figure 2 The area of the Urban Agglomeration Split

Source: Authors

3. Development of the Municipality of Lećevica Using EU Funds and the ITU Mechanism

The Municipality of Lećevica belongs to the hinterland part of the Urban Agglomeration Split and the Split-Dalmatia County, consisting of the settlements Lećevica, Radošić, Kladnjice, and Divojevići. The Municipality of Lećevica covers an area of 87.37 km², which constitutes 6.79% of the total area of the Urban Agglomeration Split and 1.93% of the total area of the County. According to the 2021 census, the municipality has a population of 495 inhabitants. The existing state of settlement systems in the Municipality of Lećevica is determined by past development and processes of population gathering in several smaller hamlets within the settlements.

In the financial period 2014-2020, the Municipality of Lećevica demonstrated significant interest and need for utilizing non-repayable funds from the ITU mechanism. It successfully prepared, applied for, and implemented 5 projects within the Operational Program Competitiveness and Cohesion and the Operational Program for Human Resources Development in 2014-2020, as shown in Table No. 2.

Table 2 ITU projects of the Municipality of Lećeveica

No..	Project Name	Beneficiary	Total Project Value	Grant from ITU funds
1	Otvorene ljetne pozornice „Uređenje bunara pišteti” / Open Summer Stage “Renovation of the Pišteti Well”	Municipality Lećeveica	172.374,41 EUR (1.298.755,00 HRK)	146.518,24 EUR (1.103.941,75 HRK)
2	Razvoj usluga i kapaciteta razvojne agencije općine Lećeveica „Lasta” / Development of Services and Capacities of the Development Agency of the Municipality of Lećeveica “Lasta”	Development Agency of the Municipality of Lećeveica “Lasta and Municipality Lećeveica	216.712,09 EUR (1.632.817,27 HRK)	184.205,26 EUR (1.387.894,56 HRK)
3.	Multifunkcionalni centar fra Ante Konstantina Matasa / Multifunctional Center of Fra Ante Konstantina Matasa	Municipality Lećeveica	621.200,85 EUR (4.680.437,73 HRK)	478.298,82 EUR (3.603.742,43 HRK)
4.	„Svi za Lećeveicu” / “All for Lećeveica”	Municipality Lećeveica	328.230,14 EUR (2.473.050,00 HRK)	328.230,14 EUR (2.473.050,00 HRK)
5.	„Zajedno za nas” / „Together for Us”	Općina Lećeveica	235.540,04 EUR (1.774.676,40 HRK)	200.209,03 EUR (1.508.474,94 HRK)

Source: Authors

3.1. Project KK.06.1.1.08 Open Summer Stages - Pišteti Well Renovation

- The total project value amounts to 4.346.772,74 EUR (32.750.759,23 HRK), of which a total of 3.694.756,83 EUR (27.838.145,30 HRK) is financed from non-repayable funds of the European Regional Development Fund.
- The project is implemented by the City of Solin with project partners: the Tourist Board of the City of Solin, the Municipality of Klis, the City of Omiš, the Municipality of Dugopolje, the City of Kaštela, the Municipality of Lećeveica, and the City of Trogir.
- The total value of activities carried out by the Municipality of Lećeveica amounts to 172.374,41 EUR (1.298.755,00 HRK).
- Locations: Split-Dalmatia County: Solin, Klis, Omiš, Dugopolje, Kaštela, Lećeveica, and Trogir.
- Project implementation period: August 8, 2018 - April 30, 2024.

Project Objective:

- As part of the integrated project Open Summer Stages aimed at revitalizing cultural heritage by providing additional amenities for the local population and tourism attractions through the construction, arrangement, and equipping of open summer stages at multiple locations in 7 different cities and municipalities of the Urban Agglomeration Split, the investment goal in

Lećeveica is the arrangement and preservation of old wells in the settlement of Radošić and the construction and equipping of a summer stage.

Construction Works on Pišteti Well Renovation - the works included cleaning, landscaping, refurbishment, and restoration of the existing three wells, construction and installation of benches and tables, appropriate signage, and the procurement of a stage (mobile platform).

- The total cost of the works amounted to 172.374,41 EUR (939.718,75 HRK).



Figure 3 The wells of Pišteti before and after the works
Source: Municipality of Lećeveica

3.2. Project KK.03.1.2.10 Development of Services and Capacity of the Development Agency of the Municipality of Lećeveica - Lasta

- The total project value is:
- 216.712,09 EUR (1.632.817,27 HRK)
- 85% of the project value, amounting to 184.205,26 EUR (1.387.894,56 HRK), is financed from non-repayable funds.
- 15% of the project value, amounting to 32.506,83 EUR (244.922,60 HRK), is financed from the municipality's own funds.
- Project implementation period: November 30, 2020 - November 30, 2023.

Development Agency of the Municipality of Lećeveica was established in 2018 as an institution owned by the Municipality of Lećeveica. It was founded with the aim of assisting in the identification, preparation, and implementation of projects for the Municipality of Lećeveica, entrepreneurs, and family agricultural holdings, as well as strengthening local development. The agency also plays an important role in the development of civil society, various clubs, and associations aimed at increasing the quality of life in the Municipality of Lećeveica.

Until 2023, the Agency employed three people (a director and two expert associates), and since the beginning of 2023, two people - a director and one expert associate.

Project Activities:

A1 - Adaptation and equipping of the premises of the Development Agency of the Municipality of Lećeveica – Lasta

A2 - Strengthening of professional competencies and capacities of the Development Agency of the Municipality of Lećeveica - Lasta

- Training sessions to enhance the professional capacities of the Public-Private Interface (PPI)

- Training sessions for public procurement certification
- English language training

A3 - Preparation and implementation of a suburban innovation center program

Within the development agency, a co-working space with four workstations has been organized. This is also the only space managed by the Development Agency and is considered entrepreneurial infrastructure allocated for potential entrepreneurs for short-term or long-term leasing.

A4 - Specialized educational program “sustainable and climate-resilient agriculture”

- Lecture on “Agro-technical measures and best practices”
- Lecture on “Investment financing and product marketing”

A5 - Specialized educational-advisory program “tourism and agriculture”

This activity was conducted in collaboration with the City of Omiš and the Development Agency of the Municipality of Dugopolje ODRAZ, and two workshops were held in Omiš and Dugopolje.

A6 - Consultancy program for SMEs in the tourism sector

Throughout the project period, interested parties from the Municipality were monitored and informed about possible funding opportunities, provided advisory services for funding applications.

A7 - Establishment of an information platform for SMEs

For the implementation of this activity, a website www.ra-lasta.hr was created, serving as a platform for consulting with content on possible funding sources and entrepreneurship news. The website includes: a corner for entrepreneurs (information on what is an OPG, how to write a business plan...), projects in preparation and implementation, current calls for proposals, and news.

A8 - Business consulting services for SMEs

During the project duration, employees provided non-financial support to interested SMEs in the Urban Agglomeration of Split, with a focus on the Municipality of Lećeveica. They provided over 400 hours of business consulting through educational workshops, advisory and consultancy services, as well as information services.



Figure 4 The space of the Development Agency Lasta before and after the works

Source: Municipality of Lećeveica

3.3. Project KK.06.2.2.12.0002 Multifunctional Center “fra Ante Konstantina Matasa”

Total project value: 621.200,85 EUR (4.680.437,73 HRK)

EU co-financing of the project (85%): 478.298,82 EUR (3.603.742,43 HRK)

Project implementation period: October 13, 2016 – March 31, 2024



Figure 5 The space of the Multifunctional Center before and after the works

Source: Municipality of Lećeveica

Result of the project:

By implementing the aforementioned project, a brownfield site with a total area of 825.70 m² has been renovated, equipped, and put into operation, of which 303.63 m² pertains to the net usable area of the building, including an additional 101 m² of building extension, while 522.07 m² refers to the land around the building, which was also landscaped during the project implementation. This directly contributes to sustainable management and use of spatial resources. The importance of the renovation is emphasized by the location of the facility in the built-up area of the settlement, in a readily accessible location in the center of the municipality of Lećeveica.

3.4. Project UP.02.1.1.12.0007 All for Lećeveica

Total project value: 328,230.14 EUR (2,473,050.00 HRK)

Total grant value: 328,230.14 EUR (2,473,050.00 HRK)

Project duration: 24 months

The aim of the project is to actively involve and improve employability, as well as develop innovative social services for vulnerable groups in the UAS area, resulting in an increase in the quality of life for these target groups:

- 35 individuals aged over 54 years,
- 15 individuals aged under 25 years,
- 5 participants with disabilities,
- 10 unemployed individuals.

Throughout the project implementation, a series of engaging workshops were held for the residents of the municipality of Lećeveica, who showed great interest and willingness to participate in numerous workshops conducted over the course of 2 years. These workshops included cooking, decoupage, art workshops, volunteering workshops, sustainable development, sewing, crocheting, social games, dry-stone walling, stone carving, and various cultural activities. Additionally, during the project, 5 unemployed individuals were trained as caregivers, and 1 as a gerontology assistant.

3.5. Project UP.02.2.2.15.0086 Together for Us

The value of the project is 235.540,04 EUR (1.774.676,40 HRK). The total value of non-refundable funds is also 235.540,04 EUR (1.774.676,40 HRK). Duration: 2 years.

Project partners include the municipalities of Muć and Klis.

Target groups:

- Individuals older than 54 years
- Persons with disabilities
- Experts/people for organizing and providing non-institutional social services

During the project implementation, 3 gerontology assistants and 1 caregiver were employed, who provided daily care and assistance to 15 individuals older than 54 years and 2 persons with disabilities.

For the needs of project management and coordination, 3 project team members were employed, and a car was procured, which was available to all project beneficiaries.



Figure 6 Implemented project activities
Source: Municipality of Lećevica

4. CONCLUSION

With the help of EU grant funds from the ITI mechanism, successfully completed projects in the Municipality of Lećevica have greatly improved the quality of life for people living in the municipality and have shown that even smaller units of local self-government within the scope of the Urban Agglomeration of Split, with quality and motivated human resources, can be examples of good practice in drawing down grant funds. In 2022, the Municipality of Lećevica was the second municipality in the Republic of Croatia in terms of the amount of grant funds withdrawn per capita, specifically 8,921.76 € per each of its 495 inhabitants, and it was by far the smallest on the list of the top 10 municipalities. Upon completion of the implemented ITI projects from the financial period 2014 - 2020, the infrastructure in the municipality of Lećevica has been improved, with the renovated abandoned building of the old school of Fra Ante Konstantin Matas becoming a space that is used daily by associations, children, youth, and the elderly. Additionally, the space of the old school in the settlement of Radošić has been arranged and equipped, where numerous activities for older residents were held through two ESF projects. A car was also procured, which is available daily to the elderly residents of Lećevica. A protected site, the Pišteti wells, has been arranged, and a summer stage has been procured for use at all locations in the municipality where various outdoor activities are organized. The Lasta Development Agency has been established, providing assistance and support to entrepreneurs and to the municipality itself in implementing EU projects, all with the aim of improving the quality of life for residents of this smallest municipality in the inland part of the Urban Agglomeration of Split, as well as for the entire Split-Dalmatia County.

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SUPPORT FOR THE DEINSTITUTIONALIZATION PROCESS IN SPLIT THROUGH THE IMPLEMENTATION OF THE FOUR PALMS BROWNFIELD PROJECT

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ABSTRACT. Children and young people that are placed in homes for neglected children after turning 18 or finishing school lose the right for accommodation and care in homes and find themselves overnight on the streets, left to fend for themselves. In order to help young people in these difficult times, provide them with accommodation and help towards their independence, the City of Split, in cooperation with the Children's home Maestral, launched the EU project Four Palms, reconstructing an old abandoned building and turning it into 8 residential units, i.e. in 1 three-room apartment and 6 studio apartments for young people after leaving homes for neglected children, and in the House for Parents, with 8 double rooms where parents whose children are treated at KBC Split and whose residence is outside the city of Split can stay for free. The Four Palms project was co-financed as a brownfield project from Specific Objective 6e2 - Renovation of brownfield locations, Operational Program Competitiveness and Cohesion 2014-2020, with grants from the ITU mechanism, intended for projects of the Urban Agglomeration of Split, in the amount of €592,476, while the total value of the project was €1,327,056. The implementation of the project was successfully completed at the end of 2022 when the first tenants, former residents of the Children's home Maestral, moved into the facility, which helped contribute with the problem of introducing vulnerable groups back into society, as well as strengthening non-institutional services by increasing the capacity of accommodation units intended for the most vulnerable groups of society in the city of Split and the Urban Agglomeration of Split. As part of the implementation of the ITU mechanism, i.e. the mechanism of integrated territorial investments, as a new mechanism of the European Union created in the financial period 2014-2020 with the aim of developing large cities, the Urban Agglomeration of Split was formed, with the City of Split and 12 other local self-government units from the surroundings: the cities of Kaštela, Omiš, Sinj, Solin, Trogir, and the municipalities of Dicmo, Dugi Rat, Dugopolje, Klis, Lećevica, Muć and Podstrana.

In this paper, the successfully implemented ITU brownfield project of the City Split Four Palms is described in more detail, and other implemented ITU projects financed under the European Social Fund, which also contributed to the process of social integration of vulnerable groups and deinstitutionalization in the Urban Agglomeration of Split, are briefly presented

Keywords: *EU projects, Urban agglomeration Split, ITU mechanism, deinstitutionalization, Four Palms*

1. Introduction

The main investment policy of the European Union in the programming period 2014-2020 was regional policy aimed at reducing the gap in social and economic disparities and improving the quality of life of all EU member states' residents. This policy constituted the largest part of the European Union budget for the period 2014-2020, specifically 351.8 billion euros out of a total of 1,082 billion euros. During this time frame, many reforms of regional policy were adopted, and the share of the budget allocated to cities gradually increased. The reason for this is that two-thirds of the total population in all member states live in cities. With this trend of population migration towards cities, they become drivers of social and economic growth and development. The increase in the population also brings about a rise in the problems they face, such as unemployment, overcrowding, wealth inequality, environmental pollution, and so on. In order to reduce and ultimately solve these problems, the European Union introduced the Integrated Territorial Investment (ITI) mechanism as a tool aimed at addressing these and other developmental challenges through its implementation. Thus, in the period from 2014 to 2020, the European Union obligated all member states to allocate a minimum of 5% of funds from the European Regional Development Fund for integrated measures for sustainable urban development, while for the current period from 2021 to 2027, the minimum obligation of allocation has increased to 8%.



Figure 1 ITU mechanism logo

2. The ITI Mechanism in the Republic of Croatia

The Integrated Territorial Investment (ITI) mechanism, implemented during the period 2014-2020, focused on eight major urban centres with the highest population concentrations and capacities for project implementation. These centres were selected for ITU mechanism implementation based on criteria from the public call of the Ministry of Regional Development and EU Funds. They comprise four urban agglomerations with over 100,000 inhabitants in central settlements: Zagreb, Osijek, Rijeka, and Split, as well as four urban areas with over 50,000 inhabitants in central settlements: Zadar, Slavonski Brod, Pula, and Karlovac. In this context, the urban centre cities are not confined to their administrative boundaries but include neighbouring local government units or their parts, which together create a spatial-functional entity - an urban agglomeration or urban area. The establishment of urban agglomerations and urban areas further encourages the decentralization process as these areas become development centres, strong enough to facilitate significant economic advancements, job creation, and the creation of social climates and services that can attract population. Moreover, urban centre cities become partners in ITI mechanism implementation and part of the system that manages EU funds as they assess the quality of projects applying for funding from the Operational Programme Competitiveness and Cohesion. Projects funded must comply with the development strategies of urban areas adopted by the four urban agglomerations and three urban areas during 2017.

For the implementation of sustainable urban development measures through the ITI mechanism in the period 2014-2020, the Republic of Croatia allocated €345,351,269.00, as follows:

- €303,351,269.00 from the European Regional Development Fund and the Cohesion Fund within the Operational Programme Competitiveness and Cohesion
- €42,000,000.00 from the European Social Fund within the Operational Programme Efficient Human Resources.

Funds were allocated through public calls published by two competent Ministries and were intended to finance projects implemented in the eight selected areas within the following investment areas:

- Creating a favourable environment for entrepreneurs
- Facilitating the development of quality infrastructure for the most important economic sectors
- Reconstruction and enhancement of cultural heritage for tourism development
- Revitalization of neglected military, industrial, and other areas
- Improving public transport services
- Renovation of district heating systems
- Employment and self-employment measures
- Measures to combat poverty and social exclusion
- Improving access to high-quality social services
- Improving the adult education system
- Modernizing vocational education offerings.

In the long term, all projects planned and implemented through the ITI mechanism have contributed to the economic and social development of the Republic of Croatia and the improvement of the population's quality of life, particularly in the cities within the territory of ITI urban agglomerations and urban areas.

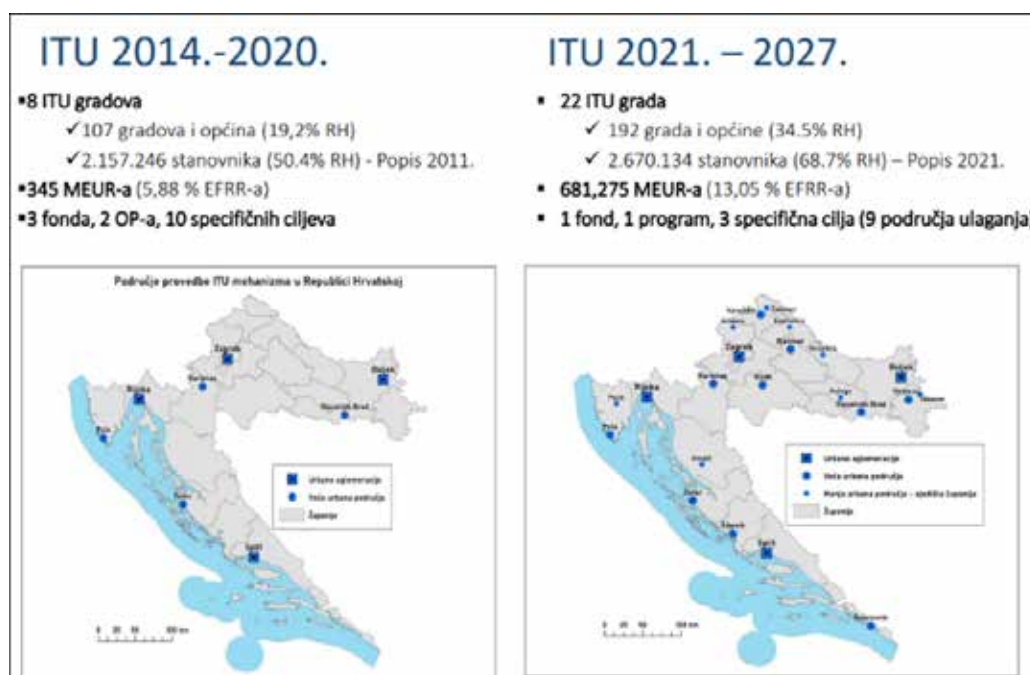


Figure 2 ITU mechanism in Croatia from 2014. to 2020. and from 2021. to 2027.

The allocation of ITU funds in the Republic of Croatia, out of a total of 681.3 million euros for the period 2021-2027, is also defined based on the population size of the city center of the urban agglomeration/urban area, grouped by ranges of the number of inhabitants, as shown in Table No. 1.

Table 1 Distribution of ITU allocation for 22 ITU cities in Croatia for the period 2021-2027

INDICATIVE DISTRIBUTION OF ITU ALLOCATION FOR THE FINANCIAL PERIOD 2021-2027 by groups based on the range of the number of inhabitants				
Ordinal number	ITU urban areas	Population range	Population of the central city	Indicative ITU allocations (2021-2027) EUR
1.	Zagreb	More then 180.000	767.131	80.500.000
2.	Split	90.001-180.000	160.577	55.000.000
3.	Rijeka		107.964	55.000.000
4.	Osijek		96.313	55.000.000
5.	Zadar	70.001-90.000	70.779	43.000.000
6.	Slavonski Brod	49.001-70.000	49.891	33.000.000
7.	Pula		52.220	33.000.000
8.	Karlovac		49.377	33.000.000
9.	Sisak	30.001-49.000	40.121	22.000.000
10.	Varaždin		43.782	22.000.000
11.	Šibenik		42.599	22.000.000
12.	Dubrovnik		41.562	22.000.000
13.	Bjelovar		36.316	22.000.000
14.	Vinkovci		30.842	22.000.000
15.	Koprivnica	15.001-30.000	28.580	18.000.000
16.	Vukovar		23.175	18.000.000
17.	Čakovec		27.122	18.000.000
18.	Požega		22.294	18.000.000
19.	Virovitica		19.302	18.000.000
20.	Krapina	Less then 15.000	11.530	13.500.000
21.	Gospić		11.502	13.500.000
22.	Pazin		8.279	13.500.000

3. Urban Agglomeration Split

The decision to establish the Urban Agglomeration Split was made by the Minister of Regional Development and EU Funds on November 30, 2015. It consists of the following local government units: City of Split, City of Kaštela, City of Omiš, City of Sinj, City of Solin, City of Trogir, Municipality of Dirmo, Municipality of Dugi Rat, Municipality of Dugopolje, Municipality of Klis, Municipality of Lećevica, Municipality of Muć, and Municipality of Podstrana. The City of Split initiated the formal process of defining the scope of the Urban Agglomeration in the second quarter of 2015. During the process, a Study of Spatial-Programmatic Dimensions of Sustainable Urban Development of the City of Split in the Context of the EU 2014-2020 was prepared, within which, respecting the principles defined by the Ministry of Regional Development and EU Funds, comprehensive criteria for determining the composition of the Urban Agglomeration Split were methodologically presented. The basic criterion that the City of Split used when including local government units in the composition was the criterion of the share of daily migrations to the city of Split being greater than 30%. The City of Omiš is the

only local government unit included in the Agglomeration based on the additional criterion of the frequency of urban/suburban transportation, as the company Promet d.o.o. provides public transportation services between the City of Split and the City of Omiš with the frequency of urban/suburban transportation. The Cities of Sinj and Trogir did not meet the basic criterion, but they were included in the composition of the Urban Agglomeration Split in accordance with the provisions of the Law on Regional Development of the Republic of Croatia, which stipulate that urban areas directly bordering the Urban Agglomeration are considered a single urban area. All proposed local government units provided consents for inclusion in the Urban Agglomeration Split at the session of the representative body. The final proposal for the composition of the Urban Agglomeration Split was adopted by the City Council of the City of Split on October 3, 2015, and was submitted to the relevant ministries for evaluation, leading to the decision to establish the Urban Agglomeration Split on November 30, 2015.

The scope of the Urban Agglomeration Split remains the same in the current period 2021-2027.



Figure 3 Area of Urban Agglomeration Split

4. The “FOUR PALMS” Brownfield Project

4.1. What is a brownfield project and what are the advantages?

A brownfield project refers to the redevelopment or revitalization of previously used, abandoned, derelict, or contaminated land. These areas are typically abandoned, inactive, or underutilized former industrial or military sites where expansion or redevelopment is complicated due to environmental contamination.

The goal of brownfield projects is to return these areas to productive use while simultaneously mitigating environmental risks and enhancing the surrounding community. This may involve activities such as environmental assessments, remediation of pollution or hazardous materials, upgrading infrastructure, and planning for redevelopment.

The advantages of brownfield redevelopment include:

- Economic revitalization: Reusing abandoned or underutilized land can stimulate economic growth, attract investments, and create jobs in the community.

- Environmental improvement: Cleaning up contaminated areas can improve air and water quality, reduce health risks, and restore ecosystems.
- Urban renewal: Redeveloping brownfield areas can contribute to the revitalization of urban areas, improve the quality of life for residents, and attract businesses and residents back to the area.
- Sustainable land use: Reusing existing infrastructure and land reduces the need for new construction on greenfield sites, preserving natural areas and agricultural land.

Brownfield projects often involve collaboration between the public and private sectors, civil society organizations, and environmental stakeholders to address environmental issues, secure funding, and plan for the future use of the area.

4.2. Basic Information about the Four Palms Brownfield Project

User: City of Split

Total project value: €1,327,056 (HRK 10,079,314.16)

Total eligible project costs: €1,327,056.08 (HRK 9,998,704.00)

Amount of co-financing (45%): €592,476 (HRK 4,464,010.86)

Own funds (55%): €745,278.82 (HRK 5,615,303.29), of which €367,290 (HRK 2,767,346.57) are from national funds



Figure 4 „Four Palms“ logo

4.3. About the project

The purpose of the “Four palms” project, implemented from March 30, 2020, to July 30, 2022, was the reconstruction of a building located at A.B. Šimića 25 in Split, in the Blatine-Škrape city district. The project financed bringing the building to the “high shell” construction level, while the furnishing of the space was financed from the City of Split’s budget to prepare it for use in the context of new out-of-institutional services provided at that location. The reconstructed space is intended for use by vulnerable groups in society and includes two main target groups:

- 1) Young people over the age of 21 without adequate parental care who are transitioning out of some form of institutional care they have been receiving, including former residents of the Maestral Children’s Home in Split,
- 2) Parents of children undergoing treatment or rehabilitation at the Clinical Hospital Center in Split who do not have accommodation while their children are in the hospital.

In this way, the project contributes to addressing integration issues for vulnerable groups in society, or reducing the cost of living caused by unforeseen circumstances. The project strengthens out-of-institutional services by increasing the capacity of accommodation units for vulnerable groups in society, thereby providing a basis for achieving a higher quality of life.



Figure 5 The old abandoned building located at A.B. Šimića 25, Split.

After signing the Grant Agreement for non-repayable funds from the ITU mechanism and conducting the public procurement procedure to select a contractor for the construction works on the “Četiri palme” facility, the construction site was officially opened on October 26, 2020. The existing building was reconstructed into a structure with eight residential units, comprising six studio apartments and one three-bedroom apartment for former residents of the Maestral Children’s Home in Split, as well as one nine-bedroom apartment with eight double rooms for parents or caregivers of seriously ill children without permanent residence in the city of Split, whose children are undergoing treatment or rehabilitation at the Clinical Hospital Center in Split..

The existing abandoned building in the very center of Split, with approximately the same footprint, was reconstructed into a four-story structure. In Picture 6, the foundations of the future “Četiri palme” building are shown. The plan was to complete the construction by April 2021, but it was extended until July 2022 when the official implementation of the project was completed.



Figure 6 Construction works for the reconstruction of the Four Palms building.

Since only the costs of reconstruction and construction of the building were eligible for brownfield investments, the refurbishment and equipping were financed by the City from its own budget, as evident from the Procurement Plan of the City of Split for 2022 in Table 2.

Table 2 Procurements for the furnishing and equipping of Četiri Palme funded from the city budget.

Subject of procurement	Name and OIB (Personal Identification Number) of the contractor	Date of conclusion	Deadline for Conclusion	Amount excluding VAT	Amount of VAT	Total amount including VAT	The contract is financed from EU funds.
Revsion of the project „Four palms“	SKT revizija d.o.o. 72568612756	14.01.2022	30 days On February 10, 2022, an addendum was concluded extending the deadline for the provision of service until June 20,2022. On June 18, 2022, Addendum 2 was signed, extending the deadline for service provision to August 20. 2022.	14.400,00	3.600,00	18.000,00	No
Equipment for the Four palms facility - furniture	NOVI AMBIJENT d.o.o. 09670452552	08.08.2022	2 monts	614.600,00	153.650,00	768.250,00	No
Design supervision - Equipping the Four palms facility	IVAARCH d.o.o. 47493769126	12.08.2022	30 days	35.000,00	8.750,00	43.750,00	No
Installation of a ramp at the "FOUR PALMS" building, A.B.Šimića 25	M-P-Beton d.o.o. 59003338799	02.12.2022	13.12.2022.	26.980,14	6.745,04	33.725,18	No

After the completion of all works and the furnishing of the space, the building became home to former residents of the Maestral Home just before Christmas in 2022. Then, on October 5, 2023, the second part of the “Four Palms” building, namely a nine-bedroom apartment with eight double rooms primarily intended for parents or guardians who do not have accommodation while their children are receiving hospital treatment at the Clinical Hospital Centre Split, was put into operation.



Figure 7 The second part of the “Four Palms” building

4.4. Other ITU projects of the Split Urban Agglomeration funded by the European Social Fund

Within the ITU mechanism, in addition to infrastructure projects funded under the Operational Program Competitiveness and Cohesion 2014-2020, projects were implemented in the Split Urban Agglomeration funded by the European Social Fund under the Operational Program Effective Human Resources, specifically through Specific Objective 9i1 - Combating poverty and social exclusion through the promotion of labor market integration and social integration of vulnerable groups, and combating all forms of discrimination, and Specific Objective 9.iv.2 - Improving access to high-quality social services, including support for the deinstitutionalization process.

Sixteen projects were contracted and implemented, as shown in Table No. 3, covering the entire area of the Split Urban Agglomeration. These projects contributed to the deinstitutionalization process of the most vulnerable groups in our society, primarily children, youth, and elderly individuals.

Table 3 The contracted and implemented ITU projects of the Split Urban Agglomeration under the Operational Program for Human Resources Development 2014-2020.

No.	Project Name	Beneficiary	Total Project Value	Grant from ITU funds
1	Zajedno za djecu Sinja	Dječji vrtić Bili cvitak Sinj	€ 304.732,68	€ 304.732,68
2	SVI ZA LEĆEVICU	Općina Lećevica	€ 328.230,14	€ 328.230,14
3	Grad Trogir-inovativno-edukacijski centar društvene inkluzije urbane aglomeracije Split	Grad Trogir	€ 322.205,69	€ 322.205,69
4	Laboratorij kreativnosti	Općina Muć	€ 257.013,42	€ 257.013,42
5	Aktiviraj se i kreni! Razvoj programa za aktivno uključivanje i povećanje zapošljivosti mladih i starijih osoba na području UAS-a	Centar za kulturu i cjeloživotno obrazovanje Zlatna vrata	€ 315.319,93	€ 315.319,93
6	Pijat dobrote	Općina Dugopolje	€ 213.405,79	€ 213.405,79
7	Korak po korak	Općina Podstrana	€ 265.116,46	€ 265.116,46
8	Zajedno smo snažniji	Udruga Anđeli	€ 253.303,17	€ 253.303,17
9	Dječji osmijeh - rana i učinkovita podrška obitelji	Grad Trogir	€ 261.134,25	€ 261.134,25
10	Širenje usluga izvaninstitucionalne skrbi - Grad Kaštela	Udruga Sv. Jeronim	€ 265.116,46	€ 265.116,46
11	Centar za socijalnu inkluziju Trogir	Udruga tjelesnih invalida TOMS	€ 265.315,11	€ 265.315,11
12	O.P.S.! Unaprjeđenje, podrška, savjetovanje	Dječji dom Maestral Split i Općina Klis	€ 243.367,92	€ 243.367,92
13	Zajedno za nas	Općina Lećevica	€ 235.540,04	€ 235.540,04
14	Podrška deinstitutionalizaciji djece s teškoćama u razvoju na području Urbane aglomeracije Split	Rehabilitacijski centar Inkludo - udruga za djecu s teškoćama u razvoju	€ 253.887,39	€ 253.887,39

15	Od institucije do zajednice - promocija i razvoj izvaninstitucionalne skrbi na području UA Split	Udruga Most	€ 113.273,67	€ 113.273,67
16	Socioterapijski klub	Udruga za inkluziju - "Lastavice" Split	€ 142.366,59	€ 142.366,59
		UKUPNO:	€ 4.039.328,73	€ 4.039.328,73

5. CONCLUSION

Thanks to non-repayable EU funds from the ITU mechanism, the brownfield project "Four palms" in the city of Split, in the Blatine Škrpe district, was successfully completed. This project contributed to solving a social issue and improving the quality of life for young people who have reached the age of 18 without adequate parental care, who have left the Maestral Home for Abandoned Children. It also provides free accommodation for parents and guardians whose children are undergoing treatment at the Clinical Hospital Center Split. In addition to addressing the housing problem for young people after leaving care homes, the facility provides them with a safe environment, facilitates their integration into society, and eases the process of becoming independent.

A total of €1,327,056 was spent on the implementation of this project, of which 45%, or €592,476, was financed by non-repayable ITU funds from the Operational Program Competitiveness and Cohesion 2014-2020. The implementation was successfully completed at the end of 2022 when the first tenants, three young people without adequate parental care, moved into the facility. In October 2023, the second part of the facility, intended for parents and guardians whose children are receiving treatment at KBC Split, was officially opened after establishing cooperation and protocols with KBC Split, informing parents about the possibility of free accommodation at the "Četiri palme" facility while their children are undergoing treatment or rehabilitation at KBC Split.

As part of the implementation of the ITU mechanism, a new mechanism of the European Union created precisely in this period from 2014-2020 with the aim of developing large cities, the Split Urban Agglomeration was formed, with the City of Split as the leading city and 12 other local self-government units from the surrounding area successfully implementing ITU projects aimed at increasing the quality of life for all residents within the scope of the Split Urban Agglomeration.

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ON A DIFFERENT APPROACH TO THE CONTINUOUS COMPOUNDING

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Abstract. Numerous formulae have been developed for calculating the future value of a current asset at a later date, based on an assumed interest rate. Given their widespread application, most of these formulae are discrete, meaning they handle discrete amounts and accumulate their value at distinct interest earning periods spread throughout a time interval, assuming a fixed interest rate. Less commonly applied are models dealing with continuous asset flow during irregular intervals, via time-varying interest rates, with the main challenge being the difficulty in their calculation. Simplified versions of such models sometimes rely on ambiguous assumptions, resulting in unsatisfactory outcomes. This paper analyses one such model and addresses the generalized case of continuous asset flow with time-varying interest rates, employing ordinary differential equations and numerical mathematics tools to achieve satisfactory precision in calculation. It is demonstrated that the formula obtained is a generalization of commonly used ones. Mathematical proofs are presented in an informal yet rigorous manner, and several examples are provided for illustration.

Key words: *future value, continuous asset flow, time - varying interest rate, ordinary differential equations, numerical mathematics*

1. Introduction

Interest represents the fee paid for utilization of another party's financial resources for a specific period of time (Šego, 2005). When funds are deposited into banks or financial institutions, interest is additional income earned by the depositor, while in the case of loans, it is the expense borne by the borrower and paid to the lender. It depends on the nominal amount of loan or deposit, method of interest calculation, repayment period, as well as on the amount of the agreed or prescribed interest rate. (Decision on the effective interest rate Official Gazette 105/17 (Official Gazette 91/22)).

An interest rate is the proportion of interest owed in particular time interval, relative to the amount lent, deposited, or borrowed (Alaif, 2023). It shows the amount of interest on 100 monetary units in that time interval. The nominal interest rate is the interest rate specified in a contract between parties or mandated by law, and its unit of time can be any period but most often it is a year. Compounding period is interval for which interest is calculated and as in the case of nominal interest rate it can be any time interval.

Interest can be calculated using either the simple interest or compound interest calculation method. With simple interest calculation method, the interest is always calculated on the

principal amount at each compounding period (Babić & Tomić-Plazibat, 1998). Compound interest calculation method means that at each compounding period interest is calculated on the principal amount increased by the amount of interest, that is interest on interest is calculated (Relić, 2002).

Two compounding methods, end-of-period and beginning-of-period, are used when calculating interest. End-of-period interest calculation refers to a method where interest is computed and either added to the principal or paid out at the conclusion of the compounding period. In this approach, interest is calculated on the principal at the start of the compounding period. Beginning-of-period interest calculation is an interest calculation method where interest is calculated at the beginning of the compounding period, with respect to the amount at the end of the accounting period. (Decision on the effective interest rate Official Gazette 105/17 (Official Gazette 91/22)).

Within this study, exclusively compound interest calculation method at the end of the period will be employed, as it is most commonly used in practice.

When interest is calculated using the compound interest method at the end of the period, the commonly used formula for computing future value $C(t)$ of principal amount C_0 is

$$C(t) = C_0 \left(1 + \frac{p}{100} \right)^{t-a} = C_0 r^{t-a}, \quad (1)$$

where a and $t \geq a$ are some moments in time, p is end of the period nominal interest rate and $r = 1 + \frac{p}{100}$ is the end-of-period interest factor. In formula (1), interest rate is assumed to be fixed.

In practice, interest rates for most loans and investments fluctuate over time. Within the next chapter formula (1) is generalized to accommodate these variations in interest rates.

2. The time – varying interest rate

The time-varying compound interest rate at the end of the period $p(t)$ is a function of time and its corresponding interest factor is $r(t) = 1 + \frac{p(t)}{100}$. As described in Baras & Kožul Blaževski (2022), to calculate the future value $C(t)$ of the principal amount C_0 deposited at the moment a , for some $t \geq a$, the time segment $[a, t]$ is divided into m equidistant subsegments $[t_{k-1}, t_k]$, $k = 1, 2, \dots, m$ of the width $h = \frac{t-a}{m}$, where $t_k = a + kh$ for $k = 0, 1, 2, \dots, m$. Approximate future value $C(t)$ at the moment t is $C_0 r(t_0)^h r(t_1)^h r(t_2)^h \dots r(t_{m-1})^h$. The actual future value can be obtained by letting $m \rightarrow \infty$, that is

$$C(t) = \lim_{m \rightarrow \infty} C_0 r(t_0)^h r(t_1)^h r(t_2)^h \dots r(t_{m-1})^h. \quad (2)$$

Given that $r(t_0)^h r(t_1)^h \dots r(t_{m-1})^h = e^{h[\ln r(t_0) + \ln r(t_1) + \dots + \ln r(t_{m-1})]}$ and the exponent is integral sum, it follows

$$\lim_{m \rightarrow \infty} h[\ln r(t_0) + \ln r(t_1) + \dots + \ln r(t_{m-1})] = \int_a^t \ln r(x) dx. \quad (3)$$

Mathematically speaking, in order for the integral sum in (3) to converge, the function $p(t)$ should be piecewise continuous with values above -100 , which is a generally applicable assumption. Therefore, the future value $C(t)$ of the asset C_0 at the time $t \geq a$ is

$$C(t) = C_0 e^{a \int_a^t \ln r(x) dx}. \quad (4)$$

When $p(t) = p = \text{const}$, formula (4) reduces to formula (1), that is

$$C(t) = C_0 e^{a \int_a^t \ln r(x) dx} = C_0 e^{a \int_a^t \ln \left(1 + \frac{p}{100}\right) dx} = C_0 e^{\ln \left(1 + \frac{p}{100}\right) \int_a^t dx} = C_0 e^{(t-a) \ln \left(1 + \frac{p}{100}\right)} = C_0 \left(e^{\ln \left(1 + \frac{p}{100}\right)} \right)^{t-a} = C_0 \left(1 + \frac{p}{100}\right)^{t-a}$$

So, formula (4) represents a generalization of formula (1).

Since derivative of $C(t)$ is $C'(t) = C(t) \ln r(t)$, the function $C(t)$ is the solution to the initial value problem for ordinary differential equations

$$\begin{cases} C'(t) = C(t) \ln r(t) \\ C(a) = C_0 \end{cases}. \quad (5)$$

This is a valuable information, especially considering that the integral $\int_a^t \ln r(x) dx$ may not be easily calculable, or even calculable at all. In such instances, an approximate solution using a suitable numerical mathematics method could be a viable option.

One of the numerical mathematics the method of choice could be the widely used 4th order Runge-Kutta (RK-4) method. RK-4 method solves the initial value problem $\begin{cases} y'(x) = \varphi(x, y) \\ y(a) = y_0 \end{cases}$ for $x \in [a, b]$ by dividing the interval $[a, b]$ to m equidistant subsegments $[x_{k-1}, x_k]$, $k = 1, 2, \dots, m$. The width of subsegments is $h = \frac{b-a}{m}$ and $x_k = a + kh$ for $k = 0, 1, 2, \dots, m$.

For each $k = 0, 1, 2, \dots, m-1$, the coefficients k_1, k_2, k_3, k_4 are created so that $k_1 = \varphi(x_k, y_k)$,

$$k_2 = \varphi\left(x_k + \frac{h}{2}, y_k + \frac{k_1 h}{2}\right), \quad k_3 = \varphi\left(x_k + \frac{h}{2}, y_k + \frac{k_2 h}{2}\right), \quad k_4 = \varphi(x_k + h, y_k + k_3 h) \quad \text{and finally} \\ y_{k+1} = y_k + (k_1 + 2k_2 + 2k_3 + k_4) \frac{h}{6} \text{ is calculated (Drmač et al., 2003).}$$

The approximation of the solution is the linear interpolation spline for the points (x_k, y_k) , $k = 0, 1, 2, \dots, m$.

In the upcoming chapter, formula (4) is extended to encompass scenarios where the interest rate is time-varying and cash flow is continuous.

3. The continuous asset flow

To extend formula (4) to the case of continuous cash flow, the cash flow is considered as a function of time, where the amount of asset at time $t \geq a$ is described by function $f(t)$. In order to ascertain the future value $g(t)$ of continuous cash flow $f(t)$, the interval $[a, t]$ is subdivided into m equidistant subsegments $[t_{k-1}, t_k]$, $k = 1, 2, \dots, m$, like in the previous chapter, each of width $h = \frac{t-a}{m}$, where $t_k = a + kh$ for $k = 0, 1, 2, \dots, m$.

The future value $g(t)$ at time $t \geq a$ can be approximated with

$$\begin{aligned}
 & f(t_0)[r(t_0)^h - 1]r(t_1)^h r(t_2)^h \dots r(t_{m-1})^h + f(t_1)[r(t_1)^h - 1]r(t_2)^h r(t_3)^h \dots r(t_{m-1})^h + \dots \\
 & \dots + f(t_{m-2})[r(t_{m-2})^h - 1]r(t_{m-1})^h + f(t_{m-1})[r(t_{m-1})^h - 1] + f(t_m) = \\
 & = f(t_0)r(t_0)^h r(t_1)^h r(t_2)^h \dots r(t_{m-1})^h + [f(t_1) - f(t_0)]r(t_1)^h r(t_2)^h \dots r(t_{m-1})^h + \\
 & + [f(t_2) - f(t_1)]r(t_2)^h r(t_3)^h \dots r(t_{m-1})^h + \dots + [f(t_{m-1}) - f(t_{m-2})]r(t_{m-1})^h + [f(t_m) - f(t_{m-1})] = \\
 & = f(t_0)r(t_0)^h r(t_1)^h r(t_2)^h \dots r(t_{m-1})^h + h \left[\frac{f(t_1) - f(t_0)}{h} r(t_1)^h r(t_2)^h \dots r(t_{m-1})^h + \right. \\
 & \left. + \frac{f(t_2) - f(t_1)}{h} r(t_2)^h r(t_3)^h \dots r(t_{m-1})^h + \dots + \frac{f(t_{m-1}) - f(t_{m-2})}{h} r(t_{m-1})^h + \frac{f(t_m) - f(t_{m-1})}{h} \right].
 \end{aligned}$$

Giving that, when the function $p(t)$ is piecewise continuous and above -100 , then

$$r(t_0)^h r(t_1)^h \dots r(t_{m-1})^h = e^{h[\ln r(t_0) + \ln r(t_1) + \dots + \ln r(t_{m-1})]} \rightarrow e^{a \int_0^t \ln r(x) dx} \text{ for } m \rightarrow \infty, \text{ it follows that the future value } g(t) \text{ of continuous cash flow } f(t) \text{ is}$$

$$g(t) = f(a)e^{a \int_0^t \ln r(x) dx} + \int_a^t f'(x)e^{a \int_x^t \ln r(y) dy} dx, \quad (6)$$

if $f(t)$ is continuously differentiable.

It can be proven that for all $c \in [a, b]$ following equation holds

$$g(b) = g(c) \cdot e^{a \int_c^b \ln r(x) dx} + \int_c^b f'(x)e^{a \int_x^b \ln r(y) dy} dx. \quad (7)$$

Namely, if $\int \ln r(t) dt = H(t) + C$, that is $H'(t) = \ln r(t)$, it follows

$$\begin{aligned}
 & g(c) \cdot e^{a \int_c^b \ln r(x) dx} + \int_c^b f'(x)e^{a \int_x^b \ln r(y) dy} dx = \\
 & = \left(f(a)e^{a \int_a^c \ln r(x) dx} + \int_a^c f'(x)e^{a \int_x^c \ln r(y) dy} dx \right) e^{a \int_c^b \ln r(x) dx} + \int_c^b f'(x)e^{a \int_x^b \ln r(y) dy} dx = \\
 & = f(a)e^{a \int_a^c \ln r(x) dx} e^{a \int_c^b \ln r(x) dx} + e^{a \int_c^b \ln r(x) dx} \cdot \int_a^c f'(x)e^{a \int_x^c \ln r(y) dy} dx + \int_c^b f'(x)e^{a \int_x^b \ln r(y) dy} dx = \\
 & = f(a)e^{a \int_a^b \ln r(x) dx} + e^{H(b)-H(c)} \cdot \int_a^c f'(x)e^{H(c)-H(x)} dx + \int_c^b f'(x)e^{H(b)-H(x)} dx =
 \end{aligned}$$

$$\begin{aligned}
 &= f(a)e^a \int_a^b \ln r(x) dx + \int_a^c f'(x)e^{H(c)-H(x)+H(b)-H(c)} dx + \int_c^b f'(x)e^{H(b)-H(x)} dx = \\
 &= f(a)e^a \int_a^b \ln r(x) dx + \int_a^c f'(x)e^{H(b)-H(x)} dx + \int_c^b f'(x)e^{H(b)-H(x)} dx = \\
 &= f(a)e^a \int_a^b \ln r(x) dx + \int_a^b f'(x)e^{H(b)-H(x)} dx = f(a)e^a \int_a^b \ln r(x) dx + \int_a^b f'(x)e^x \int_a^b \ln r(x) dx = f(b).
 \end{aligned}$$

Further on, the future value $g(t)$ of continuous cash flow $f(t)$ is the solution to the following ordinary differential equation initial value problem

$$\begin{cases} g'(t) = g(t) \ln r(t) + f'(t) \\ g(a) = f(a) \end{cases}, \quad (8)$$

Initial value problem for ordinary differential equation (8) is derived from the following

$$g(t) = f(a)e^a \int_a^t \ln r(x) dx + \int_a^t f'(x)e^x \int_a^t \ln r(y) dy dx = f(a)e^{H(t)-H(a)} + e^{H(t)} \cdot \int_a^t f'(x)e^{-H(x)} dx \text{ and}$$

$$g'(t) = f(a)e^{H(t)-H(a)} H'(t) + e^{H(t)} H'(t) \int_a^t f'(x)e^{-H(x)} dx + e^{H(t)} f'(t)e^{-H(t)} = g(t) \ln r(t) + f'(t)$$

So, similar to the future value $C(t)$ of the principal amount C_0 , the future value $g(t)$ may be evaluated by numerical mathematics.

Using partial integration for the integral

$$\begin{aligned}
 \int_a^t f'(x)e^x \int_a^t \ln r(y) dy dx &= \int_a^t f'(x)e^{H(t)-H(x)} dx = \left[\begin{array}{ll} u = e^{H(t)-H(x)} & dv = f'(x) dx \\ du = -e^{H(t)-H(x)} H'(x) dx & v = f(x) \end{array} \right] = \\
 &= f(x)e^{H(t)-H(x)} \Big|_a^t + \int_a^t f(x)e^{H(t)-H(x)} H'(x) dx = f(t) - f(a)e^{H(t)-H(a)} + \int_a^t f(x)e^{H(t)-H(x)} \ln r(x) dx = \\
 &= f(t) - f(a)e^a \int_a^t \ln r(x) dx + \int_a^t f(x)e^x \int_a^t \ln r(y) dy dx,
 \end{aligned}$$

formula (6) can be rewritten as

$$\begin{aligned}
 g(t) &= f(a)e^a \int_a^t \ln r(x) dx + f(t) - f(a)e^a \int_a^t \ln r(x) dx + \int_a^t f(x)e^x \int_a^t \ln r(y) dy dx = \\
 &= f(t) + \int_a^t f(x)e^x \int_a^t \ln r(y) dy dx,
 \end{aligned}$$

and the formula for the interest in the case of continuous cash flow at time $t \geq a$ is

$$g(t) - f(t) = \int_a^t f(x) e^{\int_a^x \ln r(y) dy} \ln r(x) dx. \quad (9)$$

4. The discontinuous asset flow

Formula (6) can be further generalized to the cases involving mixed continuous and discrete assets.

Let f be piecewise continuous, meaning it is continuous on segment $[a, t]$ except for a finite number $l \in \mathbb{N}$ of points $c_1, c_2, \dots, c_l \in \langle a, t \rangle$, $c_1 < c_2 < \dots < c_l$, where it has removable or jump discontinuities, and piecewise differentiable on each $[c_i, c_{i+1}]$. The formula for future value $g(t)$ of $f(t)$ at time $t \geq a$ can be easily obtained using (7):

$$g(t) = f(a) e^{\int_a^t \ln r(x) dx} + \sum_{i=1}^l [f(c_i+) - f(c_i-)] e^{\int_a^{c_i} \ln r(x) dx} + \int_a^t f'(x) e^{\int_a^x \ln r(y) dy} dx. \quad (10)$$

As for numerical mathematics, rewriting initial value problem for ordinary differential

equation (8) into $\begin{cases} g_0'(t) = g_0(t) \ln r(t) + f'(t) \\ g_0(a) = f(a) \end{cases}$ and $\begin{cases} g_i'(t) = g_i(t) \ln r(t) + f'(t) \\ g_i(c_i) = g_{i-1}(c_i) + f(c_i+) - f(c_i-) \end{cases}$

for $i \in \{1, 2, \dots, l\}$ at last produces the future value in the form $g(t) = \begin{cases} g_0(t), t \in [a, c_1] \\ g_1(t), t \in [c_1, c_2] \\ \vdots \\ g_l(t), t \in [c_l, b] \end{cases}$.

To expedite the convergence of the RK-4 method, it's advisable to employ this technique even in cases involving discontinuous interest rates.

5. Examples

Example 1 Calculate the exact future value $g(3)$ of the asset described by the function $f(t) = 1000 + 2000t$, assuming that compound interest rate at the end of the period is

$$p(t) = \begin{cases} 5, t \in [0, 1] \\ 10, t \in [1, 2] \\ 20, t \in [2, 3] \end{cases}. \text{ Then using RK-4 method, approximate the future value } g(t) \text{ with}$$

accuracy to four decimal places and plot the graphs of functions $p(t)$, $f(t)$ and $g(t)$.

Solution of Example 1 According to equation (6), the real future value $g(3)$ is

$$g(3) = f(0) \cdot e^{\int_0^3 \ln r(x) dx} + \int_0^3 f'(x) \cdot e^{\int_0^x \ln r(y) dy} dx = 1000 \cdot e^{\int_0^1 \ln 1.05 dx + \int_1^2 \ln 1.1 dx + \int_2^3 \ln 1.2 dx} +$$

$$\begin{aligned}
 & +2000 \cdot \left[\int_0^1 e^x \left(\int_1^2 \ln 1.05 dy + \int_2^3 \ln 1.1 dy + \int_3^4 \ln 1.2 dy \right) dx + \int_1^2 e^x \left(\int_2^3 \ln 1.1 dy + \int_3^4 \ln 1.2 dy \right) dx + \int_2^3 e^x \int_3^4 \ln 1.2 dy dx \right] = \\
 & = 1000 \cdot 1.05 \cdot 1.1 \cdot 1.2 + 2000 \cdot \left[1.1 \cdot 1.2 \cdot \int_0^1 e^{(1-x)\ln 1.05} dx + 1.2 \cdot \int_1^2 e^{(2-x)\ln 1.1} dx + \int_2^3 e^{(3-x)\ln 1.2} dx \right] = \\
 & = 1386.00 + 2000 \cdot \left[1.1 \cdot 1.2 \cdot \int_0^1 1.05^{1-x} dx + 1.2 \cdot \int_1^2 1.1^{2-x} dx + \int_2^3 1.2^{3-x} dx \right] = \\
 & = 1386.00 + 2000 \cdot \left[1.1 \cdot 1.2 \cdot \frac{1.05-1}{\ln 1.05} + 1.2 \cdot \frac{1.1-1}{\ln 1.1} + \frac{1.2-1}{\ln 1.2} \right] = 8803.48339352652...
 \end{aligned}$$



Figure 1 MATLAB in solving initial value problem by RK-4

To speed up the convergence of RK-4, the initial value problem (8) is split to segments

$$\begin{cases} g_0'(t) = g_0(t) \ln r(t) + f'(t) \\ g_0(0) = f(0) \end{cases},$$

$$\begin{cases} g_1'(t) = g_1(t) \ln r(t) + f'(t) \\ g_1(1) = g_0(1) \end{cases},$$

$$\begin{cases} g_2'(t) = g_2(t) \ln r(t) + f'(t) \\ g_2(2) = g_1(2) \end{cases}$$

and then the future value $g(t)$ is expressed as $g(t) = \begin{cases} g_0(t), t \in [0,1) \\ g_1(t), t \in [1,2) \\ g_2(t), t \in [2,3] \end{cases}$.

MATLAB is used for calculations (Figure 1) until the approximation stabilizes on four decimal places in $g(1)$, $g(2)$ and $g(3)$ (Table 1) and to plot the graphs. Graf of $p(t)$ is presented on Figure 2, while graphs of $f(t)$ and $g(t)$ are given on Figure 3.

Table 1 Convergence of RK-4 approximation for different n until desired accuracy

n	$g(1)$	$g(2)$	$g(3)$
1	3099.5933	5507.9629	8803.4549
2	3099.5934	5507.9644	8803.4815
3	3099.5934	5507.9645	8803.4830
4	3099.5934	5507.9645	8803.4833
5	3099.5934	5507.9645	8803.4833
6	3099.5934	5507.9645	8803.4834
7	3099.5934	5507.9645	8803.4834

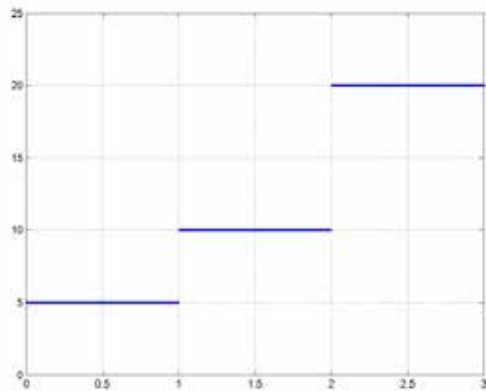


Figure 2 Interest rates $p(t)$

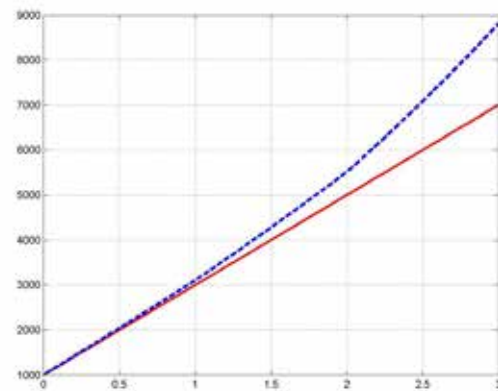


Figure 3 $f(t)$ (full) and $g(t)$ (dashed)

Example 2 Utilizing RK-4, with accuracy on two decimal places, approximate the future value $g(t)$ for the function $f(t) = 10000 + 2000t \cos 5t$ on segment $[a, b] = [0, 3]$. The compound interest rate at the end of the period is $p(t) = (6 - t)^2$. Additionally, plot the graphs of functions $p(t)$, $f(t)$, $g(t)$.

Table 2 Convergence of RK-4 approximation for different n until desired accuracy

n	$g(3)$
10	13072.07
30	13079.80
50	13079.87
70	13079.87
85	13079.89
86	13079.89

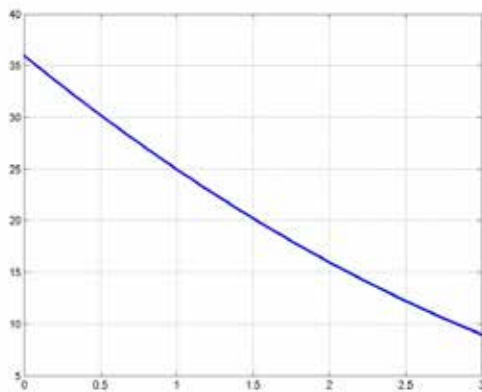


Figure 4 Interest rates $p(t) = (6-t)^2$

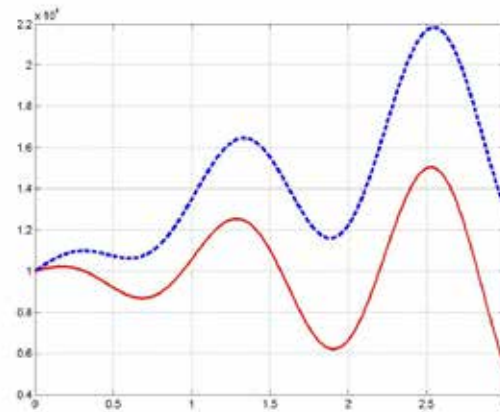


Figure 5 $f(t)$ (full) and $g(t)$ (dashed)

Solution of Example 2 With accuracy on two decimal places, the RK-4 approximation is presented in Table 2. MATLAB is employed to plot the graph of $p(t)$ (Figure 4), as well as the graphs of $f(t)$ and $g(t)$ (Figure 5).

Given that the primary application of this method is in economics, the results in the remaining examples will be accurate to two decimal places. Nonetheless, it's straightforward to extend them to the desired accuracy.

Example 3 Approximate the future value $g(t)$ of the asset described by function $f(t) = 5000 \ln(t+2)$ on segment $[a, b] = [0, 4]$ using RK-4 method with accuracy on two decimal places. The compound interest rate at the end of the period is

$$p(t) = \begin{cases} 20t + 5, & t \in [0, 1) \\ -8(t-1)^2 - 4(t-1) + 25, & t \in [1, 2) \\ -10(t-2)^2 + 2(t-2) + 13, & t \in [2, 3) \\ -12(t-3)^2 - (t-3) + 5, & t \in [3, 4] \end{cases}. \text{ Plot the graphs of all functions.}$$

Solution of Example 3 The results of RK-4 approximation with accuracy on two decimal places are shown in Table 3. MATLAB is then employed to plot the graphs of $p(t)$ (Figure 6), as well as graph of $f(t)$ and $g(t)$ (Figure 7).

Table 3 Convergence of RK-4 approximation for different n until desired accuracy

n	$g(4)$
10	12107.04
30	12108.42
50	12108.53
70	12108.56
80	12108.59
100	12108.59

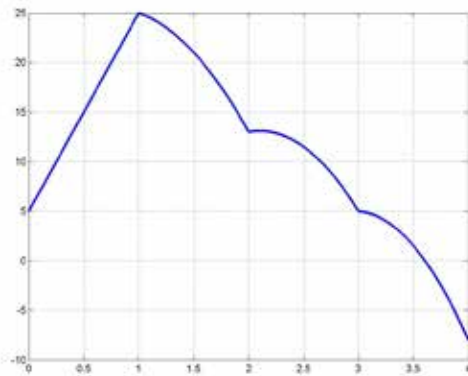


Figure 6 Interest rates $p(t)$

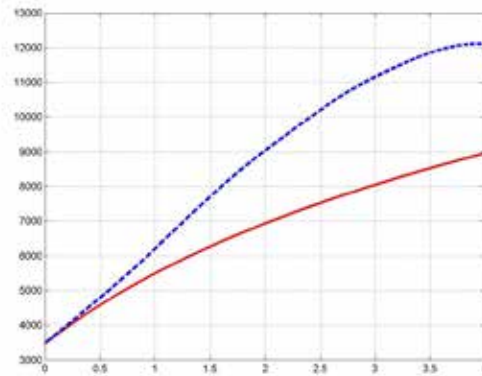


Figure 7 $f(t)$ (full) and $g(t)$ (dashed)

Example 4 Using RK–4 method with accuracy to two decimal places, approximate the future value $g(10)$ of the asset described by function

$$f(t) = \begin{cases} 2000t^2 - 2t + 5000, & \text{za } t \in [0, 4) \\ -3000(t-4)^2 + 60000, & \text{za } t \in [4, 8) \\ 5000(t-8)^2 - 15000(t-8) + 45000, & \text{za } t \in [8, 10] \end{cases} \quad \text{on segment } [a, b] = [0, 10] \text{ if the}$$

compound interest rate at the end of the period is $p(t) = \begin{cases} 2 + e^{t-2} \sin^2(t+4), & t \in [0, 5) \\ t^{t-9} - \frac{t^3}{3t+1} + 2t + 10, & t \in [5, 10] \end{cases}$.

In addition, plot the graphs of all functions.

Solution of Example 4 With accuracy to two decimal places, RK–4 approximation is presented in Table 4, and MATLAB is used to plot the graphs of $p(t)$ (Figure 8), along with the graph of $f(t)$ and $g(t)$ (Figure 9).

Table 4 Convergence of RK–4 approximation for different n until desired accuracy

n	$g(4)$	$g(5)$	$g(8)$	$g(10)$
5	39652.45	65161.98	35760.04	63706.07
10	39654.77	65161.94	35759.96	63705.40
15	39654.89	65161.94	35759.95	63705.37
20	39654.91	65161.94	35759.95	63705.36
22	39654.92	65161.94	35759.95	63705.36
25	39654.92	65161.94	35759.95	63705.36

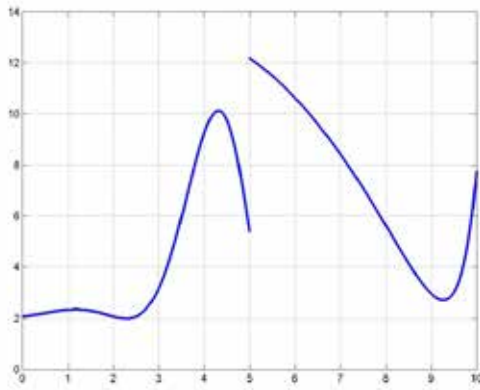


Figure 8 Interest rates $p(t)$

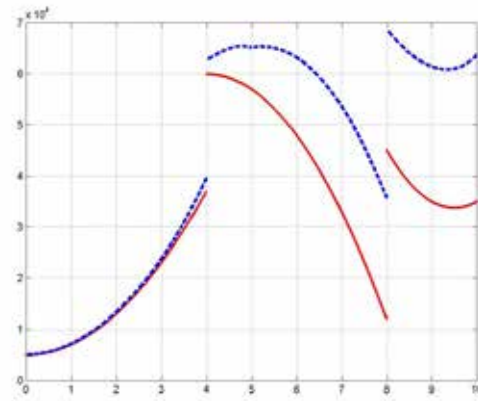


Figure 9 $f(t)$ (full) and $g(t)$ (dashed)

6. Discussion

Continuous compounding in finance entails the continuous addition of interest to the principal amount, which is then further compounded. Although not commonly utilized in financial products like loans or savings accounts due to logistical reasons, it is often used in corporate finance, particularly in investment appraisal. Continuous compounding allows businesses to assess future or principal amount with greater accuracy by assuming immediate reinvestment of income.

The commonly used formula for future value $C(t)$ in case of continuous compounding when $t \geq a$ is

$$C(t) = C_0 e^{\frac{(t-a)p}{100}}, \quad (11)$$

C_0 is the principal amount at the moment $t = a$ and p is fixed nominal end of period interest rate.

Despite its frequent use, formula (11) is ambiguous because it incorrectly combines simple and compound interest (Baras & Kožul Blaževski, 2022). It is constructed based on the premise of discrete cash flows and fixed nominal end of period interest rates. Since, in practice, cash flows frequently occur continuously over time, rather than being discrete, and interest rates may vary over time rather than remaining fixed this assumption does not hold in real world scenarios. It is primarily constructed to simplify computations.

In this paper, a formula is developed for situations where cash flows are continuous and the interest rates vary over time, without depending on the aforementioned assumption. This is achieved through gradual generalization of formula (1), as formula (11) is not suitable for generalization.

Formula (1) is utilized to calculate the future value $C(t)$ of the fixed principal amount C_0 when interest is compound and the end of the period interest rate p is constant. By extending formula (1) to the case of time-varying compound interest rate $p(t)$, formula (4) for calculating the future value $C(t)$ of the fixed principal asset C_0 is obtained.

Since the asset need not be fixed amount C_0 , but rather a time-dependent function $f(t)$,

similar method was applied to generalize equation (4) to the case when both $p(t)$ and $f(t)$ are time-varying. This resulted in equation (6) for the future value $g(t)$ of continuously differentiable asset flow $f(t)$.

Final generalization leads to the formula (10), for the future value $g(t)$ in case of piecewise continuous and piecewise differentiable function $f(t)$.

Regarding the assessment of future value for cash flows, formula (1) aligns with the scenario of discrete cash flows with discrete compounding, formula (4) corresponds to the scenario of discrete cash flows with continuous compounding, formula (6) pertains to the scenario of continuous cash flow with continuous compounding and formula (10) addresses the cases involving mixed continuous and discrete cash flows with continuous compounding.

The sequence of generalizations is as follows: formula (10) generalizes formula (6), which generalizes formula (4), and formula (4) generalizes formula (1). Specifically, for continuous and differentiable $f(t)$, formula (10) reduces to (6). For constant $f(t) = C_0 = \text{const}$, formula (6) further reduces to (4) with $g(t) = C(t)$. Finally, for constant $p(t) = p = \text{const}$, formula (4) becomes (1).

That allows for a unified approach instead of resorting to multiple formulas to compute the future value of an asset at a later date. This unification comes at a cost of having to do with differential and integral calculus: one is likely to come across complicated functions, that are hard, and in most cases impossible to integrate exactly. That is the main reason people use simple (and incorrect) formulae in the first place.

In such cases, an approximate solution using a suitable numerical mathematics method could present a viable alternative. That is the reason why each final value of formulae (4), (6) and (10) was regarded as a solution of the finite problem of a differential equation. There is an abundance of numerical methods that can calculate the figures to any given accuracy. In this paper the 4th order Runge-Kutta (RK-4) method was tested through exercises. Only the Exercise 1 can be easily solved analytically, and the result is used to test the RK-4 approximation. The other exercises are only solved approximately, to the desired accuracy.

7. Conclusion

When determining the future value of cash flows, it's important to ascertain whether the cash flow is discrete or continuous and whether compounding is discrete or continuous. Choosing the correct formula is essential as it significantly influences financial decisions.

Additionally, it is important to use models that are not based on unrealistic assumptions, regardless of the complexity inherent in their calculation, especially with the availability of software packages like MATLAB, which simplify and speed up the calculation process.

In this paper it is demonstrated how these calculations can be done using ordinary differential equations and numerical mathematics.

Future research may explore the most effective numerical method to speed up the convergence, particularly concerning the type of ordinary differential equations in question (linear differential equations of the first order). The issue of determining the present value of continuous cash flow with continuous compounding can also be considered.

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THE IMPACT OF IFRS 16 ON LESSEE'S FINANCIAL REPORTING

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Abstract. The adoption of IFRS 16 in January 2019 brought significant changes to the way lessees recognise, measure, present, and disclose leases, making it one of the most revolutionary accounting standards in recent years. Before 2019, companies that used operating leases to finance their assets were not required to report these assets or liabilities based on leases in their balance sheets. This accounting model raised concerns about the credibility of key business indicators and the reliability of financial information for stakeholders. IFRS 16 introduced a single lessee accounting model requiring recognition of assets and liabilities for leases longer than 12 months unless the underlying asset is of low value. This approach replaces the previous practice of classifying each lease as an operating or a finance lease, which can significantly affect the lessees' financial statements. This change may raise the company's overall debt, affecting its creditworthiness and financial stability. The purpose of the disclosures in IFRS 16 is to provide information in the Notes that, along with the information in the Statement of Financial Position, Statement of Profit or Loss, and Statement of Cash Flows, allows users to assess the impact of leases. This means that the lessee's financial statements now provide more accurate and relevant financial information, resulting in increased usefulness. The objective of financial reporting is to provide useful financial information about the reporting entity to existing and potential investors, lenders, and other creditors, helping them make decisions regarding providing resources to the entity. Now, users of financial statements can make different decisions compared to the previous period when lessees were not required to show leases in their Statement of Financial Position. Users must have access to accurate information regarding a company's indebtedness, as any exclusion or inaccurate presentation of such information may impact the decisions made by users based on financial information about a particular reporting entity. Leases are a significant source of external financing for companies, so it's interesting to see how the adoption of IFRS 16 has influenced the financial statements and significant financial indicators of lessees.

Key words: *IFRS 16, Lessee's Financial Statements, Operational Leases, Financial information*

1. Introduction

When a company needs to acquire assets, it can either choose to buy them or lease them. Leasing is a popular financing method for assets as they tend to become obsolete quickly and financing can be complicated. According to the Croatian Financial Services Supervisory Agency's data for 2023 (HANFA, 2024), the most significant number of leasing contracts in Croatia is for financing means of transport. Additionally, a vast majority (73%) of newly closed leasing contracts in 2023 are for financial leasing. Leasing is a popular option for companies that need to use assets without purchasing them. There are two types of leases: finance lease and operating lease. A finance lease allows the use of an asset and transfers ownership after the lease period ends, provided that all contractual obligations are met by the lessor. In contrast,

an operating lease only allows the use of the asset without transferring ownership rights. This makes leasing much more affordable compared to purchasing, especially for small or new companies that may not have the financial capability to buy all the necessary assets.

The objective of financial reporting is to provide financial information about the reporting entity that is useful to existing and potential investors, lenders and other creditors in making decisions relating to providing resources to the entity (IASB, 2018). International Financial Reporting Standards (hereafter IFRS) significantly impact financial statement preparation, recognition, and measurement. The financing of a company's assets should be clearly visible in its financial statements. Until 2019, the operational leasing allowed companies to keep leases off their balance sheets, which meant that they did not have to report future obligations. This accounting model raised concerns about the credibility of key business indicators and the reliability of financial information for stakeholders. The accounting rules for lessees changed significantly in 2019, while there were minimal changes for lessors. IFRS 16 - Leases eliminates the classification of leases as either operating leases or finance leases for a lessee. For companies with significant off-balance sheet leases, IFRS 16 is anticipated to alter their financial statements. Using a sample of 1,022 listed companies out of 30,000 total companies that utilize operating leasing and off-balance sheet leases, the International Accounting Standards Board (hereafter IASB) calculated that the long-term liabilities of the heaviest users of off-balance sheet leases in Europe were overstated by 26% before the implementation of IFRS 16.

By implementing and using IFRS 16, all market participants will have access to more precise lease information, which will create a level playing field for all. IFRS 16 enables a more accurate assessment of lease assets and liabilities as compared to IAS 17 - Leases, where only more sophisticated investors and analysts were capable of making such estimates. This paper discusses the effects of IFRS 16 from a lessee perspective. First, we will examine the disclosure requirements of IFRS 16 and how they affect the financial indicators of the company. Subsequently, we will evaluate how the adoption and application of IFRS 16 impact the qualitative characteristics of useful financial information.

2. Impacts on company's financial position, financial performance and cash flows

The objective of the disclosures is for lessees to disclose information in the Notes that, together with the information provided in the Statement of Financial Position, Statement of Profit or Loss and Statement of Cash Flows, gives a basis for users of financial statements to assess the effect that leases have on the financial position, financial performance and cash flows of the lessee (IFRS 16:51).

As shown in Table 1, the implementation of IFRS 16 and the exclusion of off-balance sheet leases accounting have had a direct effect on the Statement of Financial Position. This has led to an increase in non-current, non-financial assets, as well as an increase in current and non-current financial liabilities. There is no direct impact on the Statement of Profit and Loss, but there has been a change in the type of expenses. Operating lease expenses have been replaced by depreciation and interest expenses under IFRS 16. In comparison to the amounts reported using IAS 17, IFRS 16 is predicted to decrease operating cash outflows while increasing financing cash outflows. This is because companies reported cash outflows on previous off-balance sheet leases as operating activities when using IAS 17. Applying IFRS 16, however, includes principal repayments on all lease liabilities as part of financing activities.

Table 1 Disclosure requirements for lessees and operating leases under IFRS 16

The Statement of Financial Position	<ul style="list-style-type: none"> • The carrying amount of right-of-use assets at the end of the reporting period by class of underlying asset • Lease liabilities • Maturity analysis of lease liabilities separately from the maturity analyses of other financial liabilities
The Statement of Profit or Loss and other Comprehensive Income	<ul style="list-style-type: none"> • Interest expense on the lease liability as a component of finance costs • The depreciation charge for right-of-use assets by class of underlying asset • Variable lease payments
The Statement of Cash Flows	<ul style="list-style-type: none"> • Cash payments for the principal portion of the lease liability within financing activities • Cash payments for the interest portion of the lease liability applying the requirements in IAS 7 Statement of Cash Flows for interest paid • Total cash outflow for leases
Additional information	<ul style="list-style-type: none"> • Qualitative and quantitative information about leasing activities – for example, the nature of the lessee's leasing activities; future cash outflows to which the lessee is potentially exposed that are not reflected in the measurement of lease liabilities. • Variable lease payments • Extension options and termination options • Residual value guarantees • Leases not yet commenced to which the lessee is committed. • Restrictions or covenants imposed by leases

Source: Authors based on IFRS 16

These changes affected some financial measures. For example, recognition of an asset that was previously unrecognised will affect ratios such as asset turnover. A higher amount of assets with the same income will result in a decrease in the turnover ratio of total assets. Recognition of a liability that was previously unrecognised will affect financial leverage. Financial liabilities that are greater will have an impact on both the indebtedness indicators and the debt indicators. Recognition of depreciation and interest instead of operating lease expense will affect profit measures. Application of IFRS 16 leads to higher profitability measures that exclude interest and depreciation. Table 2 shows the impact of IFRS 16 on commonly used financial measures.

Table 2 Effects on key financial ratios

Financial ratios	What it Measures	Common method of calculation	Expected effect of IFRS 16	Argument
Total Debt to Equity Capital	Solvency	Debt/equity	Increase	Increase because financial liabilities increase due to the recognition of lease liabilities in the Statement of Financial Position.
Current ratio	Liquidity	Current assets / Current liabilities	Decrease	Decrease due to the increase in current lease liabilities while current assets remain the same.
Asset turnover	Profitability	Sales / Total assets	Decrease	Decrease due to the recognition of lease assets as part of total assets, without impacting sales.
Interest cover	Solvency	EBIT / Interest Expense	Depends	The change in the ratio will depend on the characteristics of the lease portfolio. Under IFRS 16, EBIT will increase as will interest expense.

EBITDA	Profitability	Profit (Earnings) before interest, tax, depreciation and amortisation	Increase	Increase due to the recognition of depreciation and interest instead of operating lease expense under IFRS 16. When measuring EBITDA, neither depreciation nor interest are included in the calculation.
EBIT	Profitability	Profit (Earnings) before interest and tax	Increase	EBIT will increase due to the changes in structure and amount of operating lease expense. The added depreciation charge increased less than the expense for off balance sheet leases excluded. Interest expense will increase.
ROE	Profitability	Profit or loss / Equity	Depends	Depends on the effect on profit or loss, which depends on the characteristics of the lease portfolio and the effects on tax. If there is no effect on profit or loss, then the ratio will be higher because reported equity will decrease.
Profit or loss	Profitability	As reported applying IFRS	Depends	Depends on the characteristics of the lease portfolio and the tax rate.
Operating cash flow	Profitability	Various methods - Cash flow from operating activities does not include cash related to equity and borrowings	Increase	Increase because at least part of the lease payments (those payments relating to the principal) will be moved to the financing activities in the Cash Flow Statement.
Net cash flow	Profitability and Liquidity	Difference between cash inflows and cash outflows	No change	There will be no change since the cash remains unaffected.

Source: Authors based on IASB (2016). IFRS 16 Leases, Effects Analysis

It is clear that the implementation of IFRS 16 impacts the financial statements' positions, such as assets, liabilities, equity, and operating profit. This, in turn, affects different financial ratios. However, this paper will not focus on the quantitative effect of these changes, but rather the qualitative one. In other words, the paper aims to analyse the effect of these changes on the usefulness of financial information provided in the financial statements.

3. The importance of improving IFRS 16 to increase the usefulness of financial information

In this chapter, the focus is on enhancing the usefulness of financial information by improving IFRS and cooperation between standard setters and the academic community.

3.1. The importance of cooperation between standard setters and the academic community

During the mandatory application of IFRS, scientists play a significant role in the process of adopting and amending IFRS, as well as in post-implementation reviews after the introduction of a certain IFRS. This role is demonstrated by their membership in the IASB, providing feedback on proposals for new standards, participating in the review process after the implementation of a specific IFRS, examining the impact of IFRS application on capital market participants and the market itself, presenting research findings at accountant congresses, actively participating

in other IASB projects, and more. It is widely accepted that scientists play a valuable role in the process of adopting standards, as recognized by Larson et al. (2011). There is a growing movement to involve scientists more actively in the creation of standards. The main advantage of scientists is their independence from influences such as companies, auditors, government bodies, special interest groups, etc. (Larson et al., 2011). Therefore, their views and proposals regarding standards can be considered unbiased, all for the purpose of improving the conceptual content of the standards and, ultimately, the quality of financial reporting when IFRS is applied.

Hans Hoogervorst, the Chair of the IASB in 2016, emphasized the significant role of the academic community in accounting during his speech at the 2016 annual conference organized by the European Accounting Association. He praised the high quality of comments from members of the European Association of Accountants, particularly on the development of IASB projects such as the “Conceptual Framework” and the “Disclosure Initiative”. The IASB’s website provides an overview of projects at various stages of the standard-setting process and invites scientists to get involved in the implementation of these projects if they are not already. According to Hans Hoogervorst, the IASB acknowledged the crucial role of scientists in the process of adopting accounting standards. The process is challenging as it impacts numerous companies globally and cannot be approached as a one-sided affair where “IASB is always right and everyone else is wrong.” He emphasized that the standard-setting process should be evidence-based rather than opinion-based. The IASB requires reliable information about the issues that the accounting standards seek to address. Hence, the academic community, particularly scientists, who conduct empirical research and present their findings, play a vital role in providing reliable scientific evidence.

Hans Hoogervorst highlighted the successful collaboration between scientists and the IASB in the development of the new accounting standard IFRS 16. During this process, the IASB considered 30 different scientific studies that identified the limitations of the previous accounting standard, IAS 17. The Chair of the IASB at that time stressed the importance of scientific studies in raising awareness about the need to enhance lease accounting. As a result, the IASB took a proactive approach, and the findings of these studies significantly influenced the creation of the IFRS 16. It is important to emphasize that the process of adopting this standard was long and complex. The IASB received over 1,700 letters during the consultation process. The IASB’s activities aim to strike a balance between the costs of making changes and the benefits of ensuring a stable financial reporting platform, while maintaining a high level of responsibility. According to Tokar (2016), a thorough assessment of all relevant factors is necessary.

3.2. The impact of IFRS 16 on the usefulness of information in the lessee’s financial statements

Financial statements must fairly present the company’s financial position, performance, and cash flows. Fair presentation requires the faithful representation of the effects of transactions, other events and conditions in accordance with the definitions and recognition criteria for assets, liabilities, income and expenses set out in the Conceptual Framework for Financial Reporting (IASB, 2018). The application of IFRSs, with additional disclosure when necessary is presumed to result in financial statements that achieve a fair presentation (IAS 1:15).

The fundamental qualitative characteristics are relevance and faithful representation ((IASB, 2018). If financial information is to be useful, it must be relevant and faithfully represent what it purports to represent (IASB, 2018). The usefulness of financial information is enhanced when it is comparable, verifiable, timely, and understandable (IASB, 2018), as shown in the table below.

Table 3 Qualitative characteristics of useful financial informations

Fundamental qualitative characteristics			
Relevance		Faithful representation	
<ul style="list-style-type: none">Information is relevant if it is capable of making a difference to the decisions made by usersFinancial information is capable of making a difference in decisions if it has predictive value or confirmatory value		<ul style="list-style-type: none">Information must faithfully represent the substance of what it purports to representA faithful representation is, to the maximum extent possible, complete, neutral and free from errorA faithful representation is affected by level of measurement uncertainty	
Enhancing qualitative characteristics			
Comparability	Verifiability	Timeliness	Understandability
<ul style="list-style-type: none">These four qualitative characteristics enhance the usefulness of informationbut they cannot make non-useful information useful			
Cost constraint			
<ul style="list-style-type: none">The benefit of providing the information needs to justify the cost of providing and using the information.			

Source: IASB (2018). Conceptual Framework for Financial Reporting, p. 6

Relevant financial information is capable of making a difference in the decisions made by users. To be useful, financial information must not only represent relevant phenomena, but it must also faithfully represent the substance of the phenomena that it purports to represent (IASB, 2018). To be a perfectly faithful representation, a depiction would have three characteristics. It would be complete, neutral and free from error (IASB, 2018). Neutrality is supported by the exercise of prudence (IASB, 2018). The exercise of prudence means that assets and income are not overstated and liabilities and expenses are not understated. It is estimated that listed companies using IFRS or US GAAP had approximately US\$3.3 trillion of lease commitments. More than 85% of these commitments didn't appear in their balance sheet (IFRS, 2016). This study was conducted on a sample of 30,000 listed companies using IFRS or US GAAP. Furthermore, it was found that over 14,000 companies disclosed information regarding off-balance sheet leases in their 2014 annual reports. The future payments for off balance sheet leases for those companies totalled US\$2.9 trillion (on an undiscounted basis). During the global financial crisis that began in 2008, several major retail chains declared bankruptcy because they failed to adjust to the new economic conditions. Simultaneously, they had incurred substantial obligations from long-term operating leases for their stores, which were reported to be 60 times greater than the company's total liabilities on the balance sheet.

It is clear that the introduction of IFRS 16 has significantly improved the fundamental qualitative characteristics of financial information, resulting in more useful information in the financial statements. Effective communication of information in financial statements makes that information more relevant and contributes to a faithful representation of an entity's assets, liabilities, equity, income and expenses (IASB, 2018). Starting from 2019, all assets and liabilities related to leasing must be presented in the Statement of Financial Position. Disclosed amounts of assets, liabilities, and the values of related financial ratios influence the decisions made by users of financial statements.

Comparability, verifiability, timeliness and understandability are qualitative characteristics that enhance the usefulness of information that both is relevant and provides a faithful

representation of what it purports to represent (IASB, 2018). Comparability is the qualitative characteristic that enables users to identify and understand similarities in, and differences among, items. Unlike the other qualitative characteristics, comparability does not relate to a single item. A comparison requires at least two items (IASB, 2018). IFRS 16 improves comparability between companies that lease and those that borrow to buy. IFRS 16 aimed to improve information comparability between transactions that were economically similar. The method used to finance business activities should be clearly reflected in the financial statements, impacting the financial position and performance of a company. If the company is using debt financing, this information is crucial as it affects the users of the financial statements. If this information is only found in the Notes to the financial statements, many users may overlook its importance because they do not perceive a direct influence on the financial positions and on the disclosed financial values. Before 2019, disclosing such information only in the Notes required manual adjustments.

Other than recognising lease payments as an expense in the Statement of Profit and Loss, IAS 17 did not have any direct impacts on the financial statements. Before 2019, lessees were required to disclose the following information about their operating leases under IAS 17: (a) the total of future minimum lease payments under non-cancellable operating leases; b) the total of future minimum sublease payments expected to be received under non-cancellable subleases at the end of the reporting period; (c) lease and sublease payments recognised as an expense in the period, with separate amounts for minimum lease payments, contingent rents, and sublease payments; (d) a general description of the lessee's significant leasing arrangements, including, but not limited to, the following: (i) the basis on which contingent rent payable is determined; (ii) the existence and terms of renewal or purchase options and escalation clauses; and (iii) restrictions imposed by lease arrangements, such as those concerning dividends, additional debt and further leasing. These disclosures were only visible in the Notes to financial statements.

The Notes shall disclose the information required by IFRSs that is not presented elsewhere in the financial statements and provide information that is not presented elsewhere in the financial statements, but is relevant to an understanding of any of them (IAS 1:112). According to previous research conducted by Santos et al. (2013), Dawd (2018), Tawiah and Boolaky (2019) many companies have been found to have low levels of compliance with IAS 17, with an average of less than 50%. In particular, a review of the company's financial statements revealed that the company was either a lessor or lessee, but did not provide detailed information about the lease terms in the Notes. This issue is especially common among lease users who did not provide adequate information about their lease portfolio in the Notes. Timeliness means having information available to decision-makers in time to be capable of influencing their decisions. Generally, the older the information is the less useful it is. Classifying, characterising and presenting information clearly and concisely make it understandable (IASB, 2018).

The Statement of Profit or Loss and the Statement of Financial Position are the primary sources of information about a company's financial performance and position at the reporting date and for the reporting period. Operating leasing accounting treatment for lessees has eliminated the need for manual adjustments, creating a level playing field for financial statement users comparing different companies using disclosed financial ratios. IFRS 16 has had several positive impacts on the financial reporting of listed companies. Firstly, it has led to increased transparency of information. Secondly, it has provided better information about the company's liquidity risk, profitability, and leverage. Lastly, users can now more accurately estimate the company's future cash flows. An individual investor, lender, or creditor benefits from making more informed decisions. This results in more efficient functioning of capital markets and a lower cost of capital for the economy as a whole. The disclosure of relevant financial information in a manner that faithfully represents its substance enhances the efficiency of capital markets.

4. CONCLUSION

The quality of financial reporting by listed companies is crucial for the efficient functioning of capital markets. IFRS 16 establishes principles for recognising, measuring, presenting, and disclosing leases. The primary goal is to ensure that both lessees and lessors provide relevant information that accurately represents these transactions. This information serves as the basis for financial statement users to evaluate the effect of leases on a company's financial position, performance and cash flows. The impact of IFRS 16 varies across industries and depends on a company's number of current operational lease agreements.

The implementation of IFRS 16 is expected to bring more benefits than costs. It will provide a more accurate representation of a company's assets and liabilities, improve comparability between companies, and increase transparency regarding a company's financial leverage and capital employed. The previous lease accounting model did not meet the needs of financial statement users because most leases were kept off-balance sheet as operating leases. This led to a failure in properly reflecting lessees' obligations to make future minimum lease payments and a lack of disclosure. In 2016, IFRS 16 was issued, and it became mandatory from 1 January 2019. Under this standard, lessees are required to recognise a liability for their obligation to make future minimum lease payments along with the corresponding right-of-use asset. These changes impacted the Statement of Financial Position by increasing both asset and liability values, which directly affect financial ratios. The accounting for leases and borrowings to buy assets is more comparable when using IFRS 16. Reporting financial information that is relevant and faithfully represents what it purports to represent helps users make decisions with more confidence. IFRS 16 changes the nature of expenses related to leases, replacing the straight-line operating lease expense with a depreciation charge for the leased asset and an interest expense on the lease liability, affecting some profitability measures.

It would be useful to gather feedback from various stakeholders to evaluate whether IFRS 16 is functioning as intended. Additionally, performing qualitative and quantitative research on lease accounting practices for a sample of companies across various sectors would provide valuable insights. Moreover, it would be interesting to investigate whether the adoption of IFRS 16 has increased the value relevance of disclosed financial information.

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UNDERSTANDING GENERATION Z AS A NEW GENERATION OF CONSUMERS

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Abstract. Consumer behaviour nowadays is an important field of research for many companies and marketers worldwide. The purpose of this research is to understand the needs of Gen Z as consumers to create tailored products. Gen Z is the newest generation in the working environment, and they are very digital-oriented. They grew up surrounded by technology and a new era of social media. This generation tends to spend more time online rather in the physical world. Since everything is just a click away, it is important to understand that Gen Z can be highly demanding as customers. The research contributes different methods for the exploration of Gen Z consumer habits. Methods used in this research were analysis, synthesis, and classification. To support the research, a survey was conducted with Gen Z members. This generation is often characterized by being environmentally aware, they are prioritizing health, and they are willing to pay for a premium product if it fits their personality. Generation Z is quite curious when they choose their products, but they are also willing to try and explore new things. As key findings of the research highlight, Gen Z considers online shopping as safe, time-saving, cost-effective, and less stressful when compared to physical stores. Despite their strong online activity and social media influences, this generation of consumers has firm opinions and clear preferences.

Keywords: *consumer; consumer behaviour; generation Z*

1. Introduction

Consumer behaviour is the study of consumers and the processes they use to select, use (consume), and dispose of products and services, including the emotional, mental, and behavioural reactions of consumers. It incorporates ideas from several sciences, including psychology, biology, chemistry, and economics. Studying consumer behaviour is important because it helps merchants understand what influences consumers' purchasing decisions. By understanding how consumers decide on a product, market gaps can be filled and products that are needed and outdated can be identified. Consumer behaviour is the study of consumers and the processes they use to select, use (consume), and dispose of products and services, including the emotional, mental, and behavioural reactions of consumers. It incorporates ideas from several sciences, including psychology, biology, chemistry, and economics (Solomon, 2018). By understanding how consumers make decisions on a product, marketers can create products that are needed for this generation specifically. Studying consumer behaviour also helps marketing professionals decide how to present their products in a way that creates maximum impact on consumers. Understanding consumer behaviour during purchases is the key secret

to reaching and engaging clients. Understanding the purchasing behaviour of Generation Z is crucial because this generation is the newest to join the workforce and has purchasing power.

Generation Z spends a lot of time online, so this is also one of the most common forms of shopping they prefer. Generation Z may be more comfortable online - in fact, they spend more time on social media than any other generation, and they are the first age group to be truly digitally native. However, when it comes to shopping experiences, they are more likely to prefer physical environments (Smith, 2021).

Generation Z, especially those under 20 years old (many of whom are still in school), more than any other age group, will opt for products over experiences, and they are the second most likely generation after baby boomers to say they prefer shopping in-store rather than online. It may seem paradoxical, but this could have a digital origin. Instagram is the absolute cornerstone of Generation Z's online life. Besides YouTube, it is the social platform they are most likely to use more than once a day (Jones, 2020).

1.1. Problem Definition

The research problem is the consumer habits of Generation Z. Generation Z significantly differ from all previous generations; hence their consumer habits differ as well. This is an entirely digital generation, spending most of their time on the internet and social media, so this work aims to explore their buying habits. The purpose of this research is to understand the needs and preferences of Generation Z as new-generation consumers. This understanding can help companies and marketers in developing products and marketing strategies that are specifically tailored to face the expectations and demands of this digitally-oriented generation.

1.2. Work Methods and Data Sources

Methods used in this work:

Analysis method - a method by which complex concepts, judgments, and conclusions are dissected into their simpler constituent parts, and each part is studied separately and about other parts.

Synthesis method - Combining parts or elements into a whole or assembling simpler mental constructs into complex ones and complex ones into even more complex ones.

Classification method - Systematic and complete division of the general concept into specific ones within the scope of the concept. It represents systems of groups of objects or distributions of a series of related concepts.

1.3. Work Structure

The first section covers the definition of consumers and consumer society, consumer behaviour models, the decision-making process, and factors influencing consumer behaviour. The second section examines consumer behaviour. This section defines the concept of consumers and consumer society, consumer behaviour models, the decision-making process for purchasing, and factors influencing consumer behaviour. The third section discusses Generation Z. This section provides an overview of the general characteristics of Generation Z and their consumer habits. The fourth section is the practical part of the work, analysing the research results obtained through a questionnaire. The fifth section is the conclusion of the work, presenting the conclusions of the entire work and the conducted research.

2. Consumer Behaviour

This section of the work explains the basic concepts necessary for a quality understanding of the subject matter of this work, such as consumer, consumer society, product, consumer behaviour, and factors influencing consumer behaviour. Consumer behaviour is a scientific discipline of modern times, originating in the twentieth century to analyze societal consumer habits to influence potential consumers during the purchase of products or services. Various definitions of consumer behaviour are provided in different literature; however, the following definition provides a comprehensive overview of the concept of consumer behaviour. Consumer behaviour represents the process of acquiring and consuming products, services, and ideas by the consumer unit. It also includes post-purchase behaviour (Kesić, 2006).

Consumer behaviour encompasses a wide array of activities and decisions, influenced by numerous factors. According to Schiffman and Kanuk (2007), consumer behaviour is the behaviour that consumers display in searching for, purchasing, using, evaluating, and disposing of products and services that they expect will satisfy their needs. This broad definition underscores the comprehensive nature of consumer behaviour research, which includes not just the act of buying but also the pre-and post-purchase processes. 2.1. Consumer and Consumer Society A consumer is defined as a subject (individual, household, or legal entity) acquiring a good (product/service) because they consider it suitable for meeting their own needs (Baran and Orlić Zaninović, 2019).

The fundamental purpose of studying consumers and consumer society is to explore the needs and desires of consumers or the consumer society as a whole, to place a product or service that satisfies their needs. It is important to note that merely fulfilling consumer needs does not guarantee consumer satisfaction; it is necessary to fulfil as many consumer desires as possible. According to Solomon (2018), consumer behaviour is the psychological aspect of an individual that makes a difference in purchasing any goods, services, or anything else. The behaviour of each consumer depends on many factors that are very important for any marketing team in any company or organization that deals directly with consumers.

Studying consumer behaviour involves researching, evaluating, purchasing, consuming, and post-purchase behaviour, and storing purchased products considering the environment and personal characteristics. The American Marketing Association (AMA) defines consumer behaviour as the interaction of cognition behaviour or, events in the environment through which human beings carry out the exchange aspect of their lives with various social and psychological variables at play (2022).

This interaction emphasizes the dynamic nature of consumer behaviour and the multiple influences that impact purchasing decisions. The global market is studying the diversity among consumers, producers, sellers, retailers, advertising media, cultures, customs, and, of course, individual or psychological behaviour. However, despite the prevailing diversity, there are also many similarities. The aim of studying behaviour is to provide conceptual and technical tools that will enable marketing professionals to apply them in marketing practice, both for-profit and non-profit. According to Kotler and Keller (2016), studying consumer behaviour is very important for marketing professionals because it enables them to understand and predict consumer buying behaviour in the market; it deals not only with what consumers buy but also why they buy it, when and where they buy it, and how often they buy it, and how they consume and dispose of it.

Consumer research is a methodology used to study consumer behaviour and takes place in every phase of the consumption process: before, during, and after purchase. Research shows that two different customers who buy the same product do so for different reasons, pay different

prices, use it in different ways, have different emotional attachments to things, and so on (Blackwell et al, 2006).

Consumer behaviour is interdisciplinary; it is based on concepts and theories about people developed by scientists, philosophers, and researchers in various disciplines such as psychology, sociology, social psychology, cultural anthropology, and economics. The main goal of studying consumer behaviour is to provide marketing professionals with the knowledge and skills necessary to conduct detailed consumer analyses that can be used to understand the market and develop marketing strategies. Therefore, consumer behaviour researchers, with their skills in naturalistic market settings, attempt to make a significant contribution to our understanding of human thinking. Studying consumer behaviour helps management understand consumer needs to recognize the potential for trends in consumer demands and new technologies (Barmola and Srivastava, 2010).

2.2. Consumer Behaviour Model

Consumer behaviour analysis is the correlation between behavioural psychology and behavioural economics and their contribution to the purchase or consumption of goods and services. Essentially, the way we think directly relates to the way we buy. This is relevant because it enables companies to integrate marketing efforts by focusing on things that will trigger or connect with our specific behaviour.

These triggers or connections are achieved through four key categories known as the “4 Ps”: product, price, place, and promotion (Kromachou, 2021).

Product: Product selection and branding significantly influence which product a consumer will purchase. A consumer will not buy a good or service they know they will not use, and when making a purchase, they consider branding. The major factors why a consumer will buy a well-known brand are trust in experience (associating larger brands with better user experience/service), social acceptance (consumers have the desire to fit in or be socially accepted within their social circle, and larger brands contribute to this), and loyalty (consumers develop an emotional attachment to brands that lead them to develop loyalty only to that brand. This can be formed from personal experience or the experience of others close to them).

Price: Price determination is of great significance in consumer purchasing. People will only pay for goods and services they see as having financial value or consider reasonable in terms of price. This is the biggest factor in whether a sale will occur or not. Consumers will not pay for something they do not find value in or consider too expensive.

Place: Where they shop affects the type of consumer. Some consumers prefer to shop only in physical stores, some buy exclusively in online retail. This factor depends on situational influences and online environments.

Promotion: It plays a role in determining prices for short-term and long-term goods and services. First-time buyers are more likely to buy long-term or short-term products or services if they have a low initial promotional price. Therefore, companies seek to sell their product to the consumer at a significantly lower price that the consumer would consider reasonable in the hope that they will find value and be willing to pay a premium for the continued purchase of the product or service. Repeat customers are more likely to buy short-term or long-term goods or services even if the promotional price is not significantly low. They already know the product and find value in it because they have returned multiple times to buy that product or service. Therefore, even if the promotion is as small as “5 per cent discount,” “Save 10%,” or “Buy 2, get 1 free,” the likelihood of that consumer making that purchase or buying more than usual

will be higher because they will find savings they would not otherwise achieve and know that they will ultimately use the good or service at some point. A great example would be a laundry detergent sale: the consumer sees that their favourite laundry detergent is discounted by 15 per cent. They may not need detergent at that moment, but the 15 per cent discount catches their attention and triggers a certain thought process that leads them to purchase, and in many cases, they will buy more than one, resulting in higher sales for that company.

Understanding consumer behaviour and the decision-making process can help companies create effective campaigns that lead to increased overall sales of their goods and services (Solomon, 2018).

2.3. Decision-Making Process

The decision-making process is the product of a complex interaction of external factors and personal attributes. The inner circle denotes the consumer's decision-making process about products and services, with its main steps being: recognition of the customer, information search, application evaluation, purchase decision, and post-purchase behaviour.

Customer Recognition: The consumer must realize that there is a problem or need to be fulfilled. An effective retailer will recognize that there is a difference between the actual state of the consumer and the desired state and attempt to fulfil that state of deprivation.

Information Search: In this stage, the buyer considers all existing alternatives. For example, the buyer is thirsty and considers all options of soft drinks, bottled water, juices, etc. Most information about alternatives comes from commercial sources, such as advertisements and campaigns. However, information about intangible products in the service industry would mostly come from personal experience or the experience of others.

Evaluation of Alternatives: Here, all information that helps make a purchase decision is collected and evaluated. These three stages are important for marketing professionals to understand consumer behaviour and what influences the purchase of a specific category of product and brand.

Purchase Decision: This is the phase where the purchase of the most desirable alternative takes place. However, the product category, brand, retailer, timing, and quantity play an important role in the purchase decision.

Post-Purchase Decision: Good retailers maintain a good relationship with the customer even after the purchase is made. This is done to reduce any potential cognitive dissonance the customer may experience with the product. To mitigate the negative effects of cognitive dissonance on customers, good after-sales services can be provided alongside effective advertising. This will attract more customers through word of mouth and generate repeat purchases. To be cost-effective, retailers should keep in mind to target potential customers of the company's marketing mix. It doesn't make sense to waste time targeting those who will never buy their product. Therefore, effective market segmentation is extremely important. Market segmentation involves dividing the market into groups that share similar needs and desires. This can be done using segmentation variables such as geographic, demographic, psychographic, and behavioural groups (Solomon, 2018).

2.4. Personal Factors

Personal factors are individual factors possessed by every consumer and can strongly influence their decision-making process regarding purchases and consumer behaviour in

general. These factors vary from person to person because each consumer has their own opinion about a particular product or service and shapes their consumer behaviour based on it. Not all consumers are alike, and not all products or services appeal to all consumers, so personal factors play a significant role in shaping a consumer's decision to purchase.

The most significant personal factors influencing consumer behaviour are as follows: **Motives and Motivation:** Every consumer is motivated by specific reasons for purchasing a product or service. Motive is a predisposition that directs consumer behaviour towards a goal or purchase. Motives can vary, but they are most commonly divided into rational and emotional motives. Motivation is what drives the consumer to achieve a goal or make a purchase decision (Kotler and Armstrong, 2018).

Attitudes: Attitude is the readiness of the consumer to react positively or negatively to a situation. In most cases, consumers already have their attitudes that they rarely change. Although consumer attitudes can change, it is a long and arduous process (Schiffman and Kanuk, 2007).

Personality Traits, Values, and Lifestyle: A consumer's personality is their enduring characteristic that influences their consumer behaviour. Values represent the social aspect characterized by the "correct" consumer behaviour in line with the consumer's values. Additionally, a consumer's lifestyle encompasses their activities, interests, and occupations that can influence their consumption, not only of money but also of time (Solomon, 2018).

Knowledge: The information consumers possess about specific products. This can include information about the type of product or brand, places where the product can be purchased, product price, sales methods, etc. (Business Jargons, 2022).

Changes in Attitudes and Behaviour: These factors are the primary aim of marketing activities. Since consumer attitudes are relatively constant and difficult to change, marketers employ various strategies to alter negative consumer attitudes towards a product or service (Kotler & Keller, 2016).

Personal Influences: Processes occurring within primary groups, relating to a consumer's knowledge, abilities, characteristics, personality, etc. (Barmola & Srivastava, 2010).

3. Generation Z

Generation Z includes individuals born between 1995 and 2011. The most significant characteristic of Generation Z members is the "phone in hand" phenomenon. Unlike their predecessors, this generation was born and raised with technology. It's always been normal for them to search for anything of interest on the Internet, and statistics show that Generation Z significantly contributes to creating online content. Social media platforms like Instagram, Twitter, TikTok, and Snapchat are very popular among Generation Z, while Facebook is gradually losing its popularity (Fistić, 2018).

3.1. General Characteristics

Generation Z, also known as the Face Generation or iPhone Generation, grew up with mobile devices, tablets, laptops, and social media at a time when information and technological literacy were at their highest level (Fistić, 2018). This generation lives in virtual reality and communicates through social media, accustomed to having instant access to information (Generation Z Characteristics, 2022). Despite being highly connected through social media, Generation Z is often perceived as being distant from family and friends. They are adept at multitasking and capable of performing multiple tasks simultaneously, including receiving, processing, and sharing information (Sinkovič, 2021).

Generation Z is more environmentally conscious than previous generations and exhibits a higher level of distrust towards large corporations. They are also more prone to job and career changes, growing up much faster and starting to learn much earlier than other generations. Technologically and internet savvy, they prioritize visual experiences over text and are socially responsible (The Annie E. Casey Foundation, 2021). It is predicted that this generation will revolutionize the labour market, with many from Generation Z becoming scientists, researchers, and various experts due to their predispositions (Apptus, 2022).

Part of a global, social, visual, and technological generation, Generation Z is the most connected and educated generation to date. Influencers, social media influencers, and pop culture influencers of today predominantly belong to Generation Z. This generation comprises around 2 billion people worldwide, representing and shaping the future (Bewicke, 2022). Born during times of terrorism, global recession, and climate change, Generation Z is expected to lead the necessary economic and social changes (Sinkovič, 2021).

The fundamental characteristics of Generation Z are:

Diversity – one of the key features of Generation Z is diversity. They live in a time of same-sex marriage legalization and grow up in households of various family structures (e.g., single-parent households, two-parent households, households with shared gender roles, etc.). As a result, they are less disturbed by and less concerned about differences in race, sexual orientation, religion, etc.

They are digital natives – the use of technology is normal and daily for them. Unlike millennials, who witnessed the emergence and growth of technology and social media, Generation Z was born into a world where it was already present, where information is readily available, and social media is ubiquitous. Generation Z has information at their fingertips, allowing them to expand their knowledge and be proactive in learning. However, they spend too much time in front of screens, which can lead to feelings of isolation and underdeveloped social skills.

They are pragmatic and financially aware – financial awareness is one of the fundamental characteristics of Generation Z. Many members of this generation grew up watching their parents struggle with finances during the recession. As a result, Generation Z is pragmatic, aiming to spend sensibly, have stable jobs, and invest wisely. They are facing mental health challenges – many refer to this generation as the “loneliest generation” because they spend too much time on the internet, which can lead to feelings of isolation and depression. Spending more time online means less time in the real world and less physical interaction with others. Generation Z also feels that their mental health is affected by the state of the world. They are increasingly becoming political activists, addressing issues such as gun control, police brutality, climate change, etc., which can also lead to increased stress.

They are savvy consumers – Generation Z lives in a digital world and heavily relies on their technological knowledge and social media for information and decision-making when it comes to purchasing. As already mentioned, they are pragmatic, researching and evaluating the best option before making a purchase. They value opinions, reviews, and recommendations from other users. Generation Z is attracted to sustainable products and brands and is willing to spend more money on them. They appreciate personalized products and are drawn to brands that share their views on certain political issues.

They are politically active and progressive – most of Generation Z is politically left-oriented, advocating for democracy, LGBTQ rights, and diversity, even among those who are right-leaning. Generation Z believes that the state should have a greater role in problem-solving, attributing climate change to human activities (The Annie E. Casey Foundation, 2021)

3.2. Consumer Habits

In terms of consumer habits, Generation Z is consistent with their values. Before purchasing something, they inform themselves about the product or service and conduct their research, usually through social media and the Internet. Members of Generation Z make purchase decisions based on their opinions; they are attracted to brands that are environmentally sustainable, follow corporate social responsibility, and transparency, and choose companies that highlight taking care of their employees and social issues in general. As consumers, Generation Z prefers personalization, meaning they often choose products from companies that address them personally, mainly through social media. They make purchase decisions very quickly and are not tied to their place of residence.

Consumers of Generation Z belong to a group of consumers whose purchasing behaviour is most often influenced by technology and the internet, through which they find out everything about desired products. They are also called digital natives. Access to information and new technologies is simply assumed for them, and it's their way of life. It is assumed that Generation Z will choose products in their consumer decisions that are produced and sold according to the principles of sustainable development. Members of Generation Z buy products in the health and wellness category more often than other generations because they care much more about their physical and mental health than others; they buy more local and environmentally sustainable products; they prefer simple, environmentally friendly product packaging. Generation Z likes influencer marketing, prefers to shop online, and wants to buy authentic products. This generation is not very interested in loyalty programs; they want to be independent and shop on their terms and when it suits them.

Generation Z is considered the “most challenging” consumer generation to date because they have a completely different approach to shopping than previous generations. Generation Z consumers seek products of higher quality, closely monitor product consumption, and are willing to pay more for products that meet their preferences. Generation Z is an environmentally conscious generation that cares about the planet and the future, which may represent a significant opportunity for the growth of the sustainable products market. This generation believes that previous generations have overspent and lived in a culture of capitalism and materialism, which they do not want. They prefer online payment, especially through mobile apps and “wallets,” which has led to the increased popularity and development of mobile payment apps (Apptus, 2022).

Characteristics of Generation Z consumers reflect their pragmatic approach to money. Other key influences are their affinity for technology and their interest in social welfare. Some of Generation Z's consumer habits include the following (Bewicke, 2022)

They are usually “informed consumers” and will often research and weigh information about a product before making a purchase decision. They are much less brand loyal. They place great importance on brand ethics and corporate responsibility. Among all previous generations, they make the most purchases through social media. Although they care about prices, they are not as price-focused as some previous generations, and price is not decisive for them. For Generation Z, products and brands must demonstrate a mix of value, quality, and ethical practices for them to buy. Despite being the generation most inclined to buy online, Generation Z also enjoys shopping in-store. They like interacting with salespeople who can help them with product inquiries. Generation Z consumers have high expectations regarding customer service and product quality. They prefer personalized shopping experiences tailored to their preferences.

4. Research on Generation Z Consumer Habits

The consumer habits of Generation Z differ significantly from those of other generations. This study aimed to explore Generation Z's consumer habits through a survey questionnaire.

Characteristic	Description
Method	Survey
Instrument	Questionnaire
Distribution	Social media platforms (Facebook, Instagram)
Sample	198 respondents
Question Type	Closed-ended (single and multiple choice), Likert scale
Demographic Focus	Generation Z (aged 16 to 26)
Estimated Completion Time	10-15 minutes

The research used a survey method, and the research instrument was a questionnaire. The questionnaire was chosen as the method of data collection mainly because of the speed and simplicity of distributing and collecting responses, as well as later analysing the obtained responses. The survey questionnaire was distributed to respondents via social media platforms Facebook and Instagram, where the research objective was presented to the respondents, emphasizing that the survey questionnaire was entirely voluntary and anonymous. The research was conducted on a convenient sample of 198 respondents. 198 properly and fully completed survey questionnaires were collected, and responses to each question were mandatory.

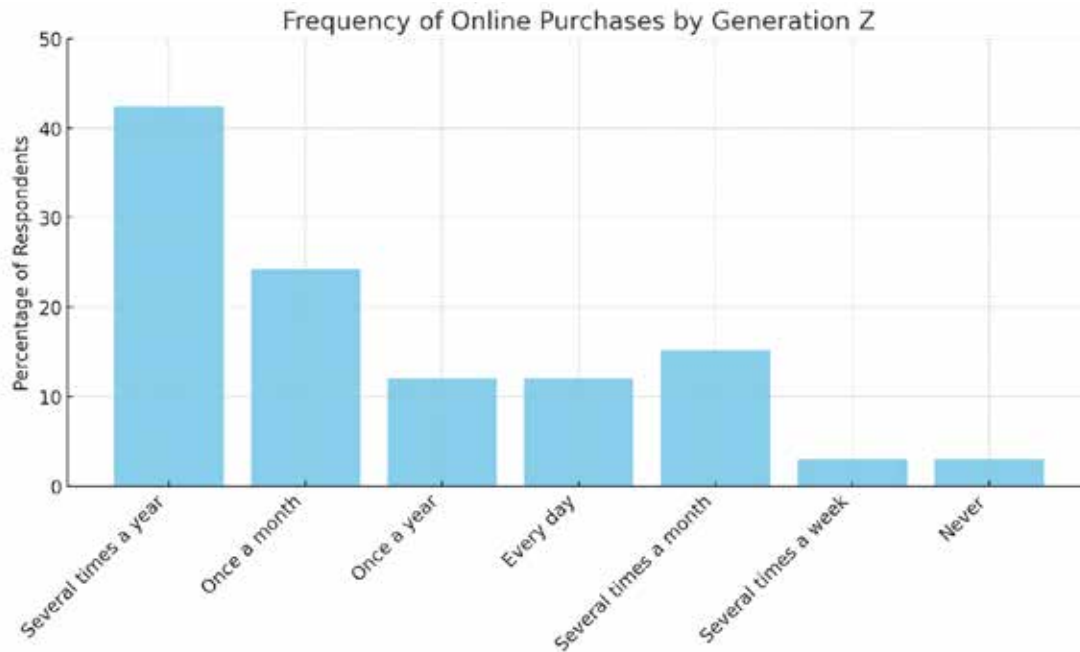
The questions were designed to be closed-ended with single and multiple-choice answers; some questions had a single option, some multiple choices, and a Likert scale was used for several questions, where respondents expressed their opinion or level of agreement with research statements (1 - strongly disagree, 5 - strongly agree). All questions were structured following the research objectives, and based on the data collected through the research, an interpretation of the results was made, as presented in the following subsection.

The first group of questions related to the subject of the research, i.e., exploring the purchasing and consumer habits of Generation Z, while the second group of questions related to socio-demographic data of the respondents (age, gender, level of education, employment status, income, etc.).

The estimated time for completing the survey questionnaire was 10-15 minutes. The study targeted Generation Z, i.e., respondents aged 16 to 26.

4.1. Analysis results

Of the total number of respondents, most of them (42.4%) make purchases online several times a year, while 24.2% of respondents do so once a month. 12.1% of respondents make online purchases once a year, with the same percentage saying they buy something online every day. 15.2% of respondents make online purchases several times a month, 3% several times a week, and the same percentage of respondents say they do not buy anything online at all.



The respondents most frequently purchase clothing and footwear online (61%), followed by electronic devices (11%) and cosmetics (11%). 8% of respondents buy food online, while 4% buy movies, music, and books online. The same percentage of respondents (4%) purchase some form of travel online, and 1% say they buy other products online.

These results indicate that Generation Z consumers mostly take advantage of online shopping and make purchases in that way. The internet represents a useful and preferred way of purchasing various products from the comfort of their own homes, so they do not need to physically visit stores. This confirms the theory that Generation Z consumers spend more time on the internet than in physical interactions, even when it comes to shopping. This is likely also influenced by the COVID-19 pandemic, which led to a significant increase in online shopping not only among Generation Z but also among all generations.

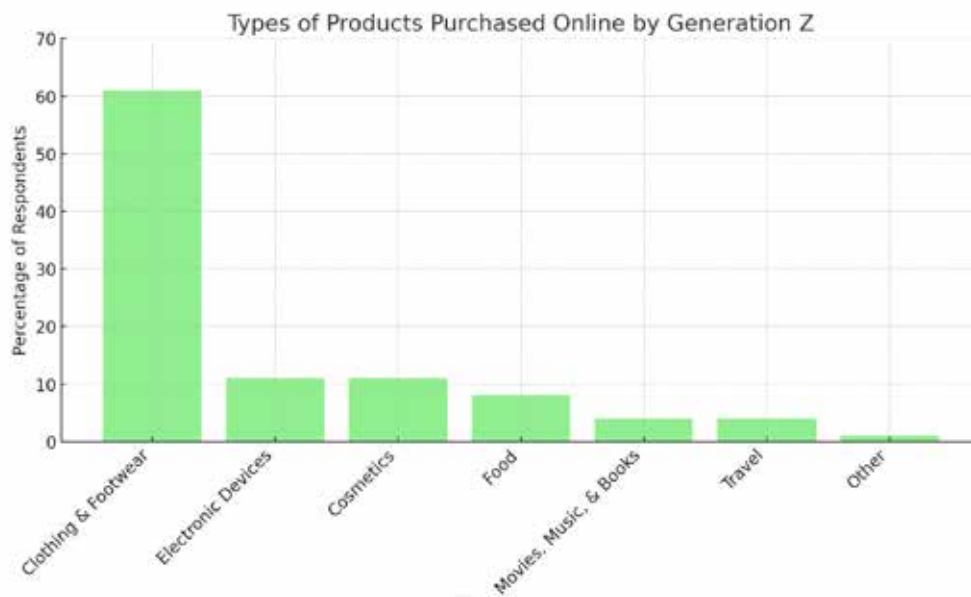
Respondents were asked to express their level of agreement with certain statements.

Statement	Completely Agree (%)	Agree (%)	Neither (%)	Disagree (%)	Completely Disagree (%)
Online shopping is safe	12.1	20	33.3	10	7.6
Prices are lower online	27.3	45.5	16.7	4.5	6.1
Product offerings are better online	34.8	34.8	18.2	6.1	6.1
Online shopping is less stressful	24.2	33.3	27.3	7.6	7.6
Shopping in-store saves time	12.1	15.2	18.2	30.3	24.2
Online shopping is faster and more convenient	33.3	33.3	15.2	6.1	12.1

Regarding the safety of online shopping, 66 respondents neither agreed nor disagreed with that statement; only 24 respondents completely agreed that online shopping is safe, while 15 respondents said they completely disagreed with it. 54 respondents agree that prices are lower through online shopping, while 69 respondents agree that product offerings are better in online stores than in physical stores. Furthermore, 81 respondents completely agree that they shop online because many products are more accessible to them, while 48 respondents say that online shopping causes them less stress than regular shopping in stores. Regarding

whether shopping in-store saves time, 72 respondents completely disagree with that statement. 66 respondents completely agree that they shop online because it is faster and more convenient, while 33 respondents disagree with it.

For respondents, the most important thing about online shopping is satisfaction with the purchased product (47%), free shipping (31.8%), discounts and attractive offers (13.6%), and free returns (6.1%). Only 1.5% of respondents say that a loyalty program is important to them. This confirms the theoretical part where it is mentioned that loyalty programs are unimportant to Generation Z when it comes to online shopping.



Overall, respondents spend the most money on the following products or services: clothing and footwear (53%), electronic devices (12.1%), cosmetics and outings (10.6% each), travel (6.1%), and the least in hospitality establishments (1.5%). It can be said that the assertion that Generation Z spends little time socializing with others has proven to be correct. They prefer to spend money on new electronic devices through which they communicate rather than on physical gatherings. When purchasing products, 117 respondents completely agree that product usefulness is most important to them, 87 respondents say that price is most important to them; the brand of the product is least important to them, and 51 respondents disagree with the statement that the brand is important at all. Furthermore, 141 respondents say that quality is important to them, while packaging is not a consideration when choosing and purchasing a specific product. The obtained results indicate that Generation Z consumers do not consider the brand of the product to be crucially important, but rather prefer quality. This can be associated with the fact that they are environmentally conscious and prefer products that are of higher quality and made from natural ingredients, even if they may be more expensive than other products in most cases. Regarding the statement that a product is of higher quality when its price is higher, 72.7% of respondents disagree, 7.6% agree with that statement, while 19.7% of respondents cannot determine whether a product is of higher quality if it is also more expensive.

The respondents were asked to express the degree to which other stakeholders influence their purchasing behaviour. Some of the social factors mentioned include partners, family, friends, media, and influencers. 72 respondents say that their partner does not influence their shopping habits at all, while for 66 respondents, friends neither influence nor do not influence, hence 1/3. Similarly, with family: while 18 respondents say that family completely influences their decisions, 33 of them say that they somewhat influence, while 45 respondents state that

family does not influence their consumer behaviour at all. Also, 36 respondents say that media does not influence their purchasing behaviour at all, while 57 respondents say that the media does not influence them, with only 6 respondents stating that the media completely influences their shopping behaviour. When it comes to influencers, 72 respondents say that influencers do not influence their shopping habits at all, 69 respondents say they do not influence, and only 6 respondents say that they completely influence their shopping habits.

Social Factor	No Influence (%)	Some Influence (%)	Complete Influence (%)
Partner	36.4	33.3	30.3
Family	22.7	44.4	33.3
Friends	30.3	33.3	36.4
Media	34.8	33.3	31.8
Influencers	34.8	33.3	31.8

These results indicate that Generation Z consumers mostly make purchasing decisions independently, research product specifications and information independently, and know what they want to buy. Some social factors may influence them to some extent, but in most cases, they are not decisive. Out of the total number of respondents, 126 say they never buy what is advertised on influencer profiles, 66 say they rarely do; 162 respondents say they are not willing to pay more for products advertised by influencers, and 114 respondents say they rarely buy what is “in”. Regarding the importance of the opinions of partners and friends when it comes to buying clothes and shoes, 21 respondents say that their partners’ and friends’ opinions are important, while 99 respondents say that their partners’ and friends’ opinions are rarely important to them; 6 respondents say they never consider others’ opinions when buying clothes and shoes. 132 respondents say they often go shopping alone, while 9 respondents say the opposite, that they never go shopping alone.

Time Spent Online	Percentage (%)
2 to 3 hours	35
3 to 4 hours	21
4 to 5 hours	23
Up to 1 hour	12
5 to 6 hours	4
More than 6 hours	5

Respondents generally spend a lot of time on the Internet. Most respondents (35%) spend 2 to 3 hours on the Internet, 21% of respondents spend 3 to 4 hours, and 23% of respondents spend 4 to 5 hours on the Internet. 12% of respondents spend up to one hour a day on the Internet, and 4% of respondents spend 5 to 6 hours, while 5% of respondents say they are on the Internet for more than 6 hours a day. Most online stores offer a “Click and collect” service. This is a service of ordering and paying for an order through a selected web store with picking up the order at a physical location of that web store. For 62% of respondents, the “Click and collect” service is useful but does not make a difference in their purchases, while 18% of respondents say they prefer the “click and collect” service and 20% of respondents say this service is not important to them at all. Half of the respondents (49%) say they rarely check the product physically in the store before buying it online, while 21% of respondents say they do it often, and 30% of respondents never check the product physically in the store before buying it online. On the other hand, 33% of respondents say they often check the product online before physically buying it in the store, while 52% do it rarely, and 15% of respondents never check the product online before physically buying it in the store.

For 48.5% of respondents, lifestyle often influences the choice of store, while for 34.8% of them, it is a rare occurrence; for 10.6% of respondents, lifestyle always influences the choice of store, and for 6.1% of respondents, it never happens. Today, most stores have a webshop service. For the majority of respondents (56.1%), the webshop is useful but not decisive, for 39.4% of respondents, the webshop is a significant factor, while for 4.5% of respondents, it is not important. Respondents mostly gather information about the product just before purchasing (57.6%), during the purchase itself (31.8%), and 10.6% of respondents say they do not gather information about the product. In this study, 80% of respondents were female, and 20% were male. The study specifically involved respondents aged 16 to 26 years. Most respondents were aged 21 to 22 years (39.4%), followed by those aged 23 to 24 years (31.8%), and those aged 25 to 26 years (22.7%). In the age group of 19 to 20 years, 4.5% of respondents participated in the study, and the youngest population was the smallest - only 1.5% of respondents aged 16 to 18 years. The majority of respondents have completed secondary education (49%), and 44% of respondents have completed undergraduate education. Others have completed higher vocational education (5%), graduate studies (1%), and postgraduate studies (1%). The largest number of respondents who participated in this study still work in some form of student job (37.9%), 22.7% of respondents are employed full-time, 10.6% of respondents are employed part-time, and 28.8% of respondents are unemployed.

Up to 4 members in the household account for 28.8% of respondents, households with five members account for 25.8% of respondents, and households with six members account for 12.1% of respondents. Households with up to 3 members account for 15.2% of respondents, those with two members account for 9.1% of respondents, and 4.5% of respondents live alone. Since members of Generation Z are a young population aged 16 to 26, most respondents are still students, unemployed, or working part-time, hence they do not have significant monthly incomes. A third of respondents (36%) have monthly incomes of up to 130 euros, and 22% of respondents have monthly incomes ranging from 131 euros to 400 euros. Other respondents (19%) have monthly incomes ranging from 401 to 660 euros, 8% of respondents have monthly incomes ranging from 661 to 930 euros, and 15% of respondents report monthly incomes exceeding 931 euros. The majority of respondents indicated that they live in households with other family members. Nearly a third of respondents (31.8%) stated that their household monthly income exceeds 1990 euro, 22.2% of respondents said that their household monthly income ranges from 1330 to 1991 euro, and 18.2% of respondents have household monthly incomes ranging from 530 to 930 euro.

4.2. Research Limitations

A limitation of the research lies in the sample of respondents, which was convenient. The study involved 198 respondents, members of Generation Z, and although their responses revealed the consumption habits of this generation, they are not sufficient to indicate the actual situation. Additionally, a limitation of the research is geographically restricted, as only consumers from Generation Z from the Republic of Croatia participated in the study. Surveys are also one of the limitation factors because they rely on self-reported data. Temporal changes can be a limitation factor, especially because this research is made among the younger generation who are influenced by technological advancements and societal shifts. The study's findings are based on data collected at a specific point in time, and these behaviours may evolve. For further research, it would be necessary to expand the geographical scope to obtain more accurate results and use a mixed methods approach and longitudinal studies to track changes in Gen Z behaviour.

5. Conclusion

This study analyzed the consumer behaviour of Generation Z, a young consumer generation born between 1995 and 2011. Generation Z is highly familiar with technology, having been introduced to mobile devices and the internet from a young age (Twenge, 2017).

This generation is considered the “most problematic” consumer generation because they have a very different view of shopping than all previous generations. They follow and leave reviews about products and services on social media, and based on others’ reviews, they decide on purchases (Fromm & Read, 2018).

Generation Z consumers are highly informed and have high expectations, both from the product itself and the customer service they interact with online or through social media chats (Williams & Page, 2011).

In the practical part of this study, the consumer behaviour of Generation Z was analyzed using a sample of 198 respondents. The results show that almost all respondents purchase products online, some several times a year, and some even daily. The most common items purchased online are clothing and footwear, as well as electronic devices (mobile phones, tablets, laptops, etc.). They shop online because it is less stressful than going to a store and because it is faster and simpler (Singh, 2014).

When shopping online, the most important factors for Generation Z consumers are satisfaction with the purchased product and free delivery. They prioritize product quality and usefulness, while product packaging and brand are considerably less important (Moore, 2012). The respondents who participated in this study do not believe that more expensive products are necessarily of higher quality, and a very small percentage of respondents are influenced by their partner, family, and friends.

However, this study did not confirm the theory that Generation Z consumers follow influencer advice and purchase products they promote. Quite the opposite, the majority of respondents stated that they never or very rarely purchase products promoted by famous influencers on social media and that they are never willing to pay more money for those products just because influencers promote them. This confirms the thesis that Generation Z consumers are unique and want to be different from others (Wood, 2013).

This study confirmed most of the theoretical facts about Generation Z consumers. It has been shown that Generation Z consumers want to be unique, prefer online shopping, spend a lot of time on the Internet, and mostly gather information about products and services that way (Smith, 2011). Additionally, the study showed that consumers of the observed generation still do not have significant personal incomes, which is not surprising given that they are very young consumers who are still studying, not working, or working part-time jobs. The research indicated that Generation Z consumers, or those who participated in this study, do not prefer product and service advertising by influencers and that such a promotion method has the opposite effect on them. It can be said that Generation Z consumers are self-aware, know what they want, and independently choose products and services they want to purchase, not allowing others to influence their purchase decisions.

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“DIGITAL MARKETING IN THE WORLD OF SPORTS: A CASE STUDY OF ATP CHALLENGER SPLIT’S SOCIAL MEDIA MARKETING ACTIVITIES”

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ABSTRACT The development of techniques and technology and the advent of the Internet have changed how we live and conduct business today. Companies’ marketing activities have also changed, and today, we are discussing digital marketing applied by all successful companies that want to grow, develop, and be competitive in the market. Currently, digital marketing activities do not bypass sports institutions and events. Therefore, this paper presents the tennis tournament ATP Challenger Split, the subject of this paper, and its marketing activities on social media profiles. This study aims to analyse the strategy and content of the implementation of digital marketing and provide an opportunity for future research. The marketing efforts were highly effective, using minimal financial investment to reach the right audience on social media platforms who are interested in sports and tennis. This confirms how the application of social media can be more successful than traditional marketing using minimal financial resources. While focusing on the budget is important, companies must also continuously develop effective marketing strategies and focus on their customers to stay competitive, using social media to gather information and deliver targeted messages. For practitioners, the findings emphasise the pivotal role of social media in achieving marketing goals and objectives. They serve as invaluable tools for gathering essential information and establishing connections with customers, suppliers, and other business partners. For researchers, this study provides a valuable template for exploring and understanding digital marketing strategies in sports events, suggesting future research opportunities to refine and expand our understanding of effective digital marketing practices.

Keywords: *digital marketing, social media, sports events, promotion*

1. Introduction

Marketers increasingly harness innovative technologies in contemporary digital landscapes to enhance their business promotion and adaptability. Digital marketing plays a pivotal role in the digital rejuvenation of enterprises as it facilitates the dissemination and acquisition of knowledge regarding events, thereby informing both consumers and businesses. Marketers are leveraging new technologies to promote businesses and to adapt to the digital era. Digital marketing is crucial for enhancing business growth, empowering both consumers and enterprises to discover events and share information with others. Mobile devices, the Internet, local area networks, digital televisions, and other media are used to collect information and conduct marketing research (Dwivedi et al., 2021). Marketing is a continuous process of creating a service or product according to the desires and needs of customers; its goal is to offer someone a specific product that satisfies their needs. Today’s way of life and work have changed. The

development of technology, the emergence of the Internet, and globalisation have changed the way of life (Reed 2018). E-commerce has dramatically changed the traditional way of doing business, and all market participants must adapt to it to survive and develop (Jain et al., 2021). Traditional marketing has been replaced by digital marketing, which represents implementing a company's marketing activities with intensive information and telecommunication technology. The changed way of life and work has brought social networks into life and work, thus becoming a global communication phenomenon. The continuous and growing number of users and the emergence of new social media platforms confirm this. Social media provide users, primarily business entities, with numerous advantages, so they are included in companies' digital marketing strategies (Koba, 2020). A case Study of the ATP Challenger Split Tennis Tournament" will elucidate the current significance of social media in marketing endeavours. This work is based on the efforts of a student responsible for promoting the tournament on social media platforms and devising a digital strategy.

1.1. Digital Marketing

In the traditional sense, as Kotler et al. (2015) defined, marketing is *"a social process by which individuals and groups obtain what they need or want through creating and exchanging products and values with others."* The American Marketing Association (AMA)¹ defines marketing as the process in which planned and executed ideas, products, and services are priced, promoted, and distributed, all to perform exchanges that will satisfy the objectives of individuals and organisations. Today's life and business have changed how people live and work. The Internet has changed our way of life and our way of doing business. Its use for business purposes, such as e-commerce, has enabled business entities to have greater interactivity, connectivity, flexibility, and cheaper and faster operations than traditional businesses (Ružić, 2014). All participants in the business process, suppliers, customers, partners, and so on, had to adapt to today's working methods to survive and remain competitive. Digital marketing has been defined in various ways by various authors. According to Panian, digital marketing is a way to carry out a company's marketing activities with intensive information and telecommunication (Internet) technology. Chaffey et al. (2009) believe that Internet marketing implies using the Internet and other digital technologies to achieve goals and support modern marketing. Siegel (2004) states that Internet marketing represents marketing in a new electronic environment. Mohammed et al. (2004) consider Internet marketing to be the process of building and maintaining relationships with customers through online activities to facilitate the exchange of ideas, products, and services and fulfil the goals of the involved parties. Based on the research of Ružić et al. (2014), digital marketing is creating an offer, pricing, distribution, and promotion to profitably satisfy the needs and desires of customers with the intensive use of digital technology capabilities. Digital channels are used daily in all segments of life and work. Brenner and Smith (2013) found that posting on social networks was the most important online activity in the United States. The average American spends 2 to 2.5 hours daily on social media platforms. The report also highlights that multi-platform use is on the rise, with 52% of online adults using two or more social media sites, a significant increase from 42% in 2013. These data underscore the importance of social media in digital marketing strategies and the need for businesses to maintain a presence across multiple platforms to reach their target audience effectively.

¹ American Marketing Association: Definition of Marketing (2013). <https://www.ama.org/AboutAMA/Pages/Definition-of-Marketing.aspx> [16.08.2021.]

1.1.1. Marketing tools on social networks

The digital marketing strategy is to attract as many visitors as possible to one's website to make a specific conversion (purchase, membership, newsletters, etc.). To achieve this, digital marketing uses various content tools and tactics like content marketing (Panda & Mishra, 2022).

1.1.1.1. Community Management

Community management refers to online communication with fans or followers on various social media platforms gathered around a brand, product, company, or public figure (Szmigin et al., 2005). This communication between the company, fans, and followers must be well understood and tailored to each company's needs. It helps the company create a positive and recognisable image for its brand and improve its business operations.

1.1.1.2. Social Media Management

Social media marketing or marketing on social networks includes creating profiles on numerous and diverse social networks, such as Facebook, Twitter, LinkedIn, Google+ network, and others, managing them (community management), creating written and visual content for publication, all for branding, promoting products and services, and improving the position of the website itself (Tuten, 2023). Although it was believed that social media members were younger people who used Facebook to exchange statuses and photos and create Facebook groups, an increasing number of business people have recently become social media members who opened their company's pages on social media.

1.1.1.3. Content Marketing

Content marketing implies the creation of original, relevant, and valuable content that will easily attract customers' attention and present certain products or services to them in an unobtrusive way (Vinerean, 2017). This form of marketing includes creating written content, blogging, electronic books (e-books), infographics, online and offline magazines, and other content to strengthen the relationship with readers and promote the business/brand.

By consistently delivering high-quality content that resonates with their audience, businesses can establish themselves as trusted authorities in their industry, strengthen relationships with customers, and ultimately drive conversions. Successful content marketing strategies are built on a deep understanding of the target audience's preferences, interests, and pain points, allowing brands to deliver content that adds value to the consumer experience.

1.1.1.4. Copywriting

Copywriting or creative writing refers to writing texts for advertisements, such as commercials and promotional materials for a specific product or service, that persuade potential customers to act (Zulkifly, 2014). A copywriter reaches customers through billboards, magazine ads, sales letters, blog posts, etc. Copywriting is a digital marketing tool that lays the foundation for content marketing and SEO.

2. Research methodology

2.1. Marketing objectives and strategy

This work undertakes an exploratory research approach, utilising a case study of applying marketing on social networks, specifically the professional tennis tournament “ATP Challenger Split Open 2020,” in the reporting period from September 14, 2020, to October 15, 2020.

Establishing clear and measurable goals is of utmost importance before embarking on marketing activities on social media platforms. These goals serve as a compass, guiding the strategy and allowing for monitoring progress and adjustments as necessary. The marketing goals for promoting the tennis tournament focused on several key areas.

First, increasing the tournament’s recognition aimed to enhance social media users’ awareness and recognition of the event. This was crucial in ensuring that as many people heard about the tournament and understood its significance. Another goal was to increase the number of followers on Facebook and Instagram, thereby expanding the tournament’s reach and audience. Engaging the audience was also a priority, with efforts to boost user interaction through likes, comments, shares, and reactions to posts related to the tournament.

The aim was to engage the audience by introducing them to the individuals behind the tournament through video content. Additionally, capturing relaxed moments with the players between matches, showcasing how they prepare, and sharing little tips and tricks was the content that showed the other side of the tournament. The goal was to build a sense of community and connection with the audience, inviting them to be part of our journey.

Promoting sponsors was essential, ensuring their visibility through social media posts, stories, and tags. Informing followers about the schedule of matches, results, and activities during the tournament was another critical goal, keeping the audience promptly updated.

In addition, increasing website traffic was targeted by directing followers to the tournament’s official website for more information and to track results. Connecting and engaging with the public involved creating interaction with followers through social media platforms, responding to comments, asking questions, and encouraging two-way communication.

Creating a positive perception of the tournament and its organisers was essential, as was providing exclusive content to followers, such as player interviews, behind-the-scenes footage, and live streams of events. Finally, gathering feedback was vital, providing channels for audience input to improve future events.

The effectiveness of a structured approach to setting and achieving marketing goals on social media platforms was pivotal in successfully promoting the ATP Challenger Split Open 2020.

Dokyun Lee, Kartik Hosanagar, and Harikesh S. Nair (2018) state that social media content engineering can impact user engagement by measuring likes, comments, shares, and click-throughs for messages. Their analysis reveals that brand personality-related content, such as emotional and humorous content, is positively associated with higher engagement. This suggests that firms gain from sharing their brand personality and information about their social initiatives on social media. Swani et al. (2017) claim that understanding the relationship between Facebook’s social media content and format through metrics such as likes or comments is essential for businesses.

2.2. Key performance indicators (KPI)

Setting a clear strategy is paramount to success in any marketing activity. However, a strategy’s effectiveness can only be determined through systematic measurement, where key

performance indicators (KPIs) become highly significant. KPIs are essential metrics that help evaluate the progress and impact of marketing activities against the set objectives. Establishing and monitoring these KPIs makes it possible to ensure that the strategy remains on track and make informed adjustments to enhance performance and achieve goals.

In the ATP Challenger Split Open 2020, a comprehensive set of key performance indicators (KPIs) was established to measure the effectiveness of the marketing strategy on social media platforms. The focus was on several crucial metrics to evaluate the reach and engagement of the tournament's digital presence.

The total reach was measured to determine the number of unique users encountering tournament-related content across social media platforms. The engagement rate was another critical KPI, calculating the percentage of users interacting with the content through likes, comments, shares, and reactions. Additionally, the click-through rate (CTR) assessed the proportion of users who clicked on links directing them to the tournament's official website or other landing pages, providing insights into the effectiveness of the calls to action.

Brand awareness was another significant focus, monitored through the frequency of tournament-related mentions or hashtags on social media. Sentiment analysis played a crucial role in understanding the perception of the tournament, analysing whether the mentions were positive, negative, or neutral, thus determining the overall brand sentiment.

Content performance was evaluated by identifying the top-performing posts based on engagement metrics such as likes, comments, shares, and other forms of interaction. This evaluation helped determine which types of content, whether videos, photos, or stories resonated best with the audience, enabling more effective content planning and creation.

Audience interaction and feedback were also tracked to understand the quality and frequency of interactions with followers. This included monitoring responses to comments and questions and collecting feedback through various channels. This feedback provided valuable insights for improving future events and fostering a more engaged community.

Focusing on these KPIs allowed for the accurate measurement of marketing strategy success. This data-driven approach enabled informed decision-making, optimisation of future campaigns, and the ultimate achievement of promotional goals.

3. Case study – „ATP Challenger Split Tennis Tournament”

This tournament was a significant milestone for the city of Split and tennis players across the country because this tournament returns after 22 years in Split, Croatia, for the first time since 1998². Croatia has numerous renowned tennis players on the global stage, such as Goran Ivanišević, who won Wimbledon in 2001, as well as Marin Čilić, Borna Ćorić, Mate Pavić, Ivan Ljubičić, and Mario Ančić and many more. Bringing back such a prestigious tournament to what is often considered the most sports-oriented city in the world was a tremendous success.

This achievement highlights the continued importance of tennis in our city and offers a unique opportunity for young players to witness and engage with professional athletes. The revival of the Split Open reinforced the city's rich sporting heritage. It inspired the next generation of tennis players, ensuring the sport remained a vibrant and integral part of the community.

The Split Open tennis tournament has immense significance beyond being a professional event returning to Split after 20 years. It plays a vital role in promoting tourism and showcasing

² ATP Tour. "ATP Challenger Split." ATP Tour, n.d., <https://www.atptour.com/en/tournaments/split/8388/overview>

the beauty of the Adriatic coast.³ The tournament attracts visitors worldwide, highlighting Split's rich cultural heritage and stunning coastal scenery. This influx of tourists boosts the local economy, bringing attention to the region's attractions, hospitality, and unique charm.

By hosting the Split Open, sports are celebrated, as is Split's position as a premier destination for international visitors. The tournament is a powerful promotional tool for the Adriatic coast, enhancing its reputation and attracting tennis fans and tourists. This dual impact on sports and tourism underscores the broader significance of the Split Open, benefiting both the local community and the wider region.

The first edition of the tennis tournament Split Open was supposed to have taken place in April 2020, but due to the global COVID-19 pandemic, the tournament was postponed and took place in September 2020. The agency PlayHR, in collaboration with the Tennis Club Split, organised an international men's tennis tournament. The Ministry of Tourism and Sports of the Republic of Croatia, Split-Dalmatia County, the City of Split, the Split Tourist Board, and the Public Institution for Sports Facilities supported this tournament. The tournament was held for eight days. User profiles were created and edited - the Facebook page "SPLIT OPEN" which, in just 30 days of systematic work on content and campaigns, gained 1,006 followers, which was an excellent result considering the budget of only \$132.80, to which tennis fans themselves also contributed by sharing and commenting on the content.



Picture 1.: The ATP Facebook profile

Source: Facebook. <https://www.facebook.com/Split.Open.Tennis.Tournament> [30.08.2021.]

This image illustrates the layout of a Facebook profile. It is crucial to highlight the tournament's sponsors prominently on the primary visual and the significant dates. Additionally, include the previous year's winner to represent the tournament effectively. This approach ensures comprehensive visibility for our sponsors and honours past achievements.

After the tournament's Facebook page was created, promoting the event on the platform was crucial to maximise reach and engagement and increase brand awareness. The goal was to connect with as many people as possible, encouraging them to share, like, and comment on the presented content on social media platforms. Given the limited timeframe, implementing paid campaigns using the Meta Business Suite (formerly the Facebook platform) was necessary.

A specific budget was allocated for these campaigns to ensure effective promotion. This strategic investment aimed to amplify reach, engage a wider audience, and generate excitement

3 Slobodna Dalmacija, <https://slobodnadalmacija.hr/sd-plus/reflektor/trebalo-je-vremena-rada-guranja-i-srece-split-se-vraca-u-kalendar-atp-a-nbsp-turnir-ce-biti-prilika-za-domace-tenisace-ali-i-dobru-promociju-grad-a-642462>

and support for the tournament. Utilising paid campaigns significantly enhanced our online presence and drove engagement.

All users who reacted to content but did not mark the page with a “like” were invited to follow it. During the reporting period from 14.09.2020 to 15.10.2020, in addition to the number of users and followers, the content achieved a specific reach ranging between 6,214 and 16,650 monthly users. This reach was facilitated through paid campaigns, as illustrated in Picture 2: Statistics on the tournament’s Facebook page.

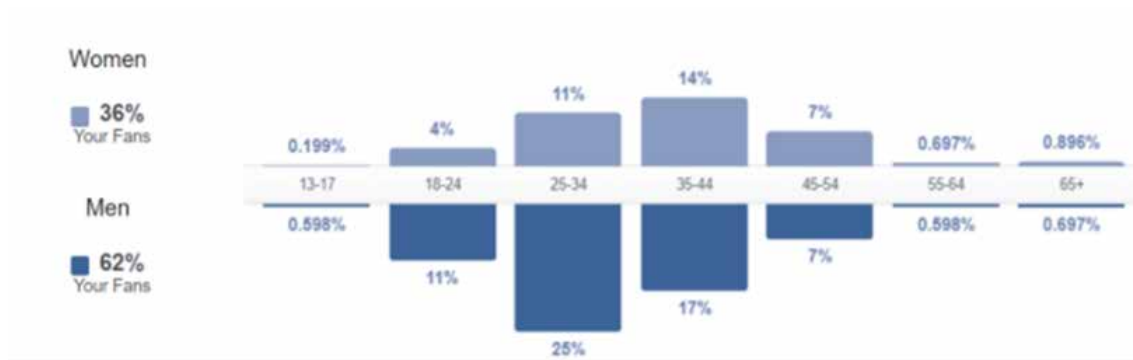
Given the limited time frame, achieving significant results with paid campaigns was possible. Investing in paid campaigns through Meta Business Suite has proven instrumental in increasing reach and engagement on Facebook. These campaigns facilitated connections with a broader audience, encouraging increased sharing, liking, and commenting on content, thereby promoting the event to residents of Split. With this strategic allocation of the paid promotion budget, achieving the same level of visibility and interaction for the tournament became attainable.



Picture 2. Statistics of the tournament’s Facebook page

Source: Split Open (2020) Activity report on Facebook and Instagram

The age structure of fans on Facebook pages can provide valuable insights into the demographics of the audience engaging with the content. Typically, this information is available in the page’s insights section, where you can see a breakdown of age groups among followers. These data help tailor the content and advertisements to different age groups’ interests and behaviours. For example, if most fans are in the 18-24 age range, the content may focus on trends, styles, or topics that resonate with a younger audience. Conversely, if the primary age group is 45-54, the content might be more geared towards issues of interest to that demographic group. Understanding age structure is crucial for effective community management and content marketing, as it allows for a more targeted approach that can lead to higher engagement and conversion rates.



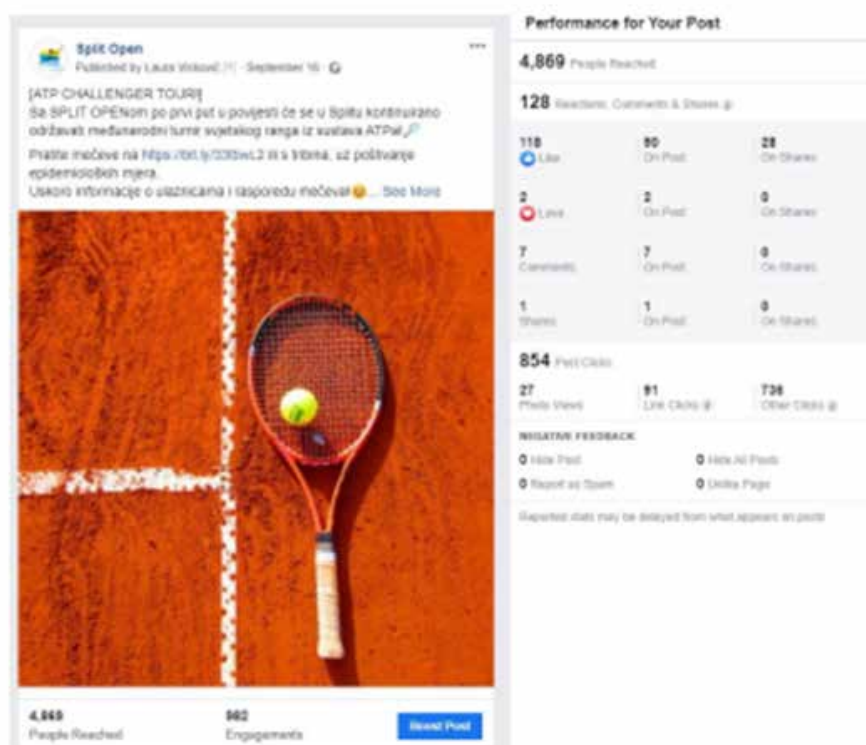
Picture 3. THE AGE STRUCTURE OF FANS ON THE FACEBOOK PAGE

Source: Split Open (2020) Activity report on Facebook and Instagram

This photo illustrates the age structure of fans on our Facebook page. The data reveals a higher number of male fans, but it is notable that the age structure for both men and women predominantly falls within the 25- to 34-year-old range. This demographic insight is crucial for tailoring our content and engagement strategies to reach and resonate with our audience effectively.

Nine advertising campaigns, eight of which were on Facebook, were created in 30 days. All campaigns were optimised, reaching 59,414 users and resulting in 161,166-page visits and content views (Facebook and Instagram).

The first post about the ATP Challenger Tour reached 4,869 people, and 128 people reacted to the post through comments, likes, and shares. These statistics demonstrate the effectiveness of social media campaigns and the engagement they generate among audiences.



Picture 4.: First post of the ATP Challenger tour

Source: Split Open (2020) Activity report on Facebook and Instagram

Spit open
Published by Laura Wilson · 1 · October 2 ·

[BORN A GÓD U POLI(FINAL)U]
 U manji od 24 sata Borna Ćokjo je porazio Nitrozema Van de Zandvoortja, porin istanjs i Alessandra Gianeseraga 6.5, 6.3 te se plasirao u polufinale Spit Opena! 🏆

👤Robert Parficio
 #Spitopen #Spitchallenger #Spitchallengertour

3,854
 People Reached

174
 Reactions, Comments & Shares

168 Like	148 Go Post	0 Go Share
5 Love	5 Go Post	0 Go Share
1 Waha	1 Go Post	0 Go Share
0 Comments	0 Go Post	0 Go Share
0 Stanes	0 Go Post	0 Go Share

541
 Post Close

75 Photo View	0 Like Close	486 Other Close
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NEGATIVE FEEDBACK

0 Hate Post	0 Hate All Posts
0 Report as Spam	0 Online Page

Reported spam may be delayed from what appears on post

Additionally, every player participating in the tournament and all sponsors were followed. This approach enabled connecting with key stakeholders and fostering a more interactive

community. Tailoring content and engagement strategies to fit Instagram's unique characteristics facilitated the successful promotion of the tournament and the city of Split. This ensured that messaging resonated with the broader and more active Instagram audience, as depicted in



Picture 5: Instagram story.

Source: Split Open (2020) Activity report on Facebook and Instagram

Only \$12 was spent on the Instagram campaigns. Among the followers of the Instagram page and Facebook, men predominated, and the most represented age group was 24 to 44 years old. Followers mostly lived in Split, followed by fans from Zagreb. Most followers were from Buenos Aires, which makes sense because the tournament winner was from Buenos Aires. Followers were most active in the afternoon and evening hours, according to the match schedules and timing of posts with results on social net. The total budget invested in advertising during the 30 days of work on social networks was 144.80 US dollars or 928.16 kuna. Despite the small budget, excellent results were achieved, and the message reached many users interested in sports and tennis. These results were also supported by the fact that local players reached the semifinals, and these results would undoubtedly have been better, considering the invested budget, if the local players had been eliminated in the first or second round. With the tournament's first edition and the activities carried out on social media on this occasion, a base of tennis fans on Facebook and followers on Instagram was built, and a solid reach of posts, engagement, and visits to the tournament was achieved.

4. CONCLUSION

The case study on the ATP Challenger Split Open 2020 presents a structured approach for implementing event-driven digital marketing strategies tailored explicitly for sports events. The methodology applied and the analysis conducted provide valuable insights into the effectiveness of such strategies. By establishing clear and measurable goals, the marketing activities were systematically planned, executed, and assessed using various KPIs to ensure the strategies remained on track and adjustments were made as necessary. In today's digital age, the Internet has revolutionised personal life and business operations. E-business offers greater interactivity, connectivity, flexibility, and efficiency than traditional methods. Digital marketing, as a subset of e-business, focuses on building and maintaining relationships with customers through online activities to facilitate the exchange of ideas, products, and services, ultimately fulfilling the goals of all involved parties. Companies must continually evolve, be customer-oriented, and leverage Internet technology to remain competitive. This technology enables businesses to collect crucial information and engage more effectively with customers, suppliers, and other partners. Social media platforms, particularly Facebook and Instagram, have become indispensable tools in

digital marketing, permeating every aspect of daily life and business. The ATP Challenger Split Open 2020 case study demonstrates how marketing activities on these platforms can significantly impact event promotion and engagement. The tournament's social media marketing efforts were analyzed from September 14, 2020, to October 15, 2020. Despite a minimal budget of 114.80 US dollars, or 928.16 kuna, the campaign achieved excellent results, reaching a broad audience of sports and tennis enthusiasts. However, it is essential to note that this research, while comprehensive, has limitations. The study's scope was confined to a single event within a limited timeframe, which may not capture long-term trends or the impact of external variables. Additionally, the reliance on social media metrics as the primary indicators of success may overlook other critical factors influencing overall event performance. Future research should explore more extensive and diverse case studies to validate and refine the findings. Long-run studies could provide deeper insights into the sustained effects of digital marketing strategies on the promotion on sports events. Moreover, integrating qualitative data, such as participant feedback and in-depth interviews, could enhance the understanding of how digital marketing influences audience engagement and brand perception. In conclusion, the ATP Challenger Split Open 2020 case study does not just demonstrate the effectiveness of digital marketing in sports event promotion; it showcases its transformative potential. Businesses can make informed, data-driven decisions to optimize future campaigns and achieve their promotional goals by focusing on key performance indicators. This approach not only enhances the visibility and success of events but also fosters a deeper connection with the audience, ultimately contributing to the growth and popularity of the sport.

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APPLICATION OF THE CONCEPT OF AUGMENTED REALITY IN TOURISM

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Abstract. The development of digital technologies has led to new solutions that are able to improve the user experience of the tourist product. In this paper, we will analyze augmented reality (AR), which is one of the tools of digital marketing. Augmented reality (AR) represents the next step in the development of virtual reality in which the real environment is connected with computer-simulated image content. Augmented reality provides the opportunity to manage digital tourism by creating real-time content tailored to consumer needs.

The goal of this paper is to use an analytical approach to determine how augmented reality can influence the increase in demand for tourist products and services. The paper points to the growing influence of the application of augmented reality tools, which, with their simplicity and usefulness, influence the shaping of consumer behavior. The above indicates that the application of digital technological innovations such as augmented reality provides the possibility of easier selection, recommendation and purchase of tourist products and services.

Keywords: *augmented reality, digital marketing, tourism, consumer behavior*

1. Introduction

Tourism, like all areas of business, strives to keep up with the development of new information and communication technologies. Striving to modernize its business processes and activities, the most room for progress is provided in the quality construction of interaction between the providers of tourist services and the users of tourist services themselves. (Custódio-Santos M., Veiga C., Aguas P, 2016, 654-669) It is precisely in this area that tourist organizations invest most of their resources. Although many internet services provide tourists with information about the places they intend to visit, as well as the possibility of making a reservation from home, many tourists, when arriving at the destination, continue to use classic maps, guides, brochures and other helpful literature. (Rayman-Bacchus L., Molina A., 2001, 589-605) A step forward was achieved with the use of GPS devices, which enable an easier and simpler way of planning a tourist trip. However, the essence remained the same, with the difference that in this case maps were used in digitized form. (Savchuk V., Pasichnyk V., 2015, 65-72) Furthermore, software manufacturers for mobile devices that used GPRS technology offered the possibility to access geo-location services through applications for mobile devices, which, although limited in terms of the content provided and the way in which they present the content, were the first step in the application of mobile devices for this purpose. Considering the above, concepts like geo-locating and obtaining context-based information are gaining more and more attention. In short,

geo-location services provide the possibility of determining the position of a certain object by defining its geographical coordinates, in a certain physical space. Based on geo-location data on positioning, context-based information can be provided, so information is presented according to the determined position of the user. Although the application of GPRS technology on mobile devices, as a replacement for paper maps, represents progress, the advantages it brought are exclusively related to the classic digitization of content and the addition of shorter textual descriptions to the map. (Berger S., Leahmann H., Lehner F., 2003, 243-256)

In today's time, there are certain technologies available to us to make a qualitative improvement in the presentation of tourist information that we use when organizing a tourist trip. One of the technologies that offers a wide range of applications and is widely used on mobile devices is Augmented reality (AR) for tourism presentation. (Kečkeš A. L., Tomićić I., 2017, 157-167) In order to expand market opportunities, we must think comprehensively, and use the possibilities of new technologies to create innovations that will bring significant improvements for users. The introduction of augmented reality in the field of digital marketing represents the next development step of mobile services adapted to tourism, which enables the provision of contextual information, thus expanding the possibility of customization in the form and amount of information related to the place of visit. (Plotkina D., Dinsmore J., Racat M., 2021, 1-19)

2. Literature review

Augmented reality is a new field of research in the computer science. Augmented reality is not the same as virtual reality, but its variation, that is, the next stage of development, which allows the user to see the real world with virtual objects overlaid or combined with real images. (Liang L. J., Elliot S., 2020, 15-30) In this case, the user does not appear completely inside a closed world where reality and experience is artificial in a comprehensive 3D space such as the concept of virtual reality, but is in real world, which is additionally adapted, shaped and supplemented with the necessary contents. (Zuhriy S., et. al., 2020, 216-225) In augmented reality, the user perceives virtual and real objects that coexist in the same space. Augmented reality can also be seen as a middle ground between virtual reality which is completely artificial and real presence which is real. Although the beginnings of the development of the concept of augmented reality go back to 1960, when the first flight simulators were designed for the needs of aeronautics, as well as the further development of the technology, there was still no clear definition of augmented reality. A contribution to this is the fact that augmented reality separated from virtual reality and became a new area of research and separate development after 1990. According to Young and Khoo-Ltimore, the concept of augmented reality must meet the following requirements:

- Augmented reality differs from the concept of virtual reality
- Augmented reality differs from concepts such as mixed reality with the need to implement 3D content in the real world
- Augmented reality combines the real world with digital content,
- Augmented reality requires the system to be interactive with the user,
- Augmented reality reacts and adapts in real time, which is different from techniques that display images in the real world (eg CGI). (Young R., Khoo-Latimore C., 2017, 1-27)

Although the concept of augmented reality is relatively well-known, its potential has not yet been sufficiently exploited. There are several areas of its use, the degree of utilization of which

varies. The next section will show some of the benefits. For example, military aircraft have long used "head-up" displays (HUD) on pilot helmets, which display graphics that are in front of the view of the real world (Chauvin C., Said F., Langlois S., 2023, 217-232). These graphics provide information about the terrain, flight directions, tracking of given routes on the ground or in the air. Augmented reality applications can also be used in museums, galleries, national parks or in open spaces, where objects such as buildings, sculptures, artefacts and images can be extended or supplemented with information (text, image, sound, video, symbols), which will be transmitted to users via the device at the moment they approach the object. (Xia G., Wang R., Gong Z., 2022, 33-45) The first example of mobile augmented reality was the Turing Machine. A Turing machine is a mathematical model of computation that describes an abstract machine that manipulates the symbols on a tape according to the rules in a table. Although the model is simple, it is capable of implementing any computational algorithm. The next example is the HMD screen (head-mounted display). An HMD display is a display device, worn on the head or as part of a helmet, that has small optics built into the display in front of one or each eye. (Xu X., Mangina E., Campbell A. G., 2021, 1-14) HMDs are widely used in the field of video games, aviation navigation, engineering and medicine. Also, another area of application of augmented reality is the assembly and maintenance of complex mechanical devices such as electric motors, where instead of viewing manuals with text and images, 3D images are displayed projected onto the equipment itself, showing the steps to be performed or how to perform a certain action. The same applies to regular device maintenance, where parts or consumables need to be replaced. (Ariansyah D., et. al., 2022, 1-18) Another example of this type of application is the Tesla car manufacturer that uses HUD displays, Web AR, and AR mobile applications for repair and safe driving. Likewise, future doctors can use augmented reality as an important aid in visualizing, conducting or training doctors, by simulating images created on the basis of data obtained from magnetic resonance imaging, PET-CT scanning or using ultrasound. (Parsons D., MacCallum K., 2021, 77-91)

3. Application of augmented reality in tourism

Technology has always been the driver of development in tourism, which is manifested through continuous innovation. Since the advent of the Internet, through the combination of IT technologies, there have been major changes in the field of digital marketing, which has affected tourism production and consumption, as well as other business segments. (Kushwaha B. P., 2020, 2029-2041) Some of the most important improvements have been achieved in the area of reducing production costs, distribution and sales activities, global promotion of tourism, increasing the offer, choosing vacation spots, and creating new relationships between users and suppliers of tourism products. (Graziano T., Privitera D., 2020, 666-679)

Digital marketing uses some of the most radical technologies, such as the internet, which has the ability to influence changes in the perception and attitudes of consumers, i.e., the behavior of tourists. (Sundaram R., Sharama R., Shakya A., 2020, 244-254) Among the most significant changes, we can mention the possibility of direct interaction of consumers with producers of tourist services (which in this case replace tourist intermediaries) and with destinations (direct ordering of more personalized products and services). (Rangaswamy A., et. al., 2020, 79-90)

The rapid transfer of data generated by the use of the internet also changes the consumer's response time, which is significantly reduced today, which motivates organizations to manage information more effectively. On the other hand, consumer reactions to online requests can influence satisfaction and the decision to choose a tourist destination. Therefore, a quick response to customer inquiries and requests is an essential factor in the success of small and

medium-sized tourism companies, which in turn affects greater reputation and loyalty. (Jiang S, et. al., 2023, 242-257) Although in the first years of the internet, personal computers were the dominant instrument of online advertising, in recent years mobile devices have taken center stage. Informative inquiries and reservations via applications on mobile devices are increasingly common among most users. The main reason for the success and expansion of augmented reality in tourism is the simplicity and speed with which they enable obtaining solutions and information in real time, which satisfactorily fulfill the needs of tourists. (Loureiro S.M.C., Guerreiro J, Ali F., 2020, 1-21) The use of augmented reality on mobile devices shapes consumer behavior in such a way that it becomes part of the user's own experience, since the application of augmented reality affects the enhancement of sensory aspects and improves the user experience, which affects the memory of the event. (Kazami S. H. A., et. al., 2021, 1-28)

Another important element to keep in mind is that the increase in available information through mobile devices can change the decision-making context, especially when the tourist is in constant motion or at a destination, because mobile devices are the ideal instrument for quickly deciding on different options and instantly, thus time is saved. (Chiu C.C., Wei W. J., Lu J. C., 2019, 1811-1826) For example, using an application that collects recommendations from other users (such as Booking.com) or just friends (such as Reedit), based on the collected data, it is possible to create current and useful information for tourists visiting a certain tourist destination.

4. Augmented reality and the tourist experience

Augmented reality is one of the technologies that can contribute the most to improving the experience of tourists in a destination. By augmented reality we mean an environment that includes, at the same time, virtual reality and elements of the real world, which can communicate with each other. (Park S., Stangl B., 2020, 1-11) Unlike virtual reality where everything is artificial, the augmented reality system improves or enriches the environment by supplementing it with virtual information that seems to coexist with the real world. When augmented reality is combined with mobile devices, its use is reduced to simple pointing towards a physical object or its surroundings, whereby the necessary information is generated on the screen that describes the observed object or its surroundings in more detail. Information can be obtained in the form of video, sound, text, symbols or markers, behind which there are elements from the real world. (Ghandour A., et. al., 2021, 1-16)

The advantages of applying the concept of augmented reality from the users point of view is the simplicity and affordability of the technology, which can be made available to a wide group of tourists via a smartphone or tablet. (Cibilić I., Poslončec-Petrić V., Tominić K., 2021, 1-5) Furthermore, the concept of augmented reality exponentially increases the possibility of interaction and obtaining information about the tourist destination. From the point of view of tourism organizations, augmented reality, in general, includes a recommendation effect based on the experience of other users, through innovations in augmented reality, which affects positioning ahead of the competition. From the point of view of the destination, in addition to all the previously mentioned factors, we must take into account the fact that augmented reality enables the expansion of experiences and experiences in tourism, which affects the creation of synergy between visitors and the destination.

By including a large amount of information in augmented reality and managing it, tourist destinations become smart, which enriches the experience of tourists (for example: availability of customer service, free Wi-Fi networks, location of cultural institutions, information services, thematic routes). Since users create additional information by using it, here we have the

opportunity to find out in real time the preferences and tastes of visitors about products and services, as well as the tourist places, they visited. (Anand K., et. al., 2022, 236-259)

5. Potentialities of augmented reality applied to tourism

In order for tourist destinations to remain competitive on the global market, constant improvements in new technologies are needed, with innovations in the field of applications for mobile devices especially dominating. In today's tourism market, the application of the concept of augmented reality is at the beginning, therefore the future development of augmented reality tools can provide significant competitive advantages to those destinations that have adopted this technology. (Ronaghi M. H., Ronaghi M., 2022, 1-9) There are two types of positive effects of augmented reality. In the first case, it is about free and simple technologies that are adapted to the new profiles of tourists, who are inclined to accept and test new technologies, and the benefits they provide in the place of tourist stay. Also, here we are talking about tourists with experience who are very sensitive to the quality of service where personalization is required. On the other hand, providers of tourist services provide personalized information and, in interaction with users, reduce the time it takes to get the requested answer. Therefore, from the point of view of attracting new demand and commercializing the tourist destination, the introduction of augmented reality as a way of sightseeing gives tourist organizations the opportunity to better understand the tourist market, determine market segments, and within them choose their target markets and improve the quality and satisfaction of the tourist's stay in the tourist destination.

The next benefit comes from the ability that augmented reality has in increasing the experience of tourists, at the moment of consumption of the tourist product. Augmented reality offers real-time information about objects of interest to tourists that are placed in the observed environment. This immediacy in the application of augmented reality represents a great help to tourists for those destinations with which they are not sufficiently familiar. (Kounavis C. D., Kasimati A. E., E. D., 2012, 1-5) Also, from the user's point of view, the tourist experience can be radically improved through augmented reality. The ability to interact better, personalization and interesting things brought by augmented reality are facts that must be taken into account in order to enrich the tourist experience. For example, tourists exploring a destination (visiting a national park, museum, gallery, archaeological site, city park) can add layers of interesting information to the reality they see (for example, google maps layers). On the other hand, augmented reality brings improvements to the visit as a replacement for billboards that can interfere with the display in sensitive localities.

Innovations in the interpretation of museum exhibitions, such as the inclusion of educational and entertainment content, observation of objects from a different angle, time travel simulations that enable the return of historical memory or the facilitation of visits by people with disabilities. (Ghouaiel N., et. al., 2016, 21-31) Other authors add that different uses and scenarios for specific augmented reality, for example visualization of a 3D object, reconstruction, animations, make it possible to improve various factors of the tourist experience (attractions, news, motivation, security, suggestions). (Panou C., et. al., 2018, 59-67).

The development of artificial intelligence (AI) is closely related to augmented reality. AI models are very effective in performing tasks such as scanning objects, rooms, faces, as well as in creating informative content in different formats (video, sound, image, text). (Sahu C. K., Young C., Rai R., 2020, 4903-4959) However, augmented reality technology advances beyond the use of artificial intelligence to interpret sensor data. There are several important tasks that artificial intelligence fulfills to complement and enhance the AR experience:

- Creating realistic human models and scanning objects: artificial intelligence has helped AR to go from simple analysis of key points of a person's face to actually

reconstructing a face or other objects into a realistic appearance of a 3D model for use as an avatar or an asset used in a virtual environment (for example, the protector of the city as a tourist guide).

- Object detection and marking: sensors can recognize objects and mark them. This is useful for more than just identification, as virtual objects can be superimposed on real-world ones to facilitate AR interactions (for example, tagging famous historical buildings).
- Text recognition and translation: users can simply point their camera at informational text and have it translated in real time. The increasing development of generative AI models such as Chat-GPT indicates many possibilities for future use for augmented reality (for example, text translation in hospitality establishments). (Tiple B., et. al., 2024, 505-516)

6. Limits in the use of augmented reality in tourism

The great potentials involved in the tourism use of augmented reality imply certain risks associated with the use of this technology. In this case, we distinguish the following types of restrictions or risks. The first risk is related to the ability to last as long as the technology itself can last. All technologies have their life cycle, which can be longer or shorter, which can affect the sustainability of implementing a long-term business strategy in tourism. The reduction of costs and the appearance of new devices that integrate augmented reality such as Google Glass or Microsoft HoloLens, as well as the tendency to incorporate new features such as 360° views and the use of holograms, can guarantee the spread of this technology among consumers, but one should always keep in mind the risk of technological substitutions. (Santi G. M., et. al., 2021, 1-18) The speed of technological changes also represents a limitation when taking into account the temporal dynamics of tourism planning, which takes shape much more slowly.

Another limitation has to do with the usability characteristics of the technology itself, which especially applies to mobile devices (for example, the possibility of augmented reality software upgrades). Practical aspects such as signal availability, battery life, weight of the mobile device, screen reflection, price of mobile services (roaming) or lack of Wi-Fi zones can reduce the interest of users. (Li M., et. al., 2015, 278-286) Also, among the possible negative impacts of augmented reality on the tourist experience is the processing of large amounts of information that the tourist receives in different forms, which can confuse the user, as well as due to physical fatigue during more demanding interpretations, complicated use due to upgrading the application, dissatisfaction with the quality or inadequacy of the received content and ways of receiving information. (Chandra A. N. R., Jamiy F. E., 2019, 1269-1273)

A third component that can reduce the use of augmented reality is the human factor. Users have their own limitations and preferences on a cognitive and perceptual level. Personal aspects are crucial, and certainly influence the tourist's decision to continue using conventional means of supporting the tourist visit, such as classic guides, maps, plans, brochures, etc. For this reason, it is necessary in future business to personalize the use of augmented reality and take into account the differences between users (age, gender, origin, previous experience in the use of technology, etc.) before proposing elements of augmented reality for a tourist trip. Furthermore, the ability to recognize and interpret visual stimuli is not the same for everyone. As we do not all have the same ability to recognize and interpret received information stimuli, it is very important to prepare precise data, which will clearly and without overloading with information, meet the needs of the user.

7. Methodology

In researching the concept of augmented reality, we start from the perspective of the characteristics of the tourism industry. This new form of organization and implementation of tourist activities does not refer exclusively to the previously defined consumer orientation, but also to the consumer who is now actively involved in the tourism process using digital applications as a digital marketing tool. In the observed case, consumers are involved in the development of the product itself and can influence its design by adding the necessary content. The main point of sale is no longer the physical market but the online space, and online communication takes the first place in the activities of building relationships with consumers. In this case, the tourist's behavior shapes the tourist profile, which affects the very appearance of the application model. We observe the characteristics of the application used in augmented reality from the context of the user. The methodology used to create an augmented reality application for the tourism presentation in this study is a process approach to product development. This methodology has seven steps: application concept, application design, content collection, application development, application testing, application distribution and application upgrades. The purpose of using a phased approach is to make the augmented reality model easier to understand, design and implement.

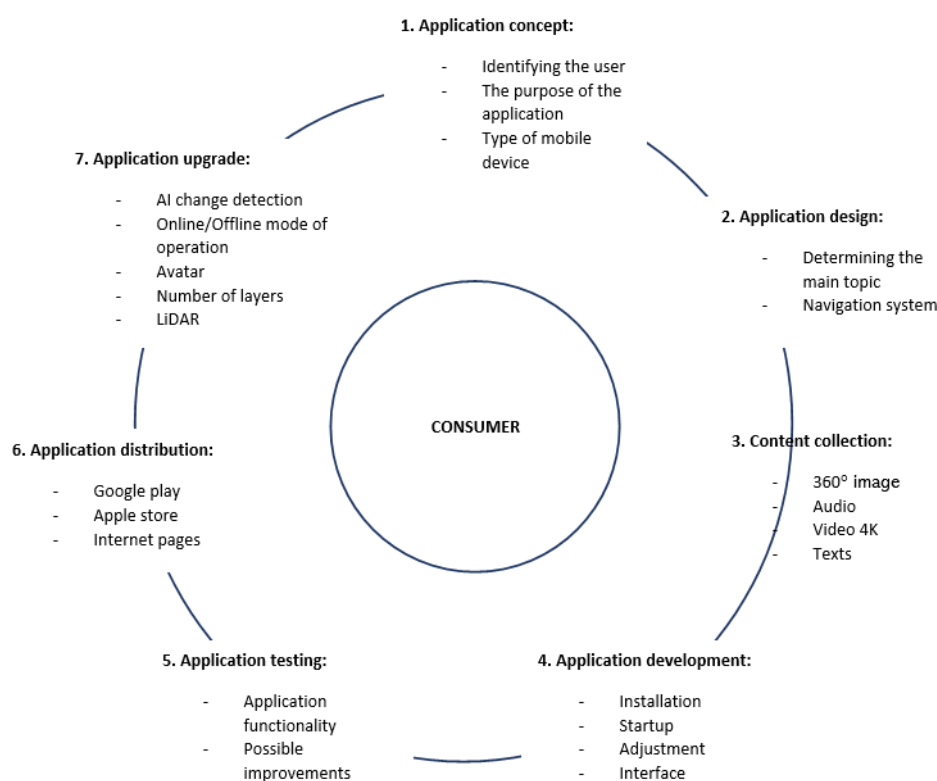


Figure 1 Augmented reality application development model. Source: According to the author of this paper

7.1. Application concept

In the conceptualization phase of the application, several activities are carried out, including the identification of the user and the purpose of the application, then the development of the concept, and the collection of materials that will be used in the augmented reality application. The activity of user identification includes the search for data sources, their collection and processing, and the presentation of information to tourists through an augmented reality application. In the

second activity, the purpose of the application is determined, which is to help tourists find out which tourist attractions are in the place they are visiting through education. In addition to the above, the application also enables travel agencies and cultural institutions to promote new content and other useful information (working hours, purchasing tickets, organization of tourist tours). In the third activity, the minimum software requirements on which the augmented reality application will be installed for devices based on the Android system and the Apple iOS system are determined. In the fourth activity, starting from the phase of user identification to the phase of determining the software platform of the device, the concept of the application is determined, and further direction in the development of the application is determined. When creating, it is necessary to choose a suitable program in which the application will be created. The concept of the application should contain an introductory page, menu, navigation, images, video, audio, tutorials.

7.2. Application design

In the design phase, the activities carried out relate to the design of the interface and navigation. To define the interface and action of each page in the application, designing the navigation is intended to describe the flow of each function of movement between the pages that are connected. Designing the structure of the interface and navigation provides a general description of the application for planning tourist activities. The design of the navigation structure in the application for getting to know tourist attractions includes the creation of the main menu and subcategories such as scanning, overview of tutorials, sound recordings and images.

7.3. Content collection

In this phase, it is necessary to collect materials in certain standard formats, such as images in jpg format, icons in png format, video in mp4 format and sound in mp3 format. The activities carried out in this phase refer to the search for content from internet sources and then their import into the application. Image processing activities provide further possibilities for the process of drawing and editing images. Audio addition activities in the application include the ability to add audio to each image display. In the activity of collecting video content, it is possible to add effects that emphasize or describe the video content. The aforementioned activities have the role of improving the user experience of tourists.

7.4. Application development

This phase consists of several steps that were previously carried out, starting with the application concept phase, application design, creating the interface, navigation structure and gathering information content. From each of the image, sound and video sources, it is collected into a unique entity that, through the use of software tools, creates content according to a predetermined design.

7.5. Application testing

In this phase, the application functions of each page are tested (navigation, interface, sound, video, scanner). If there is an error in one of the existing functions, the application will be corrected in accordance with the problems found. Test results are successful when all pages,

menu functionality and content navigation are tested. During testing, we obtain information about the functionality of the application by including a certain number of users in the test process. The result is feedback from each tester, on the basis of which further improvement of the application is carried out.

7.6. Application distribution

This phase represents a very important part, which consists of connecting previous activities into the final version of the application, which needs to be further distributed to users. The application is stored on the Internet services Google play, Apple store, and on the websites of tourist organizations. When downloading, we have to choose a file format that will be suitable for most mobile devices (for example, apk format).

7.7. Application upgrade

The integration of generative artificial intelligence (AI) with AR is expected to improve the creation of digital worlds, for example improving the display of works of art or the creation of realistic characters in the form of tourist guides. Another possibility concerns the application of sensory technology, including haptic gloves and devices that stimulate senses such as smell, to create more immersive experiences or LiDAR layers. The main trends of augmented reality are diverse and innovative, signaling significant technological progress and applications in the tourism industry. Connecting the physical and digital worlds will provide users with a new level of tourist experience, which is why it is already being used in many areas of digital marketing.

8. Conclusions

A review of the possibilities and limitations of using augmented reality as a tool to improve the tourist experience indicates the following. Augmented reality represents a creative technology with great possibilities of transforming the visitor's tourist experience in interaction with the elements of the tourist destination. Ways of interpreting the content that can be produced by augmented reality can directly affect the appeal to users which is further transmitted to other users through recommendations. Augmented reality represents a new form of communication with consumers, which is one form of digital marketing strategy based on new technologies. It can also be concluded that the application of augmented reality is increasing in parallel as technological tools are used for the purpose of tourism needs, and there is still a lot of room when it comes to improvements and solving obstacles that limit it in terms of technological, legal, functional adaptations. We can also conclude that augmented reality can play an important role in defining the competitiveness strategy of tourist destinations, which are based on the use of new digital technologies. As long as the improvements in terms of applicability and usefulness are evaluated adequately, to make an appropriate balance between costs and benefits and real effects, in that case there can be an increase in the quality of the offer of the tourism sector and, in parallel, the satisfaction of tourists.

The application of the concept of augmented reality in the presentation of tourist attractions can turn the virtual world into the real world, using interactive simulations in space, visualization using 3D objects accompanied by other information in the form of animation, sound, image or text. An application based on augmented reality enables the creation of a lasting user experience. Through interactive exchange and data collection, we can find out the opinions of tourists about tourist attractions, which can help in adjusting tourist promotion, targeting tourist attraction,

and facilitating the interactive finding of tourist attractions for tourists. This research aims to present the process of creating an application for getting to know tourism with the application of augmented reality technology. The paper uses the methodology of development in stages, which begins with determining the concept and design of the application. This is followed by the collection of material that will be used in the content presentation. When all the necessary materials are collected, the development and testing of the application follows. Finally, after the distribution of the application through computer services, it is possible to upgrade the application based on the previous experiences of the user. For further research, it can be recommended to add the feature of location detection as an accurate direction indicator, also the feature of visitor density information, increasing the interaction using artificial intelligence is needed.

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IN PURSUIT OF THE ECONOMICS OF HAPPINESS IN RURAL ENVIRONMENTS: THE ROLE OF CULTURAL ASSOCIATIONS IN THE ACHIEVEMENT OF SUSTAINABLE TOURISM

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Abstract. Post-pandemic tourism must consider a radical change in its strategy and objectives. It is necessary to go beyond assessing results based only on quantitative data to focus on qualitative ones that consider the destination, its residents and the achievement of triple-impact sustainability. In other words, to achieve what is known as the economics of happiness. All the agents involved in the tourist experience, therefore, must contribute to the achievement of a sustainable and responsible tourism, human in its approach and respectful of the heritage and traditions of the destination as well as its people. In this sense, cultural associations are a type of Social Economy organization that are proving to be a highly effective tool to achieve these objectives, especially in rural areas with a high risk of depopulation. The aim of this paper is to demonstrate that thanks to this type of associations, the tourist experience becomes a valuable asset, since the visitor will recommend it, and it also reverses the problem of depopulation through a triple impact sustainability. To demonstrate the value of a cultural association as a valuable tool for a rural community, a qualitative analysis has been carried out through personalized interviews with members of an association that has just celebrated its 20th anniversary, in a rural environment with high rates of depopulation. The achievements of this cultural association, which also promotes quality and responsible tourism, have resulted in a sustainable increase in economic activity; an increase in the population, which is no longer aging; greater social cohesion among residents; a rise in residents' self-esteem and sense of belonging; and the protection of the natural, cultural and historical heritage of the rural environment in which the association operates. The humanistic factor developed by cultural associations, especially in the field of tourism, leads to the economics of happiness, which fulfils triple impact sustainability. In the specific case of the association analysed here, the use of its model is being requested by regional governments, and even already replicated, in other parts of depopulated rural Spain.

Key words: *Economics of happiness, triple sustainability, cultural associations, tourism excellence*

1. Introduction

It is a recognised truism that money does not bring happiness and it may be added that this is a fact not only at a personal level but also for the residents of a tourist destination. The tourism activity can, and does, generate significant income for the community in which it takes place; however, a bad tourism policy can lead to the anti-tourism sentiment that began to stir just before COVID-19 and is brewing again, unfortunately. It seems that the period of mandatory worldwide confinement, in general, did not make the sector rethink what was not being properly managed. Focus has returned only on numbers (on international arrivals, overnight stays, expenditure) and on their fast growth to offset the losses from pandemic restrictions. In other words, the tourism policies that operated until 2019 and that led to the outbreaks of tourism-

phobia have been revived. Income is essential, and even more so in small rural towns where it is a fundamental pillar of the subsistence of their residents, but it is possible to combine economic sustainability with resident satisfaction in destination. In fact, the happiness economics can contribute to the wellbeing of a community.

In psychological terms, well-being or happiness is defined as experiencing positive emotions and relationships by developing personal potential and taking control of one's life. This makes individuals aware of their abilities, which, in turn, enables them to overcome life's stress, work productively, and contribute positively to their community (Ruggeri et al., 2020; Huppert, 2009; World Health Organization, 2001). Therefore, it can be concluded that achieving a well-being state implies, on the one hand, higher productivity, increased creativity, and more socially oriented behaviours. On the other hand, achieving better personal performance also leads to greater life satisfaction, which, in turn, leads to better economic performance at the national level or, as some authors call it, ecological economics (Isham et al., 2021). That is, to approach economic activity from a multidisciplinary approach in which economic governance that promotes human well-being, sustainability and justice is pursued. Increased productivity can have both a positive and a negative impact on a worker's well-being, which becomes a paradox: it increases the demand on the job (fewer workers doing more work), which becomes a precursor of job burnout; and it creates job insecurity due to the fear of losing one's job if the expectations set by management are not met. Therefore, economic progress should not be measured in terms of GDP growth or labour productivity but through indicators that focus on well-being and quality of life.

Successful economic development is also inconceivable without the implementation of ethics and social responsibility that permeates all layers of the corporate structure (Bocean et al., 2022). If workers are involved in socially responsible actions, their motivation, commitment and loyalty increase, thus generating an increase in productivity and also, a greater propensity to innovate, which is the definition per se of the social economy and of the world of co-operative enterprise in particular. This commitment and loyalty to the enterprise, as well as the values that it implements, become its brand identity and generate its own sustainability and that of its environment, contributing to the responsible development of a better world (Ravina-Ripoll et al., 2021; Harju et al., 2021; Iriarte & Musikanski, 2019). In addition, consumers are increasingly demanding more sustainable companies and products that are guided by ethical principles of environmental responsibility and decent work. Happiness management therefore becomes a strategic, innovative, and disruptive factor within Sustainable Development Goal 12 (Responsible Production and Consumption). It is not possible to disentangle the economics of happiness from the Sustainable Development Goals (SDGs) as there are clear intersections between the indices used to measure happiness levels and the SDG framework.

It is essential to ensure that tourists enjoy their experience and the value of the destination where they live so that they can understand the importance of protecting it, of its sustainability. In this sense, the *First Report on Tourists with Sustainable Values* (SAÓ, 2024) was recently carried out in Spain, for which an online survey of 2,665 people was conducted. The aim of this study was to check whether tourists are really aware of the value of each territory and the need to travel in a responsible way; what they understand by sustainable tourism; and their willingness to pay more for more responsible tourism. Some results are particularly noteworthy:

- 84.7% see sustainable tourism as a necessity that should always be fulfilled. What is most surprising is that young people do not indicate this premise as relevant (25% in the 18-34 age group).
- These types of experiences already exist in Spain. However, 45% would not know where to find them, which should lead to the reflection that suppliers are failing on

the one hand, and that the way in which these experiences are launched in the market should be improved, on the other.

- Spanish tourists do not consider sustainability as the main premise when organising a trip (only 18%) compared to factors such as location (35%) or quality of accommodation (26%), for example.
- 78% would not be willing to pay more for a trip or experience with sustainable values; only the bracket comprising the 35-54 age group (15%) would do so. However and here is the incongruity, they would be willing to pay more for organic food, with higher production costs. Some of the comments among respondents ranged from paying more just for quality, to the fact that it should be the norm without implying a higher price, or without making it a luxury trip.

In other words, tourists are not clear about what sustainability and responsible tourism are and what they imply. It is therefore the duty of the sector to develop an educational activity in this sense to ensure that quality, sustainability and responsibility are understood as a whole and to avoid possible misunderstandings once the tourist arrives at his destination, as is often the case.

If we assume that happiness is an inherent part of the tourism experience, the need to focus tourism destination, governance and tourism policy strategy in general, towards the achievement of all stakeholders' wellbeing at every level becomes apparent. Following this, the above concepts will be grounded in rural tourism to better understand their relevance. Then, reference will be made to the importance of cultural associations as cornerstones in achieving the happiness economics and the livelihood of rural communities. And finally, a case will be presented that has managed to combine triple-impact sustainability with sustainable tourism development, the community's livelihood, and the protection of its natural and cultural heritage.

2. Tourism and the protection of rurality

Rural environments are ideal settings for rest and, therefore, for achieving an optimal state of wellbeing. For this reason, they are a clear choice for those individuals who live in urban environments and in highly stressful situations. Moreover, this scenario increased exponentially after the suspension of confinement, as tourists were looking for open and healthy spaces. Thus, it is assumed that rurality is the gateway to positive experiences and wellbeing for visitors. This is why rural tourism becomes an important driver of health by bringing the tourist into direct contact with nature.

Happiness as a tourism strategy is a basic objective when promoting tourist destinations, as visitors are looking for experiences that make them feel good. However, in underdeveloped regions, as is often the case in rural destinations, it should be worked on as a medium and long-term strategy rather than looking for immediate results (Robina-Ramírez et al., 2023a; Leal-Solís & Robina-Ramírez, 2022; Sánchez-Oro et al., 2021a; Robina-Ramírez et al., 2023b; Lopes et al., 2023; Sánchez-Oro et al., 2021b). This is where residents play a major role if they actively promote and support the tourism experience. In this way, new visitors will be attracted to enjoy a memorable experience as well. Tourism planning thus becomes the key to satisfying the visitor, but also the community both economically and socially, by maintaining and respecting its cultural identity, its landscapes, its biological diversity, its historical heritage, and its traditions. In fact, in Spain there are cases where this planning has been a resounding failure, as it has set out strategic objectives that are appropriate for a developed territory, but not for a developing one, without, for example, solving such essential problems as accessibility. Another added problem is the political factor since, on too many occasions, initiatives are

attempted without the involvement of the real experts just for electoral gain, or only statistical and quantitative data on tourist supply and demand are considered. Therefore, the main objective should be the development of a tourism strategy designed by all the parties involved that seeks a sustainable benefit over time to consolidate the region as a tourist destination. The establishment of a relationship of trust between all parties is crucial for the creation of sustainable tourism, creating a real balance between society, the environment, and the economy. If this is fulfilled, tourism undoubtedly becomes a lifeline for less developed, typically rural regions in danger of depopulation.

It is essential to control tourism development as much as possible in order to avoid the indiscriminate growth that Spain has suffered since the mid-1960s, where the only aim was to generate income. However, it has ended up being a negative burden due to the overcrowding of certain areas, the deterioration of natural spaces, and the negative impact on residents, which has led them to turn against the tourist experience, with the consequences this implies for a sector that is so important for our country. It is clear that this model must change as the medium- and long-term implications are more than evident, i.e. loss of tourists and detriment to the economy. Rural tourism in Spain is widespread throughout the country and allows for diversification in these rural environments, as tourism has played a very important role as an alternative to traditional agricultural activities (Nieto Masot & Ríos Rodríguez, 2021). However, this can also be a problem as so much focus has been placed on this alternative opportunity that the primary sector has been neglected and, in fact, at national level it is disappearing in a worrying way. In addition, the State does not value the relevance of the sector, consequently the society does not value it either and, as a result, young people are not encouraged to develop their working life in the agro-food sector. This means that the effect that is intended as a palliative to depopulation may turn into its opposite, if young people continue to move to urban areas in search of a different life perspective.

3. Cultural associations and their relevance to triple impact sustainability

Culture is essential to the well-being and development of citizens for several reasons: i. it satisfies cultural identity; ii. it fosters community cohesion and a sense of belonging; iii. it contributes to the educational development of individuals; and iv. it facilitates the openness of societies through their participation and expression in cultural activities.

Cultural associations are entities belonging to the Social Economy. In Spain, they are a key player in the economy in the culture and leisure sector, where their weight in the total number of private companies reached 35.2% in 2023 (CEPES, 2024). Its great importance lies in the fact that the Social Economy contributes to social cohesion through:

- inclusive economic sustainability;
- the reduction of inequalities;
- higher levels of employment stability;
- lower wage disparities (wage levels are much more egalitarian);
- the relevance of the role of women and the reduction of inequalities compared to the market economy;
- a greater willingness to offer job opportunities to people with no previous work experience and, in particular, to those belonging to groups with low employability.

In terms of rurality, the Social Economy has a key role to play as it contributes to territorial cohesion by generating activity, employment, and the supply of services that are key in rural

areas. Its various entities are mostly located in municipalities with less than 40,000 inhabitants, show a higher concentration of entrepreneurship in intermediate cities and rural areas, their sectoral distribution favours the diversification of the rural economy, and improve the competitiveness of the rural economy as well as helping to halt depopulation thanks to a range of care and educational services. In conclusion, the principles and differential values of the Social Economy have translated in monetary terms into total benefits (direct and indirect) of 11,023 million euros, of which 46.9% is linked to the employment of groups with difficulties in accessing employment and 23.6% to greater employment stability.

Cultural associations are non-profit entities, although they can be beneficiaries of donations and private contributions, as stated in the Spanish Patronage Law. They are therefore the best way to access channels and services that would be out of reach for individuals. They consist of groups of citizens in pursuit of a common goal, i.e. the preservation, production, distribution, practice, or participation related to a cultural good or service. In the case of cultural objectives, they can certainly be part of the cultural offer in question. Consequently, these types of associations become an important backbone of the society in which they develop by adopting a liaison role between the needs and preferences of citizens and the actions to be implemented by cultural policies.

Considering that happiness is inherent to the tourist experience, cultural associations and their members become the cornerstone (Sanagustín-Fons et al., 2020). On the one hand, they represent the community in the destination and, therefore, have a very specific and real perception of what residents feel and think about tourists; on the other hand, they have a deep knowledge of the cultural heritage that they represent and, consequently, become a direct link and experience in relation to the tourism product. For this reason, in many cases, these associations carry out activities, performances, and exhibitions in the territory to which they belong and with its residents. In this way, they work to preserve both their tangible and intangible cultural heritage (myths, legends, traditions, etc.), but also, their natural heritage; at the same time, they make people become aware of their heritage wealth.

As far as tourism is concerned, cultural associations can become a valuable tool to avoid mass tourism, on the one hand, and to favour the deseasonality of the sector, on the other. However, it is important to take appropriate measures, both at public and private level. Despite the progress of rural tourism in Spain in recent years and political declarations, that are more related to electioneering than reality, the sector still has low productivity. It has not been able to work towards deseasonality, and in addition, it has a saturation of non-differentiated offers, which are sometimes poorly integrated with the activities that the environment can offer; its marketing tools are also very weak; and finally, associationism is still weak or emerging here, which makes co-operation and networking difficult. It would be necessary to target international markets in the off-season instead of always focusing on the domestic market, as in other countries, school and public holidays do not coincide with ours which could be an important option for the development of rural tourism throughout the year. It should not be overlooked that the international market generally has a longer average stay and, consequently, higher income, besides the fact that they tend to book well in advance, unlike the Spanish market, which is more prone to last-minute bookings. Therefore, a drastic new approach to rural tourism policies is required in order to focus on the search for quality and authenticity, which is what the international market is looking for.

In Latin America, for many years they have been aware of the power of associations in the development of community-based tourism as an essential pole to protect indigenous communities, their culture and traditions, that is, their survival as communities (Méndez-Pedroza & Vinasco-Guzmán, 2015). Through the development of SMEs, whether commercial

or cooperative in nature, the community becomes the owner of the tourism business; they are the main actors, developers, and beneficiaries. The income generated through tourism activities stays in the community and, in this way, the sustainability of the destination is perpetuated at all levels. However, it is essential to emphasize that this type of tourism requires a more exclusive, less crowded experience, more focused on emerging destinations. And what could be more emerging than a rurality ignored by public officers and, therefore, at risk of extinction.

International Rural Women's Day, an initiative launched by the UN in 2008, aims to highlight a vital segment of the population, as they make up a quarter of the world's population. In rural environments, women are fundamental since they grow most of the food that nourishes us and, consequently, they strengthen local economies and generate a certain resistance to climate change. They help to settle the population, prevent masculinisation and ageing, and drive economic diversification in the community. They are the most important defenders of natural and cultural, tangible, and intangible heritage (Riquelme-García, 2014; Sánchez-Muros & Jiménez, 2013). Historically, they have always adopted a key role as guardians of culture and traditions in their respective communities, even from pre-historic times. However, since the end of the 20th century, rural women in Spain began to abandon their places of origin and there was a feminisation of emigration. This is a trend that must be reversed because without them rurality will die. This is where cultural associations play a decisive role, as women take on a predominant position in them.

It is similarly essential to focus on young people as the guarantors of their community's future. Education is fundamental in this case and, more specifically, heritage education: the greater the knowledge of heritage, the greater the defence of it. One cannot respect and preserve what one does not know. Similarly, it is essential to make society at large understand that heritage can become a key economic asset for rural areas, provided it is properly structured, moving away from the concept of mass tourism that still prevails in the sector, even though the pandemic might have helped to change the paradigm. Perhaps that change may one day come from rurality. On the other hand, education in social values derived from an interest in history, identity and collective memory is promoted. This in turn leads to a closer bond between community members and therefore generates greater social cohesion, thus developing social sustainability, a key factor in any society. Again, cultural associations are decisive since they promote entrepreneurial initiatives, especially among young people, and become the breeding ground for the creation of small businesses, which, in many cases, work by and for the tourist activity derived from the very purpose of the association to which they belong.

4. A best practice case

Rural tourism in Spain is still consolidating its progression and thus, in 2022 there was an increase of 2% compared to the previous year (Observatorio del Turismo Rural, 2023). Expenditure is also maintained, which contributes to the local economy: 56% in restaurants, 26% in the retail of local products, 17% in leisure activities, and 1% in other types of activities. The profile of the rural tourist is still predominantly female (67%), aged between 40 and 64 (77%), and mainly in family mode (59%). Tourists continue to be predominantly national (96%) compared to 4% of foreign tourists, although there has been an increase of two points compared to 2021. Another encouraging result in this annual report is that at last rural tourism breaks are becoming deseasonalised with a greater distribution of travellers throughout the year, thus generating more sustained occupancy.

The good practice case presented below is located in a Spanish region with a very high rate of depopulation in rural areas. It is the autonomous community of Castilla y León (located in

the central plateau of the country) and, specifically, in a small village in the province of Soria, Garray, rich in natural and, above all, cultural heritage (the important Celtiberian archaeological site of Numantia is located there). For this reason, the different regional municipalities are devising various strategies to alleviate this situation. Proof of this is the data on travellers for the year 2023 (INE, 2024a), which shows an increase of 7.8%, more or less the same in all months of the year; in other words, there has been a clear reduction in the seasonal nature of tourism. With regard to the data on tourist accommodation, an increase of 4.2% is observed in the autonomous community.

Nevertheless, this was not always the case; in fact, the municipality of Garray had a census of 362 inhabitants in 1998, in a clear trend towards depopulation and, consequently, an ageing population. For this reason, 25 years ago, a group of women from the village set themselves the challenge of putting on a performance commemorating the battle of the Numantines against the Romans, in the face of the scepticism of many of the villagers and the support of the mayor and the director of the Numantia archaeological team. These same women created the costumes and clothing necessary for the performance, which achieved great social and media repercussions. This success justified the need to make these popular performances permanent, which have been held every summer since then and are free of charge. This led to the creation of a Celtiberian cultural association in 2003, of which the author of this article has been an active member since its inception and which has allowed her to monitor and analyse the results for 20 years. The association was created with the aim, through historical reconstruction, of establishing links between the scientific work of archaeologists at the site of Numantia and its didactic presentation, thus making a living past available to everyone, always with the utmost historical rigour and a focus on the dissemination and teaching of this common past. However, the most important objective was, and is, to reinvigorate the municipality, to create cohesion among its members, to develop a sense of belonging and, above all, pride in its historical roots, and to generate long-term triple impact sustainability.

At present, the association has 790 members (both residents of the village and from other parts of the province and the country), of which 66 are companies or legal entities and 724 are individuals; of the latter, 396 are men and 328 are women. The age range is as follows:

Table 1 Age range among members of the association

Between 0-20	Between 20-40	Between 40-60	Between 60-80	Between 80-100
71	152	272	190	39

The first thing that stands out is that there is no age segregation and that practically the whole village participates in the activities carried out through the association, from babies to people over 90 years of age, both as individuals and as entire families.

On the other hand, the association moves half a million euros every year in cultural projects. In addition, it has a staff of around twenty workers, financed by institutions and a hundred companies, aged between 20 and 50. In other words, it attracts wealth to the town and generates employment among its young people and among those with problems of access to employment.

The tourist seeks an integrative experience at destination. To achieve this, direct and genuine contact with the resident is essential, which, on the other hand, implies a sensitivity of the visitor towards the culture and particular way of life of the receiving community. In addition, in the case subject of analysis, this is the fact because it is the villagers themselves who become the creators, developers, owners, and promoters of the tourist activity; and, moreover, they receive the visitor in person. Here it is not possible to find companies from outside the village that develop an economic activity, nor actors or similar that carry out the historical re-enactments

and other activities. The association was clear from the beginning that all actions would be by and for the people of Garray; and this has been the case to date.

The main activities of the association can be grouped into five main blocks:

1. Popular performances in Garray, in which an episode of the Numantine Wars is re-enacted every year, with limited seating capacity (about 5,000 people) and free.
2. Didactic performances, whose aim is to disseminate Celtiberian culture by showing daily life in Numantia; how they dressed, worked and fed; rituals; war preparation and tactics; and funerary rites. All of them are made solely and exclusively by the members, with the utmost historical rigour thanks to the collaboration of the director of the archaeological site and the member archaeologists. They take place all over Spain and are always free of charge for the public.
3. Re-enactment days at the archaeological site, where members become authentic Numantines, bringing the streets, houses and corners of Numantia back to life. In this way, visitors to the archaeological site are immersed to the Numantia of the 2nd century BC while receiving explanations from archaeological guides.
4. Celebration of *Samain* from the archaeological site, the Celtic predecessor of today's Halloween, which took place as a great feast before their gods under the light of the full moon and in front of large bonfires to scare away evil spirits. Visitors can take part in this celebration free of charge. In addition, since 2023 it has taken on an international character as it is celebrated together with invited Celtic groups from Brittany, Ireland and Scotland, accompanied by their folklore and gastronomy.
5. Guided tours of the archaeological site, at a cost of €5. Revenues are re-invested in the preservation of the site and the archaeological excavation work. It is very important to emphasise that a primary objective of the association has always been to control the carrying capacity of the site and, consequently, of the village in which it is located. For this reason, only guided and pre-arranged visits are allowed in order to control the number of visitors and the care of the historical heritage. In 2023, over 40,000 people visited Numantia, thus benefiting the accommodation and hotel industry, as it is necessary to go through the centre of the village to get to the site.

In order to confirm the hypothesis that the association has been an important incentive for the social cohesion and sense of belonging of the residents, in December 2023 personalised interviews were carried out with a representative group of members, 33 people in total. The interviewee's profile is summarised as follows:

Table 2 Survey Factsheet

Age bracket	<ul style="list-style-type: none"> ▪ 51.5% between 51-80 years ▪ 48.5% between 20-50 years
Place of residence	<ul style="list-style-type: none"> ▪ 54.5% in Garray ▪ 15.2% in the province of Soria ▪ 30.3% in the rest of Spain
Membership length	<ul style="list-style-type: none"> ▪ 54.5% between 15-20 years ▪ 15.2% between 10-15 years ▪ 30.4% less than 10 years
Active participation	<ul style="list-style-type: none"> ▪ 75.8% always or regularly ▪ 12.1% sometimes ▪ 3% hardly ever ▪ 9.1% never

Participation is particularly important as it means the survival of any association. It is therefore clear that this association is in good health. The last percentage indicated does not refer to people who are not involved in any way but to members who probably live outside this geographical area and therefore their collaboration is residual, e.g. as members of the public attending the various activities, disseminators of the association and its work, or even researchers. However, here, active participation is associated with the fact of characterising oneself as Numantine or Roman for the different events, hence, they do not consider their involvement from their places of origin as active participation.

The second block of questions focused specifically on what belonging to the association has meant to them. The results were as follows:

- 100% agreed that belonging to the association makes them feel part of a community.
- 100% agreed that belonging to the association has helped them get to know their Celtiberian past.
- 100% agreed that belonging to the association has helped them develop a sense of pride in their Celtiberian past.
- 100% agreed that belonging to the association has generated a greater cohesion between the residents of Garray and its surroundings.
- 100% consider that the association has been relevant in the economic development of Garray.
- 80% consider that the association has been relevant in the attraction and retention of young residents and families in Garray.

Therefore, it is confirmed that the association has indeed generated a greater sense of belonging to the community, social cohesion, self-esteem, and pride in their roots.

The results of the 20 years of existence of this association are described below in social and demographic terms (INE, 2024b) and also in economic terms (Registro de Turismo de Castilla y León, 2024):

- **Number of inhabitants:** since 1998, the population has increased by 112%. In 2023, moreover, there is a beginning of a trend towards the de-masculinization of the territory, since in the under-18 age group (17.7%), 54.5% are female youth for the first time. On the other hand, the widest range (66.5%) is between 18 and 65 years of age, a very important figure because it represents the active population; and only 15.8% are over 65 years of age. In other words, the phenomenon of an ageing population has finally been reversed.
- **Population vegetative growth:** the following graph shows how there has been a progressive increase in the number of births and, therefore, in the rejuvenation of the municipality:

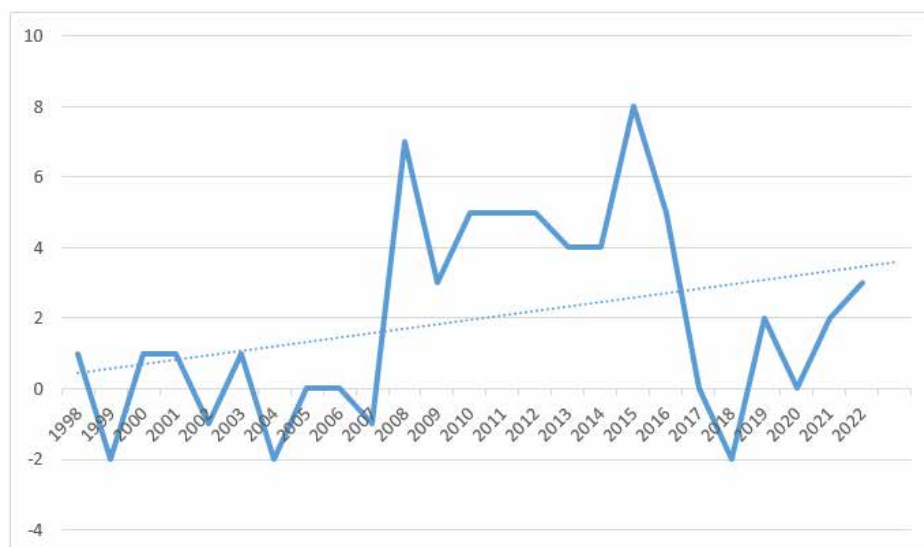


Figure 1 Population vegetative growth

The highest number of births takes place in the period of consolidation of the association and the development of its historical tourist activities; this is also the time when there is the greatest movement of settlement of young families in search of a better life, economically, familiarly and socially.

- **Business activity:** from 2003 to 2023, there has been a vertiginous increase of almost 1,100% in the creation of companies with a registered name in Garray, i.e. from 6 companies to 65 in a municipality of 767 inhabitants. All of them base their activity around the development of the association and, consequently, the services that the population needs to cover, for both residents and visitors, i.e. companies in the agro-food sector, retailing, and services. In the latter, a distinction is made between general services, such as a pharmacy, plumbing, electricity, etc.; and tourist services, which have increased by 1,200% in the period analysed, 55.4% of the total, distributed as follows:

Table 3 Tourist businesses

Accommodation	Bars and restaurants	Leisure and adventure activities
18	10	8

Before 2003 there were only 3 businesses related to tourism and the hotel and catering industry. In other words, 91.7% of the businesses shown in the table are the result of the entrepreneurial activity of young people, both residents and those who decided to settle in the town in view of the opportunities it offered for the future.

This social and economic success has led to other equally important results, which are listed below:

- An exhaustive and sustained educational work carried out in the schools of the area, as well as at the archaeological site, to educate children and young people in the value of their historical and heritage roots.
- Intense research work and its dissemination in publications and at national and international conferences by archaeologists who are members of the association.
- The Spanish Ministry of Culture has placed its Heritage department at the disposal of the association to collaborate in the defence of the archaeological site of Numantia;

and almost from the beginning, it has handed over to the association all the work related to visits to the site and, therefore, also the responsibility for its conservation and defence.

- In 2018, for the commemoration of the 2150th anniversary of the episodes of the Roman and Celtiberian wars in Numantia, the Spanish Ministry of Culture declared this event of public interest; this meant fiscal aid to the companies that collaborated in its organisation. On the other hand, the fact that His Majesty, King Felipe VI, accepted the invitation of the association to be Honorary President of this event was of exceptional relevance. All this contributed to the municipal campaign to promote the area and led to a significant increase in visitors (28%) throughout the year.
- Last October, the association received the award in the category *Promotion of Culture and Tradition* at the Castilla y León Awards, which are held annually by the regional government.
- During 2023, several activities have been developed for the presentation of the association's model as well as advisory services in other municipalities at risk of depopulation, both within the province and in other Spanish regions, always completely free of charge. Therefore, the association has become a paradigm to be transferred for the common good.

5. Conclusions

According to popular saying, money does not bring happiness, but it helps. This is where the economics of happiness comes into play to highlight the importance of the economic sustainability of municipalities, but also social and environmental sustainability. These are the three legs to the happiness system, so if one is removed, the system collapses.

In terms of tourism, happiness is undeniably a key factor when it comes to living a tourist experience. This is constantly being highlighted and, in fact, the Madrid Hotel Business Association has recently launched the fourth edition of the *Travelling for Happiness* awards, whose aim is to recognise the sector's best practices in the areas of sustainability and corporate responsibility, both nationally and internationally. These awards consist of four categories: 1. sustainable gastronomy; 2. responsible wellbeing; 3. regenerative tourism; 4. conscious culture and art; 5. sustainable leadership; 6. decarbonisation; and 7. social impact. As a result, it can be stated that the economics of happiness is finally emerging in the tourism sector.

Where it is of utmost importance to ensure triple-impact sustainability is in rural areas, generally in serious danger of depopulation now. If economic and environmental sustainability are fundamental for the survival of destinations, social sustainability is no less so. This is where one of the entities of the Social Economy plays a key role, i.e. the cultural associations. Their aim is to strengthen economic sustainability, protect the natural and cultural heritage, as well as customs and traditions, and consolidate the community by reinforcing the cohesion of its members which, in turn, leads to an increase in their feeling of belonging and, consequently, in their self-esteem. In this sense, the aim of this paper has been to present a case of good practice that has been analysed for 20 years and which confirms the effectiveness of cultural associations in protecting rurality by putting the economics of happiness into effect. A description has been given of how the creation of such an association in a tiny rural village in central Spain has succeeded in reversing the phenomenon of depopulation based on a historical heritage of great importance in the country, such as the archaeological site of Numantia, placed at the service of visitors and tourists. This long period has brought enormous prosperity to the village, which can be summarised as follows:

- A surge in the number of SMEs with registered offices in the municipality and which, therefore, generate income for and from the village.
- A significant increase in the population, with the settlement of young families and the beginning of a de-masculinization of the population, which has been noticeable recently.
- A remarkable sense of belonging to the community, of pride in their roots, of self-esteem and cohesion among residents thanks to their participation in the conception, design, development and implementation of the various historical recreation activities that they carry out inside and outside their geographical area.
- Intense work to protect and disseminate their archaeological heritage, both at an educational level in schools to raise awareness among children of its value, and at a scientific level in the fields of archaeology and history.

Triple-impact sustainability has been established and will continue to be so by ensuring the carrying capacity of the site and the village itself from the very creation of the association. Therefore, what is sought is a quality tourist who appreciates the value of the heritage on offer, the traditions, customs and gastronomy that can be enjoyed, and a personal experience of history alongside the protagonist residents. All this would be impossible within a mass tourism model, which, unfortunately, is still all too prevalent in the most renowned tourist destinations, especially in the sun and beach segment. Such a model can only mean bread for today and hunger for tomorrow, as the saying goes; until the sector is truly aware of this, real sustainability will continue to be undermined.

Therefore, cultural associations can undoubtedly be beneficial for all parties involved, for the destination and its inhabitants, for the defence of cultural and historical as well as natural heritage, and as a result, for the development of excellence in the tourism experience.

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SOCIALLY RESPONSIBLE MARKETING IN THE COSMETICS INDUSTRY

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Abstract: Socially responsible marketing has become an increasingly important aspect of modern business as companies seek to align their operations with societal expectations and values. This shift towards more socially conscious business practices has been driven by various factors, including changing consumer attitudes and expectations and heightened awareness of environmental and social issues. One industry that has been actively embracing this trend is the cosmetics industry, which must meet evolving customer expectations to remain competitive. This paper explores the concept of socially responsible marketing in the cosmetics industry and demonstrates how companies in this sector adapt to new business challenges and changing societal norms. The paper discusses the role of social performance reporting in the cosmetics industry. It highlights the importance of measuring and reporting companies' impact on all aspects of society, including economic, social, and environmental. This is critical for companies to demonstrate their commitment to socially responsible practices and ensure that their operations are truly sustainable in the long term. The paper also provides valuable lessons for researchers and practitioners. It offers a roadmap for other companies looking to develop more sustainable and socially conscious business models. It brings several valuable insights for researchers interested in socially responsible marketing and the cosmetics industry. Researchers can gain valuable insights into successful strategies and potential challenges associated with implementing socially responsible marketing initiatives by investigating how specific companies in the cosmetics industry adapt to these changes.

Keywords: *socially responsible marketing, cosmetics industry, corporate-social marketing, consumers*

1. Introduction

The historical, social, and environmental problems contemporary society faces, especially in the last 20 years, have resulted in developing ideas and concepts of socially responsible business. Socially responsible business is a concept related to the application of business activities that affect the main stakeholders of business processes and the broader environment in which the company operates. The idea of socially responsible business has expanded due to the increased number of educated and aware consumers and the development of information technologies. In current marketplaces, Corporate Social Responsibility (CSR) is a new expectation to be fulfilled by organisations to build a positive reputation and signal their stakeholders. In this respect, analysis of the consequences of perceived firms' responsibility on consumer behaviour

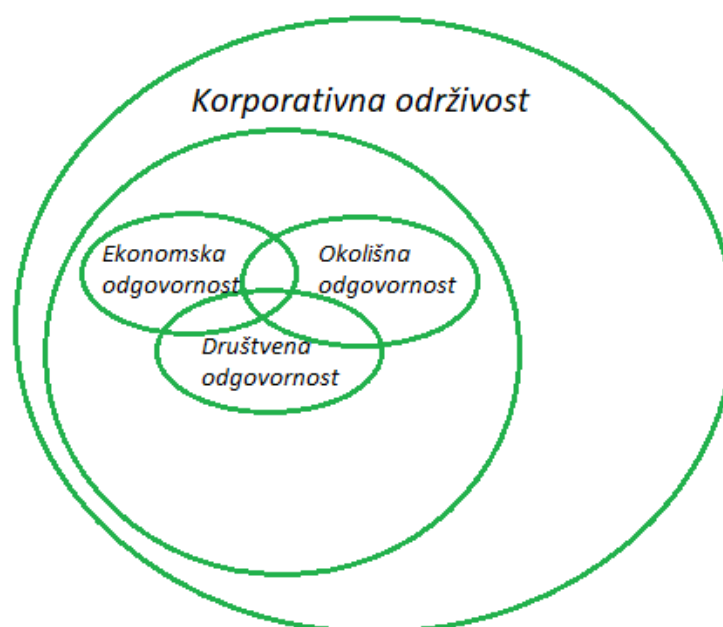
(Green & Peloza, 2014; Salmones et al., 2009) has been a common topic in recent marketing literature. Moreover, significant evidence indicates a positive link between involvement in social and environmental causes and consumer goodwill towards firms and brands (Chernev & Blair, 2015). Social responsibility in business has become a key concern for companies worldwide. With consumers becoming increasingly aware of environmental and social issues and demanding more from the companies they buy from, businesses are under growing pressure to operate responsibly and sustainably. Social responsibility in business concerns a company's impact on society and the environment (Benoit-Moreau & Parguel, 2011). It encompasses many initiatives and practices to promote sustainability, fairness, and accountability. One aspect of social responsibility in business is social responsibility marketing, which involves communicating a company's commitment to responsible business practices to its customers and stakeholders. This type of marketing aims to build brand reputation and customer loyalty by demonstrating that a company is accountable and ethical in its operations. Companies engage in social responsibility marketing for various reasons (Brønn & Vrioni, 2001), including increased customer engagement and loyalty, enhanced reputation and brand image, and improved employee morale and engagement. Research in the cosmetics industry has shown that socially responsible marketing can positively impact consumer behaviour (Vázquez-Burguete, 2017). This is particularly evident in the case of The Body Shop in Pakistan, where consumers are aware of the brand's corporate social responsibility practices (Hasan, 2018). Findings of the study reveal that most of the consumers of The Body Shop in Pakistan know that the brand follows CSR as its vital business function. Implementing socially responsible marketing, which focuses on sustainable development and social values, can enhance the competitiveness of businesses (Rybina, 2020). Vázquez-Burguete et al. (2017) found that young consumers displayed a lower consideration of responsibility criteria in their purchase decisions. In contrast, the 51–75 age group pointed to an overall lack of knowledge about them. Additionally, women, in contrast to men, tend to be more responsibility-conscious when acquiring cosmetics. Socially responsible marketing is a concept of marketing management. Although socially responsible marketing is a way to increase the competitiveness of business entities, the tools of socially responsible marketing are broader than classical marketing and include marketing, consumer research, and the study of social and environmental consequences of the production and consumption of manufactured goods and services. Organisations that adopt the societal marketing concept will most likely make long-term profits and benefit society (Abratt & Sacks, 1988). Authors like A. Sahota (2014) have investigated sustainability as a leading force in the cosmetics and personal care industry. He found that rising ethical consumerism and the need for resource efficiency are making cosmetic companies -from small, independent firms to global giants -take steps towards sustainable development. He explores the concept of social responsibility in business and social responsibility marketing, drawing on the insights and perspectives of leading researchers and practitioners in this field. The importance of socially responsible business in the cosmetics industry is reflected in many cosmetic products containing ingredients that can hurt the human body. Among other things, many cosmetic products are tested on animals. This work shows the application of socially responsible marketing in three cosmetic companies. The purpose and goal of the article is to show the practical methods of socially responsible business.

In the following sections, the authors delve deeper into the concept of social responsibility in business, including its evolution, importance and impact on companies, customers, and society. We will also explore the various practices and initiatives that companies engage in as part of their social responsibility efforts and examine the role of social responsibility marketing in promoting responsible business practices.

1.1. Conceptual definition of socially responsible business

“Socially responsible business is a business concept based on the business entity’s concern for its impact on society and the environment.” Such business has a positive impact on society and the environment. The concept of socially responsible business began to develop in the second half of the 20th century when people’s concern for a better quality of life arose. A significant work in creating this topic is Rachel Carson’s *Silent Spring* (1962), which discusses the harmful use of pesticides and herbicides. The paper describes the destructive impact of the uncontrolled use of pesticides and herbicides on the environment. Among other things, the author cites the adverse effects of industrialisation on people’s health. Since that time, many authors have written and published on this topic. “Socially responsible business becomes a mandatory business policy, and managers are encouraged to make decisions and follow desirable guidelines to achieve higher goals and common values of society.” Today, socially responsible business is a widely accepted concept. The European Union has published a series of documents encouraging the application of socially responsible businesses to organise business organisations. However, most often, due to insufficient education, many managers fail to apply the concepts of socially responsible business and take an active role in the concept above. “For this reason, socially responsible business implies strategic planning and investment in long-term prosperity; since applying socially responsible business, the company’s reputation grows, employee motivation, better working environment, better acceptance of the company by the environment, which ultimately brings a long-term return on investment.” By accepting the principle of social responsibility, a Slovenian company accepts the obligation to make decisions based on a systematic approach that does not only take into account the factors essential for gaining profit but also deals with ongoing issues such as sustainability, human rights, and long-term social and environmental prosperity.” Thus, socially responsible businesses play a significant role in contributing to the long-term sustainability of developing companies.

Figure 1 Relationship between corporate sustainability and corporate social responsibility



Source: Matešić, M., et al. (2016), according to data from Marrewijk (2003).

The example of Figure 1 shows the interdependence between the terms sustainability and responsibility. The concept of corporate sustainability is superior to the concept of social responsibility, but it is also closely related to them. Maintaining corporate sustainability is possible by assuming the company’s economic, environmental, and social responsibility.

1.1.1. Advantages of implementing social responsibility within the company

The application and importance of socially responsible business and behaviour have grown in the last ten years. An increasing number of companies are integrating social responsibility into their operations to improve their reputation in the community, increase their competitive advantage and achieve long-term sustainable development. Applying the mentioned activities leads to developing products and services that have increased productivity and improved quality of life. Companies organise their operations in such a way as to minimise their impact on the environment. For example, more rational use of resources reduces the environmental impact. Reducing waste through separate waste collection and recycling reduces the company's costs. Companies that do not invest resources in improving socially responsible businesses face pressure and condemnation from the public and executive and legislative authorities. Implementing social responsibility contributes to attracting and preserving a quality workforce of exceptionally skilled and highly educated workers. This concept also affects the company's market value because the implementation of socially responsible business is considered an expression of the quality of company management.

1.2. Conceptual definition of socially responsible marketing

“Social responsibility” is defined as “intelligent and objective concern for the well-being of society that limits the behaviour of individuals and corporations from extremely destructive activities, regardless of how quickly they are profitable and leads in the direction of positive contributions to the well-being of people, which can be defined in different ways.” Due to the increasing impact of business activities on the environment, there was a need to change the existing marketing theories and concepts. The above resulted in significant changes that were a response to the current business challenges of modern society. New terms such as “social marketing”, “micro marketing”, and “quality-of-life marketing” (QOL marketing) have begun to be associated with the term marketing. The mentioned terms are aimed at improving the quality of life, environmental protection and social responsibility. Social responsibility has an increasing influence on the making of managerial business decisions. “Socially responsible marketing appears to respond to numerous criticisms addressed to the marketing profession. Criticisms are related to three important segments in which marketing impacts consumers, competitors, and wider society. “ Business marketing decisions are increasingly based on ethical principles. Socially responsible marketing directly includes the social responsibility of the marketer. This responsibility can be divided into three categories: responsibility towards the public, responsibility towards meeting the set environmental requirements, and responsibility towards employees, participants in sales channels, shareholders, and competitors. “ Today, before the production of its products, almost every company thinks about the positive and negative effects of production on society. Social marketing assumes that the company's task is to determine the needs, wishes, and interests of the target markets and fulfil them more efficiently than the competition in a way that protects or improves the overall betterment of consumers and society. “ Today, marketing activities increasingly use the quality of life marketing philosophy. It represents “a business mechanism that plans, determines prices, promotes, and distributes economic goods to consumers in such a way as to ensure their greatest possible well-being.” This term implies the development of products and services that will benefit consumers in all spheres of their lives without any negative consequences.

1.3. Socially responsible marketing in the cosmetics industry

Consumers and customers in the cosmetics industry are susceptible to the marketing activities of the companies whose products they consume since they directly affect their organisms. Consumers are concerned about how these products affect their health, the health and safety of their loved ones, and the environment. Many companies declare themselves ethical and socially responsible, but this is not the case. Companies compete for the highest possible profit in a highly competitive market, often neglecting ethical behaviour and morals in business". The modern cosmetics industry is characterised by continuous technological progress and innovation. Manufacturers follow current trends by trying to meet the specific needs of smaller market segments by adapting their marketing efforts. This strategy allows them to form higher prices than usual. In 2020, significant trend changes in the cosmetics industry took place. The pandemic and mandatory mask-wearing resulted in a decrease in the purchase of cosmetic products. On the other hand, there has been a boom in online sales, especially of perfumes. Perfumes proved to be the product with the most significant resistance to the crisis. New technologies in production and packaging represent the biggest trends in the cosmetics industry. The cosmetics industry is subject to change. Cosmetics are not only used by women but increasingly by men as well. More and more brands are creating products based on a formula for men. "Increasingly, individualised approaches and personalised cosmetics are in focus. With sales through pharmacy channels, such an approach is expected to increase with pharmacists' advice as experts. The pandemic has increased sales of products for hand care and hygiene. One of the trends in the growth of consumer awareness of the impact of cosmetic products on environmental pollution is the most crucial trend in the cosmetic industry that will affect its further development.

1.4. Marketing activities in the cosmetics industry

In the last few decades, ecological and morally acceptable cosmetics have gained more and more importance in cosmetics. The number of consumers interested in buying and using such products is increasing, and more and more companies are introducing products produced naturally into their range. The new generation of the so-called "blue beauty" is also considered pure cosmetics, which refers to cosmetics that aim to preserve the seas and oceans. There are numerous companies that, before launching their new products, have researched each target group of consumers and adapted their advertising strategy to it. Today, cosmetic products are most often promoted through influencer marketing. The most popular social network for this purpose is Instagram. Instagram is primarily a visual medium through which it is possible to direct marketing efforts to the desired audience. Furthermore, one of the growing trends in packaging made from recycled materials is reducing the negative environmental impact. In addition, manufacturers avoid using questionable ingredients, but natural ingredients are encouraged to make the product as safe as possible for human health. All of the above led to the natural look trend that started in 2019 and continues today.

1.4.1. Testing cosmetic on animals

Although animal testing of cosmetic products has been banned in the EU since 2013, this does not prevent certain manufacturers from using this testing method. "Each year, approximately 35,000 animals in Europe and millions worldwide are exposed to intense suffering from questionable tests of cosmetic products or their ingredients." Furthermore, research has shown that consumers of cosmetic products are sensitive to animal testing and vehemently oppose it.

The socially responsible business practices on the example of selected companies from the cosmetics industry

How cosmetic brands implement their corporate social responsibility and their role in assuming responsibility will be analysed below through the examples of the brands of L'Oreal, Beiersdorf and Coty Inc.

L'Oreal is a leading cosmetic brand and the largest cosmetic company in the world, headquartered in Paris. It operates in more than 150 countries around the world. Eugene Schueller, a French chemist of German origin, founded the company in 1909. L'Oreal has branches in New York, Montreal, Melbourne, Copenhagen, and Düsseldorf. It employs 72,637 workers, of which 67% are women and 33% are men. "L'Oréal's mission is to offer women and men worldwide the best cosmetic innovations in quality, efficiency and safety." The L'Oréal company shows particular concern for human resources, as well as the company's employees". The main sustainability commitments for 2030 are presented in the "L'Oreal for the Future" program, which defines the company's vision, purpose and responsibilities in the fight against the challenges facing the world. The company strives to carry out activities that respect the so-called "planetary boundaries", i.e. the preservation of Planet Earth.



Figure 4. Commitments for 2030 L'Oreal

Source: <https://www.loreal.com/en/commitments-and-responsibilities/for-the-planet/> (downloaded on 07.05.2022)

L'Oreal sets measurable goals for 2030 in terms of climate, water, biodiversity and natural resources to meet the needs of the Planet, as shown in Figure 4.

There are different ways in which the L'Oreal company promotes sustainability:

- Fight against climate change – for more than 20 years, L'Oreal has been working to reduce CO2 emissions. This was achieved by improving energy efficiency in business buildings and by increasing the use of local renewable energy sources. Since 2005, CO2 emissions in plants and distribution centres have been reduced by 87%. Production volume has increased by 37% in the same period. Also, at the end of 2021, L'Oreal had 100 carbon-neutral locations, including 25 factories.
- Sustainable water management – L'Oreal is committed to contributing to high water quality and sustainable water quantity throughout its value chain. The company reduced the amount of water used in plants and distribution centres by 53% per product compared to 2005. In addition, six are "water loop factories," meaning that all water is withdrawn, recycled, and reused. Reducing the amount of water needed to use cosmetic products has two goals: fighting and adapting to climate change. For this reason, L'Oreal teamed up with Gjosa, a company for innovation in environmental protection, and introduced L'Oreal Water Saver in January 2021.
- Respect for biological diversity: L'Oreal strives to preserve biodiversity through its activities. In its operations, it uses about 1,717 raw materials and almost 313 types of plants, which is why biological diversity is essential in realising innovations.

“In the product procurement phase, sustainable raw materials are used to reduce environmental impact. Using raw materials of plant origin respects the principles of protection of biological diversity and the production of artificial substances and is connected with the principles of green chemistry”.

The company points out that they currently use 94% of ingredients based on natural formulas from sustainable sources, none of which are linked to deforestation. The plan is to raise that percentage to 100% by 2030.” In addition, the company is investing efforts in protecting biological diversity along the entire value chain.

The long-term goals for the conservation of natural resources until 2030 are listed below:

- 95% of the ingredients in the formula will be biologically based, obtained from minerals or circular processes,
- 100% of the plastic used in the packaging will be from recycled or biological sources,
- the amount of packaging will be reduced by 20% compared to 2019,
- 100% of plastic packaging can be reused or recycled,
- 100% of the new displays will be ecologically designed, and 100% of the new freestanding stores will be designed and built by the principles of sustainability,
- 100% of waste will be recycled or reused

L’Oreal, in addition to currently taking care of socially responsible businesses, also invests significant efforts in activities that protect the environment and the community.

For beauty without animal testing - the emphasis of the entire business is on the well-being of animals, and reconstructed human skin has been used for product testing for more than 40 years, on which the behaviour of cosmetic ingredients can be monitored. New methods and technologies unrelated to animals are used for various tests.

The L’Oreal company regularly informs customers about new activities on its official Instagram page. Thus, in June 2022, it was announced that the face of the brand, the singer Camila Cabello, spoke about her commitment to the fight against climate change. In addition, six ecological projects supported by L’Oreal have been presented that fight against deforestation and protect biodiversity while improving the quality of life among local communities, especially women. By 2025, it is planned to invest 10 million euros in environmental projects under the slogan “#Ourplanetisworthit”.

The followers’ comments on this social network are incredibly optimistic, which shows how well the users have accepted this way of investing in the community.

Some user statements are as follows: “I did not know this. I love how Camila is an amazing advocate for our Planet’s sustainability. It is great to see a big brand like L’Oreal taking our Planet’s well-being seriously and doing its part in the fight against climate change. No wonder Camila loves working with L’Oreal, and it makes me proud to support her and this brand”. (User: gorgan_rozitarayeshi)

“Camila Cabello is inspiring when she talks about the Caribbean forest in Zimbabwe. A wonderful project protects biological diversity and wild animals”. (User: trumanleanne2)

“I love the environmental projects that L’Oreal supports, and I would like to talk more about it and raise awareness. I support you and your efforts.” (User: manisha_anand)

The above examples show the significant investments and efforts of the L’Oreal company in the community and the environment in which it operates. Consumers have recognised and appreciated the implementation of socially responsible businesses, which is why L’Oreal has been a positive example of corporate social responsibility performance for years.

2.2. Beiersdorf

Beiersdorf is a cosmetics company recognised worldwide. Innovative products as a result of research expertise are the main advantages of this company. The company has been present on the market for many years. Indeed, its most famous brand is NIVEA. “Nivea is one of the world’s largest skincare brands, whose products are available in 173 countries around the world.” The company’s headquarters are in Germany, and the company’s name is a derivative of the Latin words nix (snow) and nivis (snowy). The company produces body care products such as shampoos, facial cleansers, shaving creams, and tanning oils. Today, the company has an international team of 1,290 scientists who use discoveries to improve existing and create new skin care products. The Beiersdorf company cares about environmental protection and applies a socially responsible business policy. Their slogan reads: “One skin. One Planet. One care.” With this slogan, they say that healthy and beautiful skin can only be achieved by taking care of the environment. One of the ways they try to accomplish this is by reducing the CO2 footprint in products.



Figure 6. Beiersdorf company values

Source: <https://www.nivea.hr/o-nama/one-skin-one-planet-one-care/nase-obaveze> (downloaded: 08.05.2022)

The Beiersdorf company invests significant efforts in the fight against climate change by reducing CO2 emissions and saving energy in the entire value chain, as shown in Figure 6.

The company’s goals are:

- absolute reduction of total value chain emissions by 30% by 2025,
- climate-neutral business until 2030.
- production of climate-neutralized products.

The company tries to harmonise its production processes with the environment by using environmentally friendly formulas and biodegradable substitute raw materials.

The goals in this area are:

- NIVEA products without microplastics by the end of 2021 and EU formulas containing only biodegradable polymers by the end of 2025.

One of the current activities is reducing the use of plastic in product packaging. It is common knowledge how long plastic packaging takes to break down and how much plastic damages the environment. Considering the above, socially responsible companies strive to minimise the use of plastic in their production. Preference is always given to packaging that can be reused or recycled, which is why more and more consumers are choosing this type of packaging. In the world, there is a visible trend of increasing awareness of the harmfulness of plastic packaging among both consumers and producers.

The goals for reducing the use of plastic packaging in the company are:

- reduction of pure fossil-based plastic by 50% by 2025,
- 30% of recycled materials in plastic packaging by 2025,
- reduction of waste in production plants by 30% by 2025 and
- that 0% of production waste ends up in landfills.

Responsible procurement is one of the activities of a socially responsible business that shows respect for nature. “Some of the raw materials needed for production are available in limited quantities, and there is no guarantee that they will be available in the future. That is why the company supports the sustainable procurement of raw materials and constantly develops alternative solutions to maintain high product quality standards”. With these activities, the company advocates for preventing deforestation—the company cares for the community and the region where scarce raw materials grow.

The goals presented by the company are:

- all ingredients should be from sustainable sources by 2025,
- the primary raw materials are obtained without the need for deforestation until 2025,
- 100% of palm oil will be obtained sustainably by 2020.

The company attaches great importance to the preservation and protection of drinking water. One of the main goals is to reduce water consumption to a minimum.

Skincare that respects nature, people and animals is a concept called “vegan cosmetics.” Vegan cosmetics do not contain ingredients of animal origin, such as wax, honey or milk. Sourcing these ingredients socially responsibly achieves sustainable dilution for humans and animals. For this reason, the NIVEA Naturally Good line represents a line of products with vegan formulas, i.e. products 100% without ingredients of animal origin.

Through the Instagram social network, the company Beiersdorf tries to encourage its users to preserve nature and the environment and to think about how important it is for each individual to contribute to reducing the harmful impact on nature. Also, the “Beiersdorf Bike” campaign emphasizes the advantages of using a bicycle daily compared to using a car.

The excellent acceptance of the campaign is reflected in positive user reviews on social networks:

“My bike has been gathering dust for some time. When I see that, I want to ride a bike again”. (User: thereyramie)

The company has taken a negative attitude towards testing products on animals since 1992. The company’s research team was among the first to approve tests without animal testing officially. The company is also exerting influence on the authorities in China so that they would keep this type of testing. Namely, in China, such tests are still allowed. For this reason, there is no mark on NIVEA products that they have not been tested on animals since this has been implied since 2004 when the EU banned such tests. All activities that the Beiersdorf company carries out to preserve the Planet and the environment are well received by consumers, which is why the company has been presenting a positive practice of implementing social responsibility for years. Through the activities undertaken, they encourage other companies to preserve the environment and strive to raise awareness of the importance of social responsibility.

2.2. Coty Inc.

Coty is a multinational cosmetics company founded Francois Coty in 1904 in Paris. The headquarters of the company is in New York. The company produces and distributes cosmetics,

skin, nail, and hair care products and perfumes. The company's mission is to "challenge the definition of beauty, encourage authenticity and celebrate diversity." For us at Coty, beauty does not mean conforming to other people's ideas. Instead, beauty means including and freeing everyone to shine uniquely. "

Some of the company's brands include Alexander McQueen, Bottega Veneta, Burberry, Calvin Klein, Chloé, Davidoff, Gucci, Hugo Boss, Kylie Skin, Marc Jacobs, Miu Miu, and Tiffany & Co., as well as skincare brands Lancaster and Philosophy. The company promotes socially responsible business activities. A great emphasis is placed on sustainability. Sustainability goals are related to products, the Planet, and people, as shown in Figure 7.

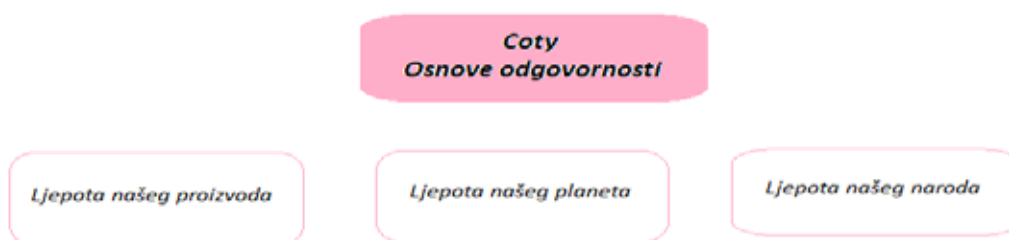


Figure 7. Coty's sustainability goals

Source: <https://www.coty.com/sustainability> (downloaded on 08.05.2022)

Time-bound goals are set within each area. Product sustainability refers to the design and development of the product, production and even the procurement of materials that go into the product's composition. The company's goals in this area are:

- from 2020, include sustainability criteria in creating all new products and
- from 2020, improving the management process of all crucial ingredients and materials required for product production.

The above refers to designing, formulating and producing products that do the least harm to the environment and create cleaner and better quality products. The Coty website states that the latest innovations and technologies are used to procure raw materials to reduce production's impact on natural resources.

Packaging plays an essential role in terms of sustainability due to its impact on the environment. Since 2018, the Coty company has been a member of the Initiative for Sustainable Packaging for Cosmetics, which brings together global cosmetics organisations to move the entire industry towards more sustainable product packaging.

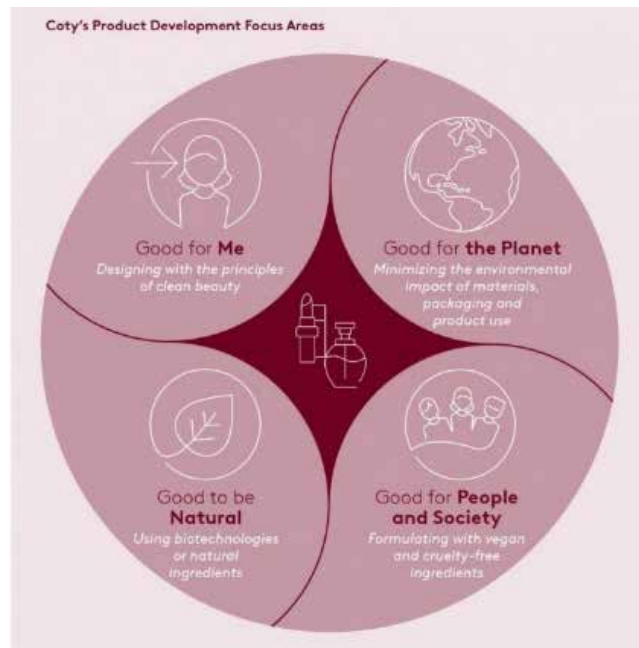


Figure 8. Target areas of new product development

Source: <https://www.coty.com/sustainability/beauty-of-our-product> (downloaded on 08.05.2022)

Figure 8 shows that the first two target areas of new product development include personalizing the product and reducing its negative environmental impact. The other two regions refer to benefits for nature, i.e., biodegradable and natural materials and gifts for nature and society, such as vegan ingredients and products not tested on animals.

The beauty of the Planet refers to preserving and protecting the natural environment and resource preservation for future generations. The company's goal is to reduce total energy consumption, use 100% renewable sources of electricity and reduce waste production.

"The above was already achieved in 2021, reducing waste production by more than 11%. "The total energy consumption was reduced by more than 10% compared to 2019."

Also, the Coty company is a member of the RE100 organisation, a global initiative of 300 influential companies that advocate using 100% renewable sources of electricity.

"The beauty of the people includes activities whose main goal is to: achieve gender balance in leadership positions by 2025, reduce the gender pay gap, pay fairly regardless of gender, introduce diversity and equality training, and continue to support the Charter for Change initiative and make making business more accessible to people with disabilities."

Each of these activities shows the importance of each multinational company to the entire society. Their influence on culture and values is especially significant in the countries where they operate. They are proof that the most significant changes can start with an individual.

CONCLUSION

A socially responsible business is one in which business processes positively affect the wider community. Each company assumes responsibility for its business activities, which the law and the higher goals of the entire society should guide. By applying socially responsible business, companies can improve the environment and society. Ecological, ethical, and legal standards in the modern world are becoming increasingly demanding, and investing more and more in innovation and development is necessary to generate new projects. Each company has its characteristic business conditions, especially those in the cosmetics industry. That is

why there is no universal way of applying socially responsible business, but it needs to be adapted. The concept of socially responsible business is becoming increasingly important every year because society and the planet face increasing problems related to natural pollution. Applying the socially responsible business concept is also one way of building cosmetic brands. Associating a brand with socially responsible behaviour has a positive effect on product sales as well as customer loyalty. This way of doing business enables the company's long-term survival in the market. Each of the presented companies strives to reduce its impact on nature through its activities because they are aware of the limitations of available resources. As mentioned earlier, three cosmetic brands are improving their reputation and gaining the trust of their stakeholders through the activities undertaken. The excellent reputation of the company affects the business results. The socially responsible business encourages an approach based on new ideas, experiences and developing new products. Cosmetic companies continue adapting to changing market conditions, one of the prerequisites for survival in the modern competitive market.

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STRATEGIC PLANNING OF TOURISM DESTINATION: THE CASE OF SOLIN, CROATIA

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Abstract. The tourism industry is constantly growing, touristic activities are gaining momentum and the number of stakeholders in tourism is accelerating. For tourism to develop systematically, ensuring sustainability, it is necessary to establish optimal strategic planning. This paper aims to present the need for tourism planning and to provide a strategic framework for the development of a tourist destination. For paper purposes, primary and secondary data were used. The paper case study is focused on Solin, a small town in central Dalmatia. Solin is rich with cultural heritage, as well as natural heritage that can attract visitors. To optimise resource allocation strategic planning is needed. The research paper provides a conceptual framework for planning tourism development aimed at maximizing economic and social benefits and to minimize negative environmental and sociocultural implications.

Key words: *strategic tourism planning, tourism destination, tourism implications, sustainability, Solin*

1. Introduction

A significant contributor to the economic growth of many nations is the dynamic business of tourism. A key component of destination management is the idea of strategic planning. The objective of this research is to furnish policymakers, industry representatives, and scholars with significant perspectives to enhance the strategic planning procedure in popular tourist destinations. Strategic planning helps destinations to achieve sustainable growth. The main objective of this paper is to illustrate the importance of strategic planning for the tourism sector. In order to gain a better understanding of the tourism industry, a detailed analysis of the supply and demand factors for the city of Solin has been conducted. In addition to the analysis, global tourism trends and their potential impact on Solin are also considered. Based on the results of the analysis, strategic recommendations for the development of the tourism industry in Solin are given.

In terms of activities specifically aimed at attracting tourists, Colin Michael Hall and John Michael Jenkins in *Tourism and Public Policy* 1995. introduced a development cycle for certain tourism products and the concept of an attraction cycle for certain destinations. This led to changes in the concept of tourism spaces triggered by the development of tourism activities. This has clear implications for what constitutes a tourism space: an area designated for tourists to engage in specific tourism activities. As the development and global generalisation of what constitutes tourist activities is enormous, there is a dichotomy between a place as a destination and a tourist place, and it becomes difficult to make a clear distinction between the two. Nicolae Ciangă, (2017) *The impact of tourism activities*. Here, the concept of what constitutes a tourism activity, and a tourism place becomes crucial to understand.

Efforts to distinguish between a destination and a place of high tourist attraction have resulted in the definition of a destination being vague and complex. Phillip L. Pearce (1988) offers a functional definition of a destination as “a stable region with internal boundaries that can be located and recognised and is used by a person or group for one or more activities with a beginning and an end”. This can be summarised as a place with specific tourist activities. It is important to understand that destinations do not exist for tourists, but that tourists create destinations.

This is a clear departure from the idea that any place with an attraction is a destination, and this clarifies the understanding of what constitutes a tourist space.

The activity theory of tourist sojourn is introduced by Dean MacCannell (1973) and his discussion of sightseers has significant and polarising implications for the pace of development of tourist spaces.

Although today there is harsh criticism of the uncontrolled development caused by the masses of tourists in a global sense, societies, in general, have only recently begun to recognise and understand the economic value and impact of tourism. Activity theory states that tourism begins as an escape from normative social and occupational roles and leads to a phase of seeking new/alternative experiences and holiday experiences. As tourism is a human activity that is inherently a change search, it is assumed that tourism is both complex and fluid and that it is difficult to start from a single ‘destination’.

Tourism is defined by the United Nations World Tourism Organisation (UNWTO) as “a journey outside a person’s usual environment for leisure, recreation and other purposes” (Edward Wray Bliss and Jeanne Liedtka, 1998). Robert Woodrow McIntosh and Charles R. Goeldner (1990) point out that it is a temporary movement and sojourn that brings some satisfaction and cumulative experiences. In the modern context, tourism can be said to involve the pursuit of various activities. Therefore, tourism products and services around activities have gained importance and may be the sole reason for certain trips (Robert Woodrow McIntosh and Charles R. Goeldner, 1986).

According to Jenny Cave & Dianne Dredge (2020), regenerative tourism requires diverse economic practices. Tourism geographies Tourism is more complex than other economic sectors as it requires the participation of four main groups of people. These include residents, public sector employees, business sector employees and tourists. Each of these groups has its view of tourism and its impact. Each of these groups has the opportunity to influence the development of tourism. Sustainable tourism is a product of the interaction of all these group members.

Many authors like Lisa Ruhanen (2004) Strategic planning for local tourism destinations: an analysis of tourism plans and Colin Michael Hall (2008) Tourism Planning: Policies, Processes and Relationships highlights the importance of strategic planning. Strategic planning is foundation of every successful destination, it provides various perspectives for local communities, ensures the protection of environmental and cultural resources, and protects the destination from being overwhelmed by the tourism industry.

Tourism is the largest single industry in the world today, which has led to many efforts being focused on this sector. Tourism offers communities the opportunity for economic and regional development through tourism revenue and job creation. In addition to the direct financial benefits that tourism brings as an industry, it plays an important role in improving the infrastructure of a destination. On the other hand, tourism can have some destructive effects on the economy of the visited country, because when the number of tourists in a country increase, the supply of goods and services often does not increase accordingly. This can lead to inflation and a balance of payments problem in the long run. Richard Sharpley (2014) Host perceptions of tourism.

2. Literature review

Many authors have emphasised the importance of strategic planning of tourism destinations. The UNWTO mentioned that “the lack of planning is responsible for most of the negative outcomes of tourism development” H. Igor Ansoff (2018) *From Strategic Planning to Strategic Management*. Nowadays, it is known that strategic planning is essential for tourism destinations to ensure that a destination’s resources are managed and sustained for the future and that various interests such as environment, finance, community, and tourist satisfaction are considered (Leonie J. Pearson, Anne Hardy & Robert JS Beeton, 2002). Partnership between the private and public sectors is a necessity to create sustainable destinations. Robin Nunkoo, Anuj Sharma, Nripendra P. Rana, Yogesh K. Dwivedi & Vivek A Sunnassee (2021) *Advancing sustainable development goals through interdisciplinarity in sustainable tourism research*. There are some examples in early tourism destinations that show that completely unregulated or unplanned tourism development will almost certainly lead to degradation of the physical and social resource base on which tourism and the destination community depend (Richard Butler, 1980; Sandro Formica & Muzzo (Muzaffer) Uysal, 1996; Clare A. Gunn, 1994; Colin Michael Hall 2008). On the other hand, destinations that have carefully planned their development are likely to have the greatest success in terms of high tourist satisfaction, positive economic benefits, and minimal negative impacts on the local social, economic, and physical environment Sustainable Tourism in Sensitive Environments.

3. Case study- The city of Solin

A little town in central Dalmatia, Solin has a long history that begins in the third century BC, when Salona, a city in the Roman Empire, had an astonishing 60,000 residents. Although Solin’s economic development in the second half of the last century focused on the cement industry and the INA Centre for Petroleum Derivatives, the city is not only dependent on tourism. However, with its rich history, inherited cultural heritage and numerous interesting tourist resources, there is an obvious need for intensive tourism development in Solin.

There are various categories within Solin’s resource base, including natural, cultural, and optical resources. The abundant vegetation that envelops the city, along with the rivers and a small lake, are examples of natural resources. The rich history of Solin and its well-preserved ancient sites are the main topics of its cultural riches. The manifestation resources, on the other hand, focus on the cultural and sporting events that take place in Solin every year. The natural resources of Solin include the river Jadro, which supplies the entire area with drinking water, the mountain Kozjak, which is of great historical importance for the defence of Solin, and the Adriatic Sea, which offers a beautiful view and is also accessible via the port of Solin. The Solin area is characterised by a warm Mediterranean climate with mild, windy winters and warm, sunny summers. Various typical Mediterranean plant species such as wild olive trees, herbs and shrubs cover the slopes of the Kozjak mountain. The cultural resources of Solin consist mainly of well-preserved Roman archaeological sites. The archaeological collection of Salona contains the remains of the Roman forum, amphitheatre and other sites that have been preserved from the Roman period. There are also monuments and other evidence of the remains of provincial Christianity, such as the Church of Our Lady of Brdo or the pre-Romanesque church of Vranjic from the 10th century. The Vid cemetery from the 1930s is also a valuable link between modern trends in art and the architecture of modernist sculptural gravestones. Numerous cultural and sporting events take place in Solin, attracting many visitors and tourists. Among the most famous events are the gladiator games as part of the “Romantic Nights in Salona”, during which the town celebrates and honours the rich cultural heritage of Solin with exhibitions, concerts, and various activities.

Solin has a well-developed transportation network that connects it to other important cities in Croatia and Europe the road network in the Solin area is approximately 79.77 km long, including 2.10 km of highways, 7.72 km of state roads, 11.8 km of county roads, 15.16 km of local roads (19.0%), and 42.99 km of uncategorized roads. highway A1 passes through the northern part of the Solin area, and although there are no exits to Solin itself, most outgoing traffic is directed towards the Dugopolje exit, approximately 14 km from Solin.

Solin offers a wide range of tourist attractions, including cultural, historical, sports, adventure, recreational and gastronomic tourism. The town is famous for its natural, cultural, and historical heritage, which has helped it become a recognized tourist brand. Tourists can visit the Salona Archaeological Collection and the Tusculum Museum, which showcase the historical and cultural heritage of Solin. Sports enthusiasts can enjoy various activities such as rock climbing, hiking or bike trails. Solin's location near the Jadro River allows for kayaking and rafting. Solin City Park offers a swimming pool, diving board, bocce ball and basketball courts. Furthermore, beach and sea activities are easily accessible from Solin. Those interested in adventure or recreational activities can consider off-road driving or boat excursions to nearby islands.

Additionally, visitors can also enjoy diverse menus and traditional gastronomy at various local restaurants within walking distance from the city center. A popular tourist site, Solin draws travelers from all over the world. The number of visitors and overnight stays in the city has been steadily rising. 32,561 people spent the night in Solin overall in 2019, a 15% increase from the previous year. The majority of visitors who stayed overnight in Solin are tourists from Germany, Slovenia, Poland, Bosnia and Herzegovina and Croatia, with 28% of tourists coming from Germany alone. The length of stay in Solin is 2.51 nights, which is slightly higher than the average for Split-Dalmatia County. Tourists visit Solin mainly during the summer season, especially in July and August. In recent years, however, there has been an increase in the number of visitors throughout the year.

Several themes that are influencing travel both domestically and internationally are highlighted in Solin's tourist development strategy. According to Mody, M. & Hanks, L. (2020) Consumption Authenticity in the Accommodations Industry, there is the increasing popularity of sustainable tourism, which emphasizes ethical travel and proactive community involvement, is one trend. Another trend is digitalization, in which social media and technology have a big impact on people's decisions about where to go. Additionally, travelers are willing to spend extra for experiences that are more authentic and individualized. Additionally, wellness and health tourism are growing in popularity. Travelers seek out experiences and settings that encourage relaxation, stress relief, and physical and mental well-being. Lastly, there's the growing importance of the "slow tourism" movement, which emphasizes slower and more immers

A SWOT analysis covers different factors that are crucial to sustainable tourism development. The Resources and attractions factor in Solin focuses on the evaluation of natural and cultural resources that contribute to its tourism potential. The natural value of Jadro River with its drinkable water supply and protected fish species. Additionally, rich cultural heritage from all ages - the bronze, Roman, early Christian, and medieval periods, now represented in the Salona Archaeological Park - offers a basis for understanding the country's history. The Human potential variable in Solin has the social aspects related to the hospitality of the local population towards tourists, including their willingness and ability to interact and help tourists feel comfortable. Also, it provides cultural events and activities to present and preserve the city's cultural heritage.

The infrastructure variable in Solin evaluates the current and potential future infrastructure to support the tourism industry. This includes recent developments such as the expansion of Split airport's capacity, The infrastructure sector plays a huge role in ensuring that tourists have access to all amenities that they require to have a comfortable and enjoyable experience in Solin. The

Management and marketing variable in Solin covers both existing and potential collaborations among different authorities and stakeholders such as the tourism board, hotel management, and other businesses invested in the tourism industry. This attempts to prevent needless long-term exploitation of the city's natural and cultural resources and to guarantee efficient administration of all the tourism resources Solin City has to offer. It is Solin's duty to maintain the delicate balance between marketing initiatives aimed at introducing new tourist audiences to the wide range of experiences the city has to offer and maintaining the city's historical legacy. As a result, more effective marketing initiatives can expose Solin to a wider range of people and boost visitors' accessibility to and interaction with the city's distinctive attractions.

The strategic framework includes principles of development, vision, mission, and strategic goals. These goals are categorized into four main sections: raising the quality of tourism products, improving existing and developing new tourism products, creating a supportive development environment, and actively managing space and tourism resources. When it comes to the strategic development of the city of Solin, it is necessary to focus on preserving natural and cultural resources, promoting sustainable development, promoting local identity, and creating a positive experience for visitors. To achieve the principles of tourism development, it is necessary to strive for sustainable tourism development that increases environmental awareness and promotes socially responsible business, which contributes to the preservation of natural and cultural heritage. By developing sustainable tourism, the entire destination is developed, ensuring that all stakeholders in tourism along with the local population benefit. To achieve the principles of development, it is necessary to fulfil several prerequisites, including diversification of tourist offers and educating and informing all stakeholders in tourism. The vision of tourist development of the city of Solin is the desired future of tourism that serves as a guideline and inspiration for all stakeholders in tourism development. All stakeholders should strive to achieve this vision through their engagement, work, and active participation in its achievement. The vision of Solin's tourism is based on rich historical heritage, highlighting the unique archaeological site, and cultural and historical heritage. Special attention is paid to the principles of sustainable tourism during the formation of the tourism vision of Solin. The emphasis is on preserving the main tourist resources and ensuring that tourism development contributes to a better standard of living for all citizens. Furthermore, the most important trends in the global tourism market are considered in defining the vision of tourism development to meet the demands and needs of modern tourists.

The mission of Solin's tourism development as a tourist destination is to encourage sustainable development through the improvement of tourism attractiveness, promoting economic and socio-cultural development, in close collaboration with the local community, entrepreneurs, and relevant stakeholders. By considering all this information, Solin persistently strives to valorise its cultural and historical heritage. The strategic goals of Solin's tourism development can be divided into four main areas:

1. Raising the quality of the comprehensive destination product:

This goal seeks to increase the quality of the tourism product by enhancing tourism services and increasing tourist satisfaction, which ultimately contributes to the development of tourism and increases the standard of living.

2. Improving existing and developing new tourism products:

This is related to developing specific tourism products and experiences that meet the needs and interests of different target groups, with an emphasis on the preservation of natural, cultural, and social resources.

3. Creating a supportive development environment:

This goal aims to create a supportive environment for tourism development, which includes the development of regional and local tourism organizations, tourism research, education, and training.

4. Actively managing space and tourism resources:

The final goal is related to the effective management of tourism resources and visitor flows and the establishment of dialogue between the local population, entrepreneurs, and tourism stakeholders. The goal is also to preserve and protect natural and cultural heritage, mitigate the negative impacts of tourism on the environment, and promote sustainable tourism development.

The operative strategy is based on projects that were developed after analysing the tourism resources, SWOT analysis, as well as strategic workshops with key stakeholders. Projects are grouped into three main categories:

1. Tourism development:

This category includes improving the aesthetic appearance of public spaces with traditional materials, using traditional elements in architectural design, installation of urban elements such as benches, waste baskets and public lighting. Careful planning of billboards and attractions. Improving tourist signage and interpretation of attractions. Creating an attractive environment with infrastructure for outdoor activities. Moreover, the construction of a marina on the mouth of the Jadro River is also planned based on carefully analyzing economic viability.

2. Development of tourism products and communication activities:

This category involves the development of new accommodation capacities, the development of a cultural and historical offer, and infrastructure for hiking and trails with additional viewpoints.

3. Sustainable destination development:

The third category emphasizes the importance of monitoring sustainable tourism development indicators, encouraging the introduction of eco-labels in accommodation capacities, and the involvement of the local population and tourism stakeholders in decision-making.

4. Conclusion

To conclude, the tourism industry's growing rapidly and tourists every day have higher expectations. Tourism must be strategic planned in order to ensure services that fits this heavy demand. This research has shown the curtail role of strategic planning in destination management, focusing on Solin. With a various analysis of Solin's resources, attractions, and current trends in tourism industry, it has been shown that strategic planning is has big part for maximizing economic and social benefits while minimizing negative environmental and sociocultural impacts. This paper shows the importance of mutual collaboration between all stakeholders included in tourism activities. Overall, this paper shows that even micro destinations like Solin can use their assets and respond to new trends without losing destination identity. Through mutual efforts and implementation of strategic framework, Solin and similar destinations can develop sustainable tourism that benefits both visitors and local communities.

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WAREHOUSE MANAGEMENT SYSTEM (WMS) IN RETAIL LOGISTICS

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Abstract. Retail expansion through various eCommerce platforms transforms traditional logistics operations. To keep up with the rising market demand, retailers focus on implementation of the Warehouse Management System (WMS). By implementing WMS in their business operations, retailers consider the three aspects of goods: right quantity, at the right place, and at the right time. WMS enables the creation of a competitive advantage for retailers. WMS's capability of comprehensively connecting warehouse management processes affects the flow of goods. The analytic benefit of the WMS is the ability to provide real-time information for retailers. With real-time monitoring of their warehouse operations, retailers can control the cost of their goods. Implementing WMS presents a challenge, due to its commercial and technical aspects. From the commercial aspect, it presents a profitable opportunity for a better placement of goods on the market. Furthermore, there is the possibility of potentially higher return on investment. There are certain technical challenges in implementing WMS that may present a concern for retailers. The WMS, during its implementation, integrates with the current operational system. If it is not integrated properly, it may result in the interference with the current operational system. Ultimately, it could disturb the flow of business operations and goods. The goal of this analysis study is to present the advantages of a highly functional WMS. It will also explore and present helpful guidelines for the WMS implementation in retail businesses. The analysis will emphasize the separate phases of WMS integration and the outcomes of each action. This paper will enhance the understanding of WMS and present its contribution in improving everyday warehouse management processes. It is essential to approach investing in WMS as a risky management strategy due to its complex technology. Adaptability to WMS presents an integral value to secure the continuity and resilience of retail business operations.

Keywords: *Warehouse Management System, logistics, retail*

1. Introduction

Within warehouse management, retailers organize their inventory, oversee orders and shipments, calculate inventory stock, and supervise workforce activities. These day-to-day activities need to be managed strategically, in such a way that leads to the highest level of efficiency. To reach a certain level of efficiency within the supply chain, retailers must obtain internal visibility and integrated warehouse operations. Industry 4.0 for retailers presents a certain push. Representing the fourth industrial revolution, Industry 4.0 implements automated processes and

data-driven technology, pushing the boundaries of capacity in manufacturing. Thus, it results in the expansion of the market supply, through quantity and diversity of assortment. Today's average consumer is technology-driven through mobile-centric information updates. Such innovations grant them the ability to quickly find clear information, and the advantage of seeking products through digital channels. Retailers implemented an omnichannel strategy approach, an effort to provide their customers with a unified shopping experience through multiple channels. Such a strategy requires retailers to fulfil orders from multiple retail formats and channels, putting pressure on their warehouse operations. In addition, today's average consumer anticipates and puts an emphasis on a swift and accurate delivery. To meet the growing needs of such consumers and to sustain a competitive edge, retailers are implementing innovative technology within their business operations. One of these technologies is the Warehouse Management System, a sophisticated software implemented within warehouse operations to simplify them and bring real-time visibility to these operations. Innovative technology can cause alarm to first-time users, and such is the case of WMS for retailers. The purpose of this analysis study is to explore the WMS and its intricacies, to emphasize the efficient flow of goods it provides to retailers, from production to distribution. WMS is recognized for its economic value in addressing supply chain challenges. Research findings related to WMS functionalities are presented in two separate business case studies. They display the phases of implementation processes and the outcomes. This analysis study seeks to provide a comprehensive understanding of the WMS and how it can contribute to the improvement of warehouse operations, thus enhancing efficiency throughout the supply chain.

2. Intelligent storage technology for unlocking tomorrow's efficiency

As an innovative approach to inventory control and execution of warehouse operations, WMS optimizes organizational processes and provides a multitude of benefits to the system's end-users, in this case, retail businesses. As a software application, that is, a digital platform, WMS is designed to manage and optimize routine operations within the warehouse infrastructure (Jenkins, 2020). Therefore, it enables harmonized coordination of day-to-day warehouse tasks and its mobile components, such as warehouse staff, warehouse equipment, customer orders, and inventory. A favourable impact of WMS in supply chain management can be noticeable in each task taking place in the warehouse, such as reception and storage of supply goods, inventory control, prioritizing, packaging and dispatching orders, transportation management, workforce management, yard and dock operation management, warehouse performance metrics and analytics (SAP, 2023). The desired outcome of using WMS lies in its ability to facilitate business automation and the optimization of inventory management.

The development of retail business through digital technology redefines the traditional approach to warehouse management. To attain a competitive leverage, retail businesses seek to obtain advanced technology, such as WMS to promptly meet the needs of their customers. The goal is to secure customer perceived value without worsening the quality and causing a cost increase of business operations. Taking into consideration the effects of Industry 4.0 which is defined by innovative technology, namely the Internet of Things and Artificial Intelligence, its outcomes are recognized in the transformation of customers' purchase patterns (Team Hopstack, 2023). As a consequence, this gives retailers the ability to adapt to the changing customer needs by creating intricate supply chain processes.

As a concept, storage of goods dates back to the first civilizations and their agricultural activities, where they were faced with the problem of preserving the quality of their harvest (Armenta, 2022). The second industrial revolution introduced innovations in the management

of warehouses. The first Automated Storage and Retrieval System Demag, now known as Dematic, was created and laid the foundations for the WMS (Hopstack, 2023). In 1971 the first distribution centre from Walmart broadened the perspective of the supply chain, reducing the shipping and restocking time by placing storage facilities in easily reachable locations (Zimmerman, 2020). To simplify inventory control and tracking the Universal Product Code (UPC) was created. It contains product information, scannable via laser or an imaged based technology and it was used for the first time in 1974 to scan a Wringley chewing gum (Jean - Hirst, 2014). American retail company J.C. Penny developed the first WMS that provided real-time insight into inventory stock, kickstarting the modern releases of the WMS (Thomas, 2024). Pioneered by Walmart, as one of the elements that accelerated the flow of goods, with little or no storage in transport through incoming and outgoing vehicles, was Cross-Docking. It was a logistics technique that contributed to the further development of warehouse operations (Jenkins, 2023). Additional logistic development was facilitated in the '90s through Enterprise Resource Planning (ERP) system by enhancing data availability, data accuracy, underlining the importance of effective planning and harmonizing the flow of warehouse operations. It created the Advanced Planning and Scheduling (APS) software (McCue, 2020).

WMS of the 21st century is paperless and cloud-based. This dramatic evolution grants access to information in real-time with the absence of manual data entry, reducing the risk of human oversight. Therefore, it secures a range of flexibility, which was priorly unimaginable.

3. Operational functionality of the WMS system and its diverse types

WMS is used in various industry fields, predominantly in the manufacturing and retail industry, for its capability to track the entrances and exits of goods through the warehouse infrastructure, optimizing warehouse procedures. The efficient and frequent utilization of the WMS is due to its operational concept, based on data as the primary resource. A summary of the WMS operational functioning in the retail industry consists of a visual display system that streamlines order sequences by prioritising them, keeps track of the number of goods in the warehouse and their location within the same establishment, stays up-to-date with the location of goods through the delivery process even after leaving the warehouse (Rittenberg and Watts, 2022).

WMS operational tasks will be more closely depicted. The first of its tasks is the reception and recording of goods through scanning the UPC. It records relevant information, such as the amount and serial product information of the goods, for their further handling within the warehouse and the WMS (Rittenberg and Watts, 2022). Additional warehouse tasks entail placing the goods within the warehouse. The WMS enables efficient placement of goods within the warehouse storage units, taking into account the weight, dimensions, and customer demand for the goods, and positioning them in such a way that decreases unnecessary staff engagement and reduces movement through the warehouse (Bilicka, 2023). Information on the stored goods is recorded in the WMS system, which enables monitoring and oversight to , avoid shortages or surpluses of stock inventory (Asim Niazi, 2021). The WMS optimizes order management and the delivery of goods by identifying efficient routes for the retrieval of goods. It applies methods such as Wave Picking and Batch Picking and, upon the order dispatch, package tags are printed to update stock inventory levels (Musaoglu 2024). A crucial role in the efficiency of the WMS is workforce management. WMS can measure workforce efficiency and assign tasks based on the warehouse staff's location, skills and priorities (Workmate Team, 2020). Additionally, real-time visibility of warehouse operations is provided by the WMS. Managers can monitor stock levels, performance rates, and executions of orders (Dewberry, 2023). The WMS assists warehouse managers in making informed decisions. Systems such as Enterprise Resource Planning,

Order Management System, and Transportation Management System, as distinctive systems designed with the purpose of optimization and automatization of business can be integrated with the WMS to improve efficiency through data synchronization (Think Inventory Solutions, 2023). A successful integration of the WMS in an ongoing business operation benefits different parties such as customers, workers and managers. Those benefits are achievable due to WMS's proficiency in tracking goods. The quick and efficient work of the WMS is evident through its data analysis capability that provides cost reduction and operational control for businesses.

The decision to choose an adequate WMS is of high significance for retail businesses. The chosen WMS and its capabilities affect the efficiency and accuracy of warehouse operations. The process of choosing the ideal WMS is an elaborate procedure where retail businesses, in today's market, have a broad selection of different WMSs, each equipped with unique features. American company Conger Industries Inc., which has provided end-to-end data solutions regarding material handling issues in warehouses over the past 70 years, listed (2024.) four types of WMS: standalone, supply chain module, ERP-integrated and cloud-based.

A standalone WMS is tailored for small and medium-sized enterprises, it enables basic day-to-day warehouse operations and is easily adaptable to combining and integrating with the current business systems solutions (Rosencrance, 2021.). Flaws of a standalone WMS manifest in the higher initial implementation and maintenance costs and challenging future upgrades of the system (Nebot, 2023). The supply chain module presents a WMS combined with the Supply Chain Management (SCM) software. It is a more cohesive approach to business operations, enabling improved insight into the supply chain operations (Lowe, 2024). The main disadvantage of a supply chain module is the risk of potential overlap with the current or future software, requiring high-cost assistance (Drzewiński, 2023). A WMS combined with ERP, that is, an integrated ERP, unifies the two software applications. Due to its data synchronization in real-time, it performs multiple operations for an inclusive approach to warehouse management (Mecalux, 2021.). Data shared between the software applications streamlines warehouse operations and reduces errors, while supporting larger supply chain operations. Such an advanced type of WMS requires information technology expertise and training to acquire the skills necessary to maintain it. It is a system that demands high implementation and maintenance costs due to its complexity (Girinath, 2023). An ideal choice for start-up businesses who want to monitor the inventory level of their goods and their movement for an affordable price in real-time is the cloud-based WMS. With a lower cost of implementation, cloud-based WMS is conceptualized as a software-as-a-service (SaaS) distribution model, hosted and managed by the service provider, and accessible through the Internet (Di Carlo, 2023). By outsourcing SaaS from third-party vendors, businesses reduce expenses needed for future investments in their information technology infrastructure. Considering that the service provider administrates the hosting of the system, data integrity and the security of this WMS type is questionable (Axacute, 2023).

Each system is distinctive, containing diverse benefits for retail businesses in warehouse management operations, the primary benefit being the enhancement of operation efficiency. Retail businesses, regardless of their business scope, view warehouse management as an essential business component. As a result, retail businesses incorporate WMS to simplify warehouse operations and secure a competitive advantage in the supply chain processes.

4. Unleashing the power of smart storage solutions and its market value

Retail businesses that recognize the need and opportunity for business growth, invest in supply chain enhancement. Such endeavour depicts retail business aspirations to increase

performance efficiency, reduce costs, and secure customer loyalty, that is, to meet customer needs before the competition.

Indian company iThink Logistics, a logistic partner that actively provides cost-effective and reliable shipping solutions for e-commerce enterprises, listed (2019.) several advantages of implementing WMS within retail businesses, such as enhanced stock control and customer service, reduction of storage costs and administration time, and the acceleration of order fulfilment and shipping. The advantages of a properly integrated WMS are numerous and can present long-lasting sustainable results for businesses. Proper integration of the WMS in retail businesses results in a highly organized warehouse, which is exceedingly efficient throughout the entire structure. Due to the WMS being a software application which integrates within a business, there are several risks and flaws in its implementation. Some flaws are WMS's high implementation and maintenance cost. Risks arise when wrong parameters of collectable data are configured, by approving misguided authorization and in the overall singular failure point of an unsuccessful implementation (Pruszyńska, 2019). Concerns of businesses going through the process of implementing WMS are justified, since the new system will be integrated with the current system in use. It could potentially cause disruptions in the overall system in the event of a malfunction.

The initiative to implement WMS involves a substantial investment, one that does not necessarily provide a return on investment (ROI). On that note, it is recommended to identify the right and favourable time for such actions. French company Reflex Logistics Solutions, a company that provides software solutions for the automatization of supply chain networks, listed (2023.) several factors that represent an ideal investment window such as: repeating missteps in the selection and dispatch of orders, difficult control over warehouse operations due to rapid business growth, desire to minimize operational errors and accelerate the delivery time, plan of implementing a multi-channel sales strategy and technological innovation within the warehouse, desire to implement quality management and setting key performance indicators (KPI's) for informed support decisions. With the 21st century's wave of technical innovations, the next generation of warehouse storage solutions enables supply chain visibility. Experts recommend the use of the innovative WMS, under the condition that the current system and its logistic functions are not able to meet the growing business needs (Whiting, 2019).

Companies that provide WMS, that is, WMS vendors, recognized the potential and the opportunity to provide innovative services and solutions for the retail logistics landscape. WMS vendors recognized the growing issues within logistics and distribution processes. Gartner, a global research company for various industries, such as information technology, listed several WMS with high reviews, such as SAP Extended Warehouse Management, Oracle Warehouse Management, Manhattan Associates WMS and others (Gartner Peer Insights, 2024). Taking into account that the information technology market is ever-changing, the amount of WMS vendors can reach a high number. E-commerce platforms predict these WMS to succeed in the year 2024, such as ShipBob WMS, Inventory Source, NetSuite WMS and others (Carter, 2023). Each WMS differs in its commercial and technical aspects. The selection of the appropriate WMS for enterprises depends on numerous factors, the two important ones being the businesses budget and its needs. The cost of a highly functional WMS varies, depending on numerous factors and methods of payment. According to the research of SoftwarePass, the average cost of a WMS is \$167 with a monthly payment per system user, which for a small business with approximately five users represents a monthly cost of over \$500 per warehouse (Bright, 2021).

	Entry level functionality	Mid-range functionality	Enterprise
SaaS (per user/month)	\$100	\$300	\$500
Perpetual license (per facility)	\$2500-\$10,000	\$10,000-\$50,000	\$20,000-\$200,000
Suited to	Companies with limited automation and inventory support – often not including methods to track goods through various channels or shipping lanes.	Growing operations requiring mid-range of services and automation, with degrees of complexity/industry specificity	Enterprises requiring latest automation software, integration with suppliers, advanced analytics, or integration with specialty assembly lines

Figure 1 Initial WMS cost for on-premises and SaaS deployments provided by Explore WMS

Source: Explore WMS (Whiting, 2024.)

Explore WMS acts as an independent resource support for businesses in the area of supply chain management and provides information regarding WMS whitepapers, WMS product comparison and WMS software directory (Explore WMS, 2022). It acts as a useful resource for retail businesses to gain diverse information regarding WMS solutions through independent research. Creating a WMS budget depends on different factors, among them is the commercial aspect of the solution, that is, its cost. It is recommended that retail businesses inquire about different proposals from WMS vendors and consider different pricing models. Most common among these pricing models are perpetual licensing which acting as an on-premises solution and a subscription model acting as a SaaS solution (Whiting, 2024). Figure 1 showcases the initial WMS cost for on-premises and SaaS deployments for entry-level, mid-range and enterprises, each with different levels of functionality. These functionalities are linked with the cost price of the solution, in relation to features such as fleet management, analytics and advanced functionalities, such as personalized audit trail with higher cost price (Whiting, 2024). It is recommended to consider all the factors that define the WMS budget for a retail business. These factors are the chosen pricing model, installation requirements, maintenance and support costs and training costs (Megusta, 2023). It is best to consider a credible price depiction through a consultancy with an official sales representative of a WMS vendor.

5. Efficiency and value of WMS through Nature's Best and Men's Warehouse

For the purposes of this analysis study two real examples, carried out by the supply chain and enterprise technology consulting company enVista, are presented. The technology consulting company enVista, with over twenty years of experience, provides its clients with innovative technology solutions that are focused on optimizing business operations, cost reduction and efficiency improvement throughout the supply chain (enVista, 2024).

Two clients that employed enVista's information technology services are Nature's Best and Men's Warehouse. These examples demonstrate two companies that successfully recognized the

right opportunity to upgrade their warehouse operation, resulting in the overall improvement of business operations.

Company enVista presented (2020.) on their official web page four warehouse management case studies, among them Nature's Best. The mentioned company is an American distributor and wholesaler of organic food products such as vitamins, food supplements, herbal products, frozen and refrigerated products, pet food and products for personal care (PitchBook, 2023). In their case study enVista presented how Nature's Best company experienced issues, such as increased labour expenses. These were prompted by staff and time management during the transportation of goods between buildings in a four-building distribution campus with three temperature-controlled zones: dry, chill and frozen. Each zone presented a case picking point to accommodate small-scale or large-scale clients. The high-priced infrastructure layout and design resulted in an unfavourable distribution performance, each product was handled 18 times before reaching the customer. Furthermore, the company required an upgrade of the distribution supply chain technology and its process, in addition to the revitalization of distribution facilities to meet the determined and ambitious development goals (enVista, 2020).

To solve these issues, Nature's Best employed enVista and implemented their three-phase solution, utilizing services such as property Consult, Implement and Operate methodology with a project timeline of 18 months (enVista, 2020). In the first phase of the project, Consult, enVista developed a supply chain strategy corresponding to the business goals of Nature's Best. It conducted material flow analyses and redesigned internal flow processes that led to the selection of a global WMS. Furthermore, during this phase of the project, enVista determined space requirements for the new facility with multiple temperature-monitored zones, centralising the operation into one distribution centre (DB). In the second phase of the project, Implement, enVista facilitated the supervision of the construction and integration of the new facility. It provided a transition from a mechanized paper-based system to RFID and voice recognition technology (enVista, 2020.). To gain a better understanding of the new technology, enVista provided training for the staff of Nature's Best. Furthermore, enVista assisted in the physical transfer of Nature's Best inventory, then valued at \$25M (enVista, 2020). In the published (2020.) case study by enVista, a WMS from Manhattan Associated was implemented for Nature's Best project. It included a user interface design, configuration, testing, training development, facility preparation, labour standards development, and SlotInfo implementation.

In the last phase named Operate, previously mentioned activities resulted , in a seamless and successful transition to the brand-new facility and improved systems and processes. both of which launched simultaneously. In numbers, the project resulted in a reduction of labour costs by over 30% and doubled Nature's Best productivity. They maintained 97% of permanent employees, reduced the majority of contract employees and eliminated non-essential positions. The management of the project, at its height, consisted of 10 people per team (enVista,2020). Nature's Best was able to operate independently and without consultancy four weeks after the launch of the project.

Another example of enVista activities is the implementation of supply chain solutions within an enterprise, the project involving Men's Warehouse. It is one of the largest American retailers of men's apparel. Established in 1973, it is owner of over 1,777 retail stores (CNN, 2009). In the published (2020.) case study by enVista, it is stated that Men's Warehouse possesses a main distribution centre of 1.1 million square feet in size. It represents the core retail distribution centre for Men's Warehouse and 60% of merchandise from K&G retail stores. The main objective of the project was to centralize retail and e-commerce systems to run their operations on a singular platform, in addition to the central Materials Handling Equipment (MHE) system (enVista, 2020).

To assist Men's Warehouse needs, enVista implemented the solution through a two-phase project. The first phase of the project was New Platform, in which enVista implemented a new WMS and a Distribution Order Management (DOM) system and integrated them within an e-commerce web platform (enVista, 2020). The DOM system assisted Men's Warehouse in making informed and strategic decisions in the fulfilment of e-commerce orders. Furthermore, it gave them the capability to put into action elaborate sourcing models as the e-commerce venture expands. Through the newly implemented WMS, Men's Warehouse gained real-time visibility, inventory accuracy and flexibility to execute customer orders more precisely (enVista, 2020). In the second phase of the project, Implementation, the focus was on implementing the new WMS and a centralized Warehouse Control System (WCS) in the Retail Distribution Operation. It replaced the Legacy Inventory Tracking system with the WMS, while the WCS centralised the management of Pick to Light, Pack to Light and Garment on Hanger Unit Sorter into one system (enVista, 2020). The result of these actions was an effective change in the product flow and utilization of the Case Level ASN receiving. In conclusion, enVista project for Men's Warehouse facilitated the distribution of resources across operations, and the consolidation of Men's Warehouse and K&G distribution operations, resulting in cost reduction and efficiency progress. The presented cases, Men's Warehouse and Nature's Best demonstrated two successful implementations of the WMS within their operations by employing the services of the company enVista. Proper implementation of a WMS resulted in a prompt return on investment and enhanced operational efficiency.

6. Conclusion

Efficient inventory management indicates the delivery of products at the right time, that is, the moment the consumer wants to purchase them. WMS established a connection between the retail store and the warehouse. As a data-driven system, when a purchase is made in the retail store, it generates information. This purchase information presents data transferred through the WMS, allowing internal visibility to its user to track inventory information within the retail store, that is, the place of purchase. Such information enables seamless tracking of inventory levels, allowing the retailer to replenish inventory as needed. Physical retail stores are just one of many ways through which a consumer can make a purchase. On that note, the integration of information between WMS stretches throughout other sales channels such as e-commerce websites. With the rise of sales channels that demand products, WMS assumes the responsibility of ensuring an efficiently managed inventory. Retailers are pushed by today's innovation and technology to implement an omnichannel strategy of approach. Furthermore, the market is oversaturated with increasing competition, each investing in its activities to approach its current and potential consumers quickly and efficiently. These challenges result in warehouse operations being more complex and pressured to maintain their operations on an optimal and thriving level while ensuring speed and accuracy. The solution can be found in the WMS, an automated system, designed to cope with the challenges of today's modern business operations. The unavoidable decision to invest in a WMS for retailers presents an obstacle. The uncertainty regarding investment return and technical competence are issues they face while making decisions on a WMS investment. For that reason, there are WMS vendors, companies that provide services and solutions for the optimization of supply chains. Among their services is system support, which ensures that the implementation of the WMS has a positive outcome. The decision to invest in a WMS needs to be made after a thorough analysis, taking into account the available budget, current and future needs and capacities of the warehouse. When the decision is reached, retailers must seek consultations with IT experts that provide WMS as a solution. A

successful implementation generates positive outcomes, cost reduction and efficiency in real-time visibility, thus adding value to the supply chain of operations. Today, innovations and technology are designed in such a way as to be comprehensive by all, regardless of their age group or educational background. It is recommended to invest in WMS to improve the overall warehouse operations efficiency, to remain competitive in today's retail market and to elevate customer service.

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SUSTAINABLE HUMAN RESOURCES MANAGEMENT: ATTRACTION AND RETENTION OF YOUNG EMPLOYEES

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Abstract. Over the last few years, the global business environment is changing rapidly and unpredictably. To survive in such conditions, companies are seeking new approaches to achieve sustainable competitiveness. Business success is being defined in more sustainable terms, which led to the question of the purpose of Human Resource Management in those conditions. Sustainable Human Resource Management emerged as the new approach that should help organisations adapt to the new environment. One of the biggest challenges companies are facing in the contemporary business environment comes from the labour market, as the consequence of demographic changes. The new generation of workers is entering the job market, and all the researches show that they are highly different from all the previous generations of employees in terms of their values, attitudes, and work behaviour. Taking into consideration the evident lack of workforce in the labour market, companies have to make efforts to attract and retain young employees if they want to ensure long-term sustainability. This means that it is necessary to know the characteristics of the new workforce and develop new methods and approaches to manage them. This paper is looking for the best approaches to attracting and retaining young employees and to analyse which of their values companies should meet to do that. The methodology includes a literature review, and a questionnaire designed to examine the expectations, values, and work-related attitudes of Generation Z and millennials. A Quantitative survey was conducted in May 2023 using an anonymous online questionnaire. Research results are compared with similar research to provide empirical evidence of the characteristics of young employees in Croatia and to compare them with their peers in other countries. The study shows that the work-related attitudes, values, and expectations of young employees in Croatia are similar to those found in other research, with few exceptions that might be explained as country-specific. Findings provide empirical evidence of the Generation Z characteristics that are universal and might and should be used to improve existing and to create new human resource practices that would ensure attraction and retention of the future workforce. At the moment companies have four different generations of employees in very different stages of their careers. Taking into consideration that the so-called baby boom generation is retiring, companies should focus their efforts on millennials and Generation Z. Knowing their preferences towards job security and financial stability, flexible work, individuality, the reputation of the company, the possibility to learn and advance as well as the changed way of communication and excessive use of technology is vital to create human resources strategies that will attract and retain young talents.

Keywords: *Sustainable HRM, Generation Z, millennials, attraction, retention*

1. Introduction

All companies throughout the world are facing challenges coming from the uncertainty of the environment that is shaped by unpredictable global events. Technology is changing faster than ever, markets are changing as well, sociocultural changes are forcing businesses to adapt their organizational culture to the new demands of buyers and employees, legal frameworks are changing and influencing businesses as well, not to mention changes in competition, labour market, etc. To be successful and survive in such conditions companies need to adapt to the new economy and to find new sources of long-term competitiveness.

Global industrialization, extensive use of non-renewable sources of energy, growth of population, and consumption are the main causes of environmental problems worldwide. Environmental protection and sustainability are immense challenges for global organizations; hence, it is imperative to deal with them by adopting curative measures (Sulphey and Faisal, 2021). Under the generally accepted concept of sustainable development, it is possible to observe the sustainable development of economic entities as an attempt to adapt this concept at the corporate level, by harmonizing the goals of value creation with environmental and social issues. In other words, it is the ability of organizations to create and maintain economic success in the context of environmental responsibility. Following existing trends, we can claim that the root of strategy and competitive advantages in the years to come will be the ability of organizations to carry out their economic activities in a sustainable manner that does not endanger the environment, and in this way, in the long term, provide themselves with the resource base necessary for both short-term and long-term success. Many companies are implementing sustainability management systems to gain competitive advantage, but for the implementation and evaluation to be successful, managers have to involve HR (Daily and Huang, 2001).

It is widely recognized that employees, much more than physical assets are drivers of business success and can be an important source of sustainable competitive advantage. According to the Resource-based view (RBV), sustained competitive advantage requires human resources and capabilities that display characteristics of rarity, imperfect imitability, value and non-substitutability (Barney, 1991). Scientists are almost unanimous in their view that human resources are one of the most significant sources of competitive advantages for organizations, and in this way, they come to the very heart of the strategic directions of organizations. Competitive advantage is based on them, and the creation of value and the value of economic entities are the result of the strategic use of human resources. The sustainability of HRM is crucial for organizations' future growth and success. It is recognized as the basis for achieving efficiency, addressing occupational health issues, managing human resources shortages, and adapting to an aging population (Mohiuddin et. al., 2022). The challenges of managing labour relations to attract and retain talent are based on fostering and increasing the participation of employee relations and sustainably managing the organization and teams (Cachón-Rodríguez et. al., 2022). Sustainable human resources management is a relatively new approach to managing people within organizations and the new approach that should help organisations adapt to the new environment. It has been evolving for nearly 15 years, but more as a theoretical concept, since practitioners are reporting that although they recognize the importance of human sustainability (76%), only 46% of them are trying to implement this concept in their business and only 10% of them are saying that they succeeded in it (Deloitte, 2024).

One of the biggest challenges companies are facing in the contemporary business environment comes from the labour market, as the consequence of demographic changes. The new generation of workers is entering the job market, and all the researches show that they are highly different from all the previous generations of employees in terms of their values, attitudes,

and work behaviour. With Generation Z or post-millennials (born between 1995 and 2012) as the newest participants in the workplace, organizations are experiencing an amalgamation of four generations at the same time. With four different generations in the workplace, organizations are experiencing a rising work-value conflict and differences in preferences in learning styles, beliefs, and communication styles (Barhate and Dirani, 2022). Taking into consideration the evident lack of workforce in the labour market, companies have to make efforts to attract and retain young employees if they want to ensure long-term sustainability. This means that it is necessary to know the characteristics of the new workforce and develop new methods and approaches to manage them. Since almost all research showed that, among other qualities, members of Generation Z are highly ethical and environmentally conscious and appreciate their work-life balance, companies should adopt principles of Sustainable human resources management if they want to attract and retain them as future workers.

2. Sustainable Human Resources Management

In response to the ever-increasing awareness and sensitivity of the world public to environmental, social, and economic problems that are a consequence of the business activities of many organizations, the readiness of the world's leading companies to prove their commitment to sustainable business is becoming more and more pronounced. In the modern world, it is increasingly becoming clear that when making business decisions, organizations must take into account the possible effect of those decisions on the environment in which they operate. In this way, they contribute to their development and growth, but also to the development and growth of society as a whole. Long-term business success is based on the decisions we make today, which must not jeopardize business in the future. This is the basis of the concept of sustainable development.

In accordance with the generally accepted concept of sustainable development, it is possible to observe the sustainable development of economic entities as an attempt to adapt this concept at the corporate level, by harmonizing the goals of value creation with environmental and social issues. In other words, it is the ability of organizations to create and maintain economic success in the context of environmental responsibility. Following existing trends, we can claim that the root of strategy and competitive advantages in the years to come will be the ability of organizations to carry out their economic activities in a sustainable manner that does not endanger the environment, and in this way, in the long term, provide themselves with the resource base necessary for both short-term and long-term success.

Sustainable development has become a generally accepted paradigm of the 21st century. Economic growth, social equality, and concern for the sustainable capacity of natural systems form the backbone of that paradigm. Although each of these elements of sustainable development has long been studied separately, it was not until 1992 at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro that politicians, non-governmental organizations, and business leaders reached a consensus that none of these three problems can be solved without taking into account the other two (Keating, 1993).

The concept of sustainability, and the phrase Sustainable Development derived from it, were officially defined for the first time in the so-called Brundtland's report published by the World Commission on Environment and Development in 1987 (Brundtland, 1987). In the Brundtland report, sustainable development is defined as a process that meets the needs of current generations without compromising the ability of future generations to meet their own needs. The 'three pillars' on which sustainable development defined in this way rests include economic, social and environmental issues. Such a broadly defined concept enabled all its

elements to be represented in the same way and to the same extent. In the short term, these elements can be viewed separately, as individually key and urgent problems, but to reach the goal of sustainability in the long term, they must all be taken into account at the same time. Moreover, they are deeply interconnected and can influence and stimulate each other.

The success of the concept of sustainable development is particularly visible at the level of economic entities, where it is generally accepted as a basic prerequisite for business (Holliday, 2001). Many of them employ special staff who deal with sustainable business issues, publish annual sustainability reports, and include sustainable development in their strategies, vision, and mission statements. Many companies launch innovative programs focused on the development of so-called green technologies (Hall and Vredenburg, 2003) and adopt environmental protection standards. After the summit in Rio, a group of conscious managers founded the World Business Council for Sustainable Development (WBCSD) to facilitate a dialogue with politicians about possible ways to achieve sustainability. Today, the council has representative offices on all continents and branches in most countries of the world. Many business executives report that the benefits of addressing sustainability accrue not only to the environment and society but also to the companies themselves, through tangible benefits in the form of reduced costs and risks of doing business, as well as through intangible benefits in the form of increased brand reputation, increased attractiveness to talent, and increased competitiveness (Dyllick and Muff, 2015). So, developing a sustainability strategy has become imperative for companies nowadays.

But developing a sustainability strategy, or prioritizing sustainability as a mission objective is one thing, and operationalizing it is another. Operationalizing sustainability will inevitably entail a shift in employees' mindsets with respect to the role they play in their organization's sustainability strategy, from sustainability being a random, occasional task to sustainability being an aspect of every part of their day-to-day job (HBR, 2023). Not only the pressures for sustainable development led scientists and practitioners to realize the need to develop more sustainable human resources strategies and activities. Many trends such as tremendous shifts in the labour market, demographic changes, lack of talent, globalization, etc. led to the development of sustainable human resources management. Sustainable management of human resources started to be discussed in the late nineties (Macke and Genari, 2019). Since then, many authors contributed to the development and clarification of the concept, trying to fill the gap between business sustainability and human resources management. According to Macke and Genari (2019), sustainability is a major principle of human resource management and it unfolds into two elements: the contributions of sustainable management of human resources applied to financial performance and organizational goals considering employees' satisfaction, commitment, and well-being; the sustainable nature of the process enables the maximization of corporate results and a decrease in damage to stakeholders.

Linking human resource management with sustainability goals helps companies in many ways. First of all, many executives are struggling to find a way to operationalize sustainability. It is a very complex task and requires all parts of an organization to be involved (all levels of organizational hierarchy, all departments and sectors, and above all, all employees). All activities of human resources management (attraction, training, development, reward system, etc) are of crucial importance for the implementation of sustainable management (Lozano and Huisingh, 2011). Some of the main obstacles for organizations come from the problems in attracting and retaining adequate employees. Due to demographic changes, especially raising awareness of sustainability issues among the young population, sustainability has become very important in attracting and retaining employees. Moreover, many of them feel proud to work in such companies and want to stay with their organizations. From the factors presented, it is conclusive that human resource management is important for environmental sustainability,

once that this process disposes tools which make it possible to mobilize employees, promote coordinated actions, and promote changes in the work process and in the behavior of the individuals (Dubois and Dubois, 2012).

2.1. Characteristics of Young Employees

Since the concept of sustainability includes a long-term perspective, organizations must necessarily anticipate future trends in the labor market in order to adapt their human resources management policies to the requirements of new generations of workers. Generational research has generalized and highlighted evolving career needs for different generation groups currently in the workforce (Barhate and Dirani, 2022). The youngest two generations currently involved in work are millennials and Gen Z. Millennials are people born between 1981 and 1995, and Gen Z were born between 1995 and 2012. Study shows that millennials easily switch jobs for an increase in pay and promotions (Smola and Sutton, 2002). The basic characteristics of the Gen Z generation are that they prefer flexible working hours, use of new technologies, hybrid work, friendly and informal contact with managers, and flat, matrix, and project organizational structures (Kawka and Borovac Zekan, 2023).

3. Research findings

To achieve the main purpose of this paper (that is, to find the best approaches to attract and retain young employees and to analyse which of their values companies should meet to do that) a quantitative survey was conducted in May 2023 using an anonymous online questionnaire (Sokolov, 2024). The questionnaire was developed based on the Deloitte Global Gen Z and Millennial Survey (Deloitte, 2023) research findings in order to examine and compare the expectations, values, and work-related attitudes of Generation Z and millennials in Croatia with their peers in other countries. 63 respondents participated in the research, and the sample consisted of people aged between 20 and 28 years, i.e. millennials and members of the Gen Z generation. All results are compared with the results of Deloitte's survey which was conducted on more than 22.000 Gen Z and millennial respondents across 44 countries and provides highly relevant data on how these generations think.

The results on Croatian respondents show that their biggest motivation in the workplace is income, but when the respondents were asked to rate the importance of this factor on a scale from 1 to 7, the majority of the answers fell to a score of 5 with 38%. This means that it is an important motivational factor, but not a crucial one, which coincides with the Deloitte research mentioned earlier in this paper. On the other hand, flexible working hours were placed as a very important factor, and on a scale from 1 to 7, the majority of respondents (30%) rated it as 6. Almost the decisive factor is flexible working hours.

Respondents were asked how important for them is personal development and training. Although salary is an important factor, personal progress and development are also important and receive almost as much approval from respondents as salary. The possibility for workplace advancement is of great importance for 38% of respondents who put it as a decisive factor, as well as the working atmosphere, which is of crucial importance for as many as 49% of respondents. The great majority of respondents highly rank freedom and creativity in everyday activities (74% give grades from 5 to 7 to this factor). All those responses match the results of Deloitte's research.

According to Deloitte's survey (Deloitte, 2023), Gen Zs and millennials continue to demand greater climate action from their employers and believe some have deprioritized sustainability strategies in recent years. They also see a critical role for employers to provide the necessary skills training to prepare the workforce for the transition to a low-carbon economy. They strongly believe that companies have a strong impact on social and environmental issues, and climate change remains a top three concern for both generations. This survey shows that Croatian Gen Zs and millennials don't consider a company's socially and environmentally responsible behaviour as a decisive factor, but a score on a scale of 1-7 (68,2% grade it between 5 and 7) indicates that it is still important for the employer to operate responsibly and sustainably.

The next set of questions investigated the entrepreneurial tendencies of respondents and their tendency to work for the same employer for a longer period. 57% of them expressed a desire to start their own business and expect their employers to train them for future independent work. As for workplace retention, the majority of respondents said that a period of 1-4 years was the period they considered staying with the same employer. 35% of respondents think that it is a good idea to change employers after 3-5 years because it provides the opportunity to acquire new knowledge and better working conditions with the new employer. When asked about changing jobs after 3-5 years with the same employer, 35% of them answered that this idea suits them and that it is not bad for a change of environment, knowledge and potentially better conditions that they can get.

For the majority of respondents, it is very important that the job is located close to their place of residence, but on the other hand, as many as 63% of the respondents are ready to change their residential address for a job that meets their wishes. In terms of travel, most respondents are willing to travel up to 20 km from their place of residence to work.

According to the results of both surveys, Gen Zs and millennials are rethinking the role of work in their lives. According to Deloitte (2023) although 49% of Gen Zs and 62% of millennials say work is central to their identity, work/life balance is something they are striving for. Having a good work/life balance is the top trait they admire in their peers and their top consideration when choosing a new employer. The vast majority of Croatian respondents do not think that employers "exploit" workers (71%) but consider work from home as the real future. As many as 49.2% of respondents believe that working from home or outside the office is the "new normal", and this coincides with the Deloitte survey. The hybrid work model (3+2) is acceptable for as many as 82.5% of respondents and confirms the desire for a better balance of life and work for the newer generation of employees. Gen Zs and millennials clearly value remote and hybrid work and see its benefits. Three-quarters of Deloitte's respondents who are currently working in remote or hybrid roles would consider looking for a new job if their employer asked them to go on-site full-time. However, it is important to stress that most of them don't feel that reducing their hours would be a realistic option as they can't afford the pay cut it would require. They also worry that their workload wouldn't be reduced accordingly and that they'd be passed over for promotion opportunities, or given less interesting work (Deloitte, 2023).

Taking into consideration that the purpose of this study is to help employers attract young employees, one group of questions examined Gen Zs and millennials' opinions about job interviews and other methods of selection. Almost the absolute majority of respondents believe that job interviews need major changes. As many as 85% of respondents think that interviews do not show their full potential, and the reason for this may be outdated questions often asked by employers. 88.9% think that the questions are out of date, and among the questions that women will often get at the interview is the family question. Women are often asked at interviews about starting a family, and 73% of respondents do not consider it an acceptable question from a potential employer. This generation simply does not accept this style of interview and the questions that the employer asks the future employee.

Analysing their views on the relationship between managers and workers, especially on their role in the work of the organization Deloitte's respondents say that they want to be empowered to drive change within their organizations. Over half of the respondents (58% of Gen Zs/55% of millennials) say their organization currently seeks input from employees and incorporates their feedback, but roughly a third (32% of Gen Zs and 35% of millennials) say decisions are still made from the top down and employee feedback is not often acted upon. Our survey shows similar results. Respondents simply do not like it when they are not respected in their daily work, and answers like "because it has to be that way" or "don't ask a lot, just do what you are told" are unacceptable for a long-term manager-employee relationship. Furthermore, regardless of the amount of income, the respondents do not like to be assigned tasks or work outside of their working hours.

Interpersonal relations are highly valued as a motivational factor. Our respondents as well as what the Deloitte research says, think that the manager should respect and encourage a different opinion, and even 93.5% of respondents think so. Respondents believe that responsibility or a sense of responsibility is a relatively important factor, and the majority rated it as 4 (49.2%) on a scale from 1 to 5. 61.9% of respondents believe that gender equality in the workplace is still a problem, which is a large percentage in this survey. Employers should work on presenting themselves as an organization that values equality and has to prove it to potential and current employees.

According to Deloitte, stress and anxiety levels are high, and work pressure is driving high levels of burnout. Nearly half of Gen Zs (46%) and four in 10 millennials (39%) say they feel stressed or anxious at work all or most of the time. Over half of Gen Zs (57%) and millennials (55%) acknowledge that their employers are taking mental health seriously, and roughly the same percentage (56% of Gen Zs and 53% of millennials) believe this is resulting in positive change. Unfortunately, in Croatia, as many as 85.7% of respondents think that employers do not pay attention to the psychological health of employees, and not a single respondent answered affirmatively, which is alarming because no one had a positive experience with employers who paid attention or had pre-set plans for the better mental health of employees. It can be concluded that the respondents believe that their psychological health is a very important item on which organisations must focus their plans and present them to future employees (as well as current ones) to provide them with additional insurance and the right intention and care for their psychological health in and out of the workplace.

Since the concept of sustainability includes a long-term perspective, organizations must necessarily anticipate future trends in the labor market in order to adapt their human resources management policies to the requirements of new generations of workers.

4. Conclusions

The fundamental contribution of the concept of sustainable development is in the recognition of the mutual influence that the natural, social, and economic environments have on each other. If we want to ensure that the needs of both current and future generations are met, we must inevitably accept sustainable development as a way of thinking when making decisions. The short-term approach to decision-making to which most business entities are inclined today has a whole series of negative consequences on their future activities.

Numerous studies show that a significant source of long-term sustainability, at the national level as well as at the level of business entities, is human resources. Human resources are also one of the significant sources of long-term sustainable competitive advantage. With their specific features, they provide key capabilities that are long-term and difficult to imitate. In this

sense, it is necessary to harmonize the strategic activities of organizations with their human resource management practices to ensure the achievement of strategic goals in the long term. In this way, the sustainable management of human resources, through the prism of strategy, becomes one of the fundamental prerequisites for achieving the long-term sustainability of economic entities.

Even though most organizations have directed their activities towards sustainability goals, the field of sustainable human resources management is still being researched and not fully implemented in most companies. The key to the successful implementation of sustainability strategies is motivated and trained employees. To achieve long-term sustainability, organizations must prepare in time for new generations of employees entering the world of work. Therefore, it is necessary to know the characteristics of future young employees in order to attract and retain them in the organization.

Many studies are exploring the characteristics of millennials and the Gen Z generation. This research analyses those generations in Croatia and compares their work attitudes and behaviors with their peers in other countries. In general, there are many similarities in research findings, and some discrepancies might be attributed to the peculiarities of the labor market in Croatia. With a higher level of youth unemployment, high level of emigration of young skilled people, lower labor mobility, unflexible companies, and lack of skilled workforce Croatia faces even more challenges in attracting and retaining young people than other countries.

So there are two basic reasons for companies to adopt sustainable human resources practices. The first reason is that it is the only way to achieve overall sustainability goals that are incorporated in almost every company's strategy. The second reason is driven by the characteristics of the young generation of employees. A great majority of them highly value environmental, social, and other sustainability issues. If companies want to attract and retain them, they have to adopt and achieve sustainability practices. And attracting and retaining young employees is a key for a long-term sustainable success of a company.

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THE EVOLUTION OF HR PRACTICES: INSIGHTS FROM SMALL AND MEDIUM-SIZED ENTERPRISES

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Abstract: In order to ensure success, entrepreneurs must possess a comprehensive understanding of human resource management (HRM) decisions. Multiple studies have shown that HRM plays a crucial role in the growth of businesses, encompassing both strategic and non-strategic tasks. Entrepreneurs and executives of small and medium-sized enterprises (SMEs) often rely on diverse networks for hiring, prioritizing psychological rewards over financial incentives. For instance, startups often face challenges in retaining highly qualified individuals in demanding and fast-paced work environments. These challenges stem from issues such as competition, uncertainty about the future of their products, unstable revenues, and the need to provide competitive compensation. Establishing a well-structured HR system is a key tool for the growth of startups and SMEs in terms of hiring new employees. The practice of HR management in SMEs is increasingly expanding due to the clear linkage between planned HR policies and the actual implementation of HR practices. Small entrepreneurs demonstrate a wider variety of HR strategies, organizations, activities, and practices. This diversity can help a company establish and maintain a competitive advantage while enhancing overall organizational performance. However, as the organization grows, HR processes become more formalized, complex, and sophisticated. The purpose of this study is to provide an understanding of the role of strategic HRM in achieving success for a SMEs with a particular focus placed on HR that might ensure long-term sustainability. It specifically examines how the strategic HRM affects the company's long-term business success. Based on the identified research issues, this paper aims to achieve the following primary objectives: describing specific theoretical and practical aspects of strategic HRM, examining the core activities of HRM focused on attaining and enhancing organizational capabilities, and illustrating the impact of systematic and thoughtful HR development on the sustained viability of an economic entity. To fulfil these objectives, the study also includes research findings from several small firms which will help to highlight the influence that systematic HR development has on the economic sustainability of a company over the long term.

Keywords: *Entrepreneurship. Small and Medium-Sized Enterprises. Human Resource Management. Contemporary Trends.*

1. Introduction

Human resource management (HRM) is a unique approach that covers an organization's operational procedures and employment strategies directed toward effectively managing its

human resources to achieve its objectives. These are activities that make people behave in ways that could enable them to develop themselves and perform their duties meeting strategic requirements as demanded by organizations. Strategic human resource management (SHRM) involves using human resources to reach organizational goals through well-coordinated HR strategies, policies, and practices. Small and medium enterprises (SMEs) also heavily rely on good HRM. The economic expansion has resulted in a rise in the need for knowledge-based information systems and competent personnel who can efficiently meet the market's demands. This demand has arisen as a result of the economic growth. Operations efficiency can be improved through the integration of human resource information systems while at the same time raising productivity levels together with employee satisfaction. Knowing HRM in theory as well as practice comes in handy during understanding challenges faced by entrepreneurial firms like resource acquisition or allocation among rapidly growing firms where these factors affect growth. Employee behaviour is controlled by HRM practices which aim at influencing business performance. This paper seeks to accomplish the following main objectives based on the identified research issues: providing a detailed explanation of the theoretical and practical aspects of HRM in SMEs. Additionally, it aims to analyze the key activities that are aimed at achieving and improving organizational capabilities, and demonstrate the influence of systematic and carefully planned HR development on the long-term sustainability of an economic entity. In order to achieve these goals, the study incorporates research findings from few small companies in the framework of a case study. This will serve to emphasize the impact that systematic human resources development has on the long-term financial stability of a company.

2. Human resources management

The rise of human resource management practices was due to the booming European economy which required efficient control over the growing labor force (Itika, J., 2011). As time passed, organizational management saw structures develop, leadership established and roles assigned. Since the 1980s, there has been a lot of literature about HRM. It is about management choices that rely on procedures and rules that determine the working relationship and seek to meet performance standards. In addition to fostering organizational effectiveness, performance also fosters social and employee well-being.

According to B.B. Mahapatro (2010), Human resources management can be defined as that part of management concerned with:

“All the decisions, strategies, factors, principles, operations, practices, functions, activities, and methods related to the management of people as employees in any type of organization.

All the dimensions related to people in their employment relationships, and all the dynamics that flow from it, and

Adding value to the delivery of goods and services and the quality of work life for employees, thereby helping to ensure continuous organizational success in transformative environments.”

Effective management encompasses various corporate resources ranging from design, production, quality control, finance, sales, and customer service, all of which involve putting up appropriate mechanisms for meeting consumer needs. For entrepreneurs, turning an idea into a viable company cannot be overstated, and human resource management has a significant impact on the coordination and generalization of work organizations (Burns and Dewhurst, 1996). It involves the management of people who are strategically important for the achievement of an organization. The company's ability to optimize material resources depends on having skilled and motivated staff members, and their effectiveness is a function of the combination of knowledge, expertise, and mindset (Uyar and Deniz, 2012).

The heart of HR functions consists of all the activities, practices, roles, responsibilities, and systems performed by organizational members, whether managerial or non-managerial (Schuler, 1995). Human resource planning is conducted during company growth to cater to future needs, while recruitment helps to get job applicants. Staff undergo orientation and training programs that develop their efficiency and assessment of employee performance is a necessary step in determining the effectiveness of such actions and the areas that still need improvement. For plans that already exist, additional requirements can be met through the recruitment process and personnel development. Performance compensation encompasses remuneration such as wages and salaries, along with social security contributions, secure working conditions, and overtime pay for work done beyond normal hours, including legal compliance services. Furthermore, communication as well as counseling schemes are used to maintain employee relationships (Uyar and Deniz, 2012).

Organizations' HRM procedures enhance performance greatly. The care taken in implementing a firm's human resource practices matters for its ultimate success since this accounts for about half of the total effect on a company's financial outcomes (Osman et al., 2011).

2.1. HRM in SMEs

The primary focus of the HRM discussion in SMEs has been the comparison of practices between large enterprises and small businesses. These include employment processes, training systems, employee empowerment, reward systems, and the role of trade unions (Tang, Y. et. al., 2007). However, little attention has been given to the various implications of HRM on performance in SMEs and large corporations or how HRM policies may affect business performance in general. However, there is a weak link between management training and the performance of SMEs. When an organization grows from being a start-up venture to a mature company with hundreds or even thousands of employees, it becomes necessary for them to adopt more sophisticated people management practices, such as HRM (Karami et. al., 2008).

Most SMEs do not have HRM departments, and all key decisions are made by the managing director or owner. Rather than being implemented through a comprehensive or systematic strategy, HRM in SMEs is often unstructured, emergent, and reactive. Consequently, there are two perspectives on HRM: 'Bleak-House' and 'Bright prospect' (Harney and Nolan, 2015). The 'Bright prospect' school of thought suggests that there is a high rate of adoption of HR practice and argues that this results in improved social relationships and easier job assignments because there are fewer bureaucratic controls (Wiesner and McDonald, 2001). In contrast, the 'Bleak-house' perspective suggests that employees in SMEs endure poor working conditions, poor health and safety standards, and limited access to trade unions, thereby increasing the chances of conflicts, turnover, and absenteeism (Wiesner and Innes, 2010). Unlike traditional human resource literature, which has formal communication and control systems, modern HRM literature incorporates more sophisticated approaches that often employ informal management techniques to exert influence over individuals. Due to budgetary constraints, owners may delay implementing a formal HRM system to avoid higher costs. To survive business activities, SMEs require some diverse yet partly standardized HRM practices in areas like recruitment, selection training, and reward systems. The workforce skill mix determines how an organization implements its HRM policies (Storey, 2001). Therefore, small firms with a higher percentage of talented employees are likely to invest in human resource management strategies that will enhance employee retention schemes, while those with a lower proportion of low-skilled workers may not find it necessary for their adoption (Bamberger and Meshoulam, 2000).

To take a step towards the open systems perspective of understanding how internal and external factors influence HRM in SMEs, it is necessary to understand the contextual nature of business. Therefore, three major perspectives have been found by researchers exploring the origins of human resources management in small businesses, which include looking at the industry or sector within which they operate, organizational or family culture, and the business environment under which any particular small enterprise operates (Dyer and Reeves, 1994; Harney and Monks, 2014).

2.2. HRM practices: insights from SMEs

Most studies concentrate specifically on various HRM practices such as recruitment, selection, training, appraisals, remuneration, and interpersonal relations. However, recent research has shown that HRM is relevant for SMEs, where results indicate that smaller firms also should have HR practices as well as big enterprises. In addition, a recent study has identified new management approaches within SMEs about cooperation and coordinated activities, job flexibility, decentralization, and work performance reviews (Zakaria et. al., 2012). These innovative HR practices that are advancing are not only limited to large companies so small businesses can benefit from them when they are implemented correctly.

Competitiveness is bound up with human resource capabilities, while human resources may influence organizational performance in the long run, thus acting as sources of sustainable competitive advantage while also serving the purpose of HRM. It becomes necessary for small-scale enterprises to have better knowledge about how different HR strategies could be efficient if they want to see their performances change (Adla et. al., 2020). The impact of an effective policy on human resource development has been examined by many scientists, showing that motivated employees with special skills can determine whether a firm will remain competitive or not in today's market-driven economy (Boeslie et. al., 2019). Thus, human resources play a major role in changing small firms' growth and development, and this area needs attention by SMEs if they want improvement in their operations through the effective implementation of good HRM policies.

No sooner does a new market or service opportunity for an invention that is technology-based come up than innovation's iterative process begins, encompassing development, production, and marketing functions. It is not uncommon for SMEs to have an emergent innovation strategy, but better results can be achieved by executives who use both planned and formalized approaches. Human resource issues such as poor training programs, management's attitude towards change and risk-taking, and a low level of experience among employees can negatively impact SMEs (Wilkinson, A., 1999). This causes managers to ask themselves whether they should bother with their HRM department when it comes to promoting innovation within their company. To understand the connection between HRM in SMEs and innovation, researchers consider aspects such as official recruitment procedures like application forms versus informal ones like word-of-mouth approaches. In the first view, hiring is mostly done by word of mouth, and HRM practices are often informal with a focus on leaders. The evaluations are random, which means 'on-the-job' training and coaching, work best at times.

From the second viewpoint, however, informal HRM practices promote stronger employee loyalty to projects than any other practice, thereby cementing the ties between workers and their managers in these small firms. SMEs' human resource systems should be geared towards turning HR into a genuine engine for innovation by adopting innovative strategies (Adla et. al., 2020). HRM encourages experimentation, risk-taking, and teamwork, hence supporting innovative strategies. Trust relationships must exist among all concerned participants whenever there are particular methods put down by HR managers to bring out the best in SMEs.

The practice-based approach to HRM and innovation is descriptive and simplistic due to its influence on interpersonal interactions. As a result, many questions remain even after adopting a relational perspective that considers many HRM practices (Boselie et al., 2019). However, the mechanisms linking HRM and innovation in SMEs remain largely unexplored, but it is important to develop HRM and innovation in small businesses to build relationships with them.

A lack of management training impedes SMEs' development due to information gaps and limited resources, so it is a bit challenging to effectively manage personnel. Changes in production technology advances in process and product technology and job satisfaction are some factors affecting human resource training approaches. Quality assurance, technical writing materials and processes, safety project funding innovation, and commercialization configuration management form part of the courses that must be taken by small and medium-scale businesses. Despite a lot of research being focused on human resource practices in SMEs from a theoretical standpoint, very little has been written about this area (Shafeek, 2016). Some researchers concentrate much more on the theoretical aspects of SMEs within HRM, while others deal with HRM practices within SMEs. However, there is a consensus around the relationship model of the basic components of HR management in SMEs (Shafeek, 2016), which can be seen in Figure 1.



Figure 1 Model of the relationship between HR components

Small and medium-sized enterprises (SMEs) with high employment rates that make significant contributions to economic growth are important for the nation's economy. Moreover, small firms exhibit greater use of HRM practices like training, yet there is a paucity of research on strategic human resource management (SHRM) in SMEs. However, smaller firms operate more flexibly than larger ones, and firm size is often seen as a moderating variable. Equally, HR experts play a critical role in establishing and maintaining a competitive advantage in SMEs, their innovative contributions greatly affect the success of the company. This can only be achieved when businesses approach their strategic HR procedures using a strategic mindset for desired outcomes. SHRM refers to a system encompassing goal-oriented actions and programmed resource allocations aimed at achieving organizational goals (Knezović et al., 2020). Its foundation is based on both internal and external alignment with business objectives. For strategic HR to bring about results, it must conform to both internal and external company goals. While less researched than large corporations, evidence shows that strategic HR practices affect performance in SMEs too. Performance depends upon an understanding of how HR operates within SMEs, which will enable them to achieve good performance levels.

Research findings from interviews with eight business owners in small enterprises are presented in the next chapter aiming to highlight the influence that systematic HR development has on the economic sustainability of a company over the long term.

3. Outcomes from interviews with SMEs owners

In this study, semi-structured interviews were conducted among eight small businesses to identify how the lasting economic sustainability of a company is affected by planned HR development. The main research questions regarding HRM practices are outlined in this paper. The interviews were carried out in six different areas, explained by the owners, who were requested to give each area a score between 1 and 5, with 1 representing strongly disagreeing and 5 strongly agreeing. Moreover, these areas acted as a basis for deeper conversation. These were selected businesses from the University Department for Professional Studies business cooperation agreement database with business entities that offer internship opportunities to students. This brings together companies from various sectors, such as computing, trade, tourism, and the hospitality industry, thus giving a wide range for analysis. However, such heterogeneity somewhat restricts this study, but still, the findings shared here about small enterprise owners' experiences can be used as significant inputs into further research on understanding their knowledge about HR management policies and practices within organizations. Average ratings will be presented in addition to detailed information concerning responses given to six main interview questions as shown in Figure 2.



Figure 2 Grades from interviews with SMEs owners (mean)

The first question addressed the assessment or perception of small business owners regarding the degree of systematic implementation of human resources (HR) development strategies and practices within their companies. The average grade for this question was 3.25, which means that there is a medium level of systemization. However, this does not show that there are no areas requiring reorganization or improvement as far as HRD is concerned; it only suggests that such places exist alongside some degree of orderliness or structure already present in terms of HRD. Therefore, what the response implies is that proprietors acknowledge both the strengths and weaknesses of current approaches to HRD within their firms, without strongly favoring one side over another (full implementation versus none at all). It can be used to further probe into specific areas related to human capital enhancement within the organization.

The second question focused on the owner's opinion about the necessity of implementing systematic HR development within their company. Owners demonstrated strong belief in these measures by awarding them an average rating of 4.5. This implies that most owners think that, without human resource development programs, no firm can grow or succeed sustainably in the long run. It denotes an intense correlation between an employer's vision for the organization and how much strategic weight is given to personnel training as one of many organizational

goals' supporting structures. This may indicate deep comprehension regarding the benefits associated with good planning and implementation of such strategies geared towards staff capacity, building an overall competitiveness improvement within enterprises.

The third question aimed to gauge the owner's perception of how effectively current HR practices contribute to the economic sustainability of the small company. The company's economic sustainability is believed to have been greatly enhanced by current HR practices, according to owners, who on average gave it a grade of 3.88. For instance, there may still be areas in need of improvement or perfection. However, this also reflects very high levels of satisfaction with the way things are done. Human resources management is important as well as staff involvement in setting goals and objectives meant for growth and business performance improvement strategies development.

The fourth question sought to understand the owner's perspective on the impact of HR development initiatives on the company's financial performance over time. The grade point average of 4.78 implies that the owners believe that HR development programs have had a substantial positive effect on the financial performance of the company in the long run. This means that proprietors see a close relationship between investments in human resource growth and better profit margins achieved by the organization. It also shows that business owners attribute much of their financial success to how good they think these systems are at improving staff productivity, engagement, or even general organizational efficiency.

The fifth question inquired about the owner's conviction regarding the importance of HR development in ensuring the long-term success of the small company. With an average grade of 4.88, owners expressed a strong and unwavering belief in the importance of HR development for ensuring the long-term success of their companies. This response suggests that owners view HR development as a critical strategic investment rather than merely a supportive function within the organization. It suggests that employers acknowledge the importance of good HR planning and implementation in molding organizational culture, promoting employee commitment, and encouraging the growth of skills within the workforce, which in turn helps towards meeting business targets. This may show a strong awareness of how successful personnel management can boost overall corporate achievements, thus indicating an intention to make human resource development a priority for long-term success and expansion in companies.

The last question aimed to understand the owner's level of optimism about the future impact of HR development initiatives on the economic sustainability of the small company. Scoring an average of 3.88, the highest score possible on this scale indicates that owners have a very high level of confidence in HR development initiatives' future influence on the economic sustainability of their companies. This means that they believe there will be more growth and success if investments are continued in human resource development. This implies that the organization expects these strategies and plans to enhance its competitiveness, improve its financial performance, and ensure its long-term existence. Here, it indicates owners desire changes in HR programs or activities beyond what has already been done. These enhancements would strengthen competitiveness with other enterprises and ultimately result in better financial outcomes.

4. Conclusion

Changes in technology, combined with shifts in dynamics and attitudes among people, are altering the characteristics of the business environment, making it more complex compared to earlier periods. Organizations, no matter on their size, have begun to perceive human resource management as a job and function that involves a comprehensive understanding of

the organization and contributes to key corporate policies. The focus of today's human resource management is not only on acquiring talent but also on retaining it.

Analyzing all the trends mentioned, it can be concluded that the focus of human resource management in contemporary small businesses is on acquiring and retaining talented employees, training and developing employees, and workforce flexibility. These tasks are achieved through a series of human resource management activities aimed at ultimately ensuring the achievement of the company's strategic objectives. The role of human resource management is to ensure that the human resources of the company create a competitive advantage. The challenges that companies face in this regard require organizations to position themselves in the market proactively and strategically.

The replies of the owners show that they seem to believe in systematic HR development's impact on economic sustainability in small firms. In other words, the owner has an optimistic attitude towards HR development strategies and practices, believing that they can improve the financial performance of a company and ensure its success over a long period. Furthermore, it is strongly believed that for economic sustainability to be achieved, there must be some developments in human resource management, along with hopefulness about what HR will bring in the future. However, this does not mean everything is perfect as per the system presently used since there could still exist areas where such methods may need some polishing or even a complete overhaul to better serve the organization's economic goals. Overall, the replies demonstrate a proactive approach to HR management and a commitment to utilizing human capital as a strategic resource to promote corporate success and sustainability.

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APPLYING THE CONCEPT OF DESTINATION MANAGEMENT ORGANIZATION IN CROATIA

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Abstract. The current model of tourism organization in Croatia has many disadvantages such as organization by administrative division, weak coordination, unclear division of tasks and responsibilities what causes a need for a different way of organization and management, which is also assumed in the Croatian Tourism Strategy by 2020. This paper gives insight to importance of applying the concept of destination management and explains the reasons of need for more efficient and functional way of organizing tourism at all levels. This concept assumes reorganization of the existing tourist board model and their transformation into destination management organization (DMO) which requires different legal, administrative, strategic and organizational determinants. Every local board represents the area where tourism activities are taking place directly and their uniqueness requires special organization that will not be generalized. Destination management is a key aspect of sustainability and competitiveness. For these reasons DMO should, using strategic management skills, turn itself into leader and developer of the destination, and this is why this kind of organizational structure is the only precondition for optimum and efficient functioning. Further prerequisites are the understanding of lifelong learning as an essential process of business improvement and investing in cooperative and stimulating interpersonal relationships with highlighted wellbeing and career opportunities. The issue of tourism development and destination management should be a matter of continuous development.

Key words: *destination management organisation (DMO), tourism, tourist board, learning and development*

1. Introduction

The concept of modern tourism cannot be imagined without organization. That is the main management tool when discussing tourism organization. Geić, S. (2007, p. 124) describes the character of tourism as a complex and spatially widespread phenomenon which needs to be coordinated and effective. Development and self-sufficiency of tourism increases the problems of organization and impose the need for efficient organizational system. That is why tourism organization is an essential condition and measure of tourist development of each country, region and tourist place. Borzyszkowski J. (2013) says that destination management organizations (DMO) are primary organizational units which are responsible for tourism development in destination. The main task of destination management is creating adequate division of tasks and responsibilities. The essence of this concept is implementing strategy that can transform and

reorganize current model of Croatian tourist boards into destination management organizations. Existing organizational model should be revised in order to respect the principles of destination functionality instead of principle of administrative division.

2. Importance and business mission of destination management in destination development

Magaš, D. (2008. p.10) explains that destination management is incorporated in different destination subsystems. Each of them, depending on their competences and level of action, contributes to successful satisfaction of guests. Magaš (2008) also considers that decentralization and fragmentation of tourism offerings are often limiting factor of competitiveness of tourist destination, hence the importance of coordinated action and management of all levels of destination management, as well as business relationships that become unavoidable in strengthening the destination competitiveness. The role of destination management is concerned with the overall tourism development and unification power of public and private sector as well as ensuring greater profitability for economic entities that directly or indirectly participate in creation of tourism products in destination area. DMO must use the knowledge to strategically assess the strengths and weaknesses of destination, align the resources of stakeholders in order to formulate competitive and sustainable strategy. Successful DMO of the future will be an intelligent agent of destination that is able to identify, engage and learn from disparate stakeholders both within and outside the destination. It must acquire, filter, analyze and prioritize data and information from various sources to create knowledge that can be used to fulfill its role in destination management (Presenza, Sheehan and Ritchie 2005). Varghese and Jose Paul (2014) explain that DMO is the nerve center of destination that holds crucial information pertaining to the market, helps coordinating and controlling the flow of tourists, tackles present trends and challenges creating a platform for all stakeholders to come in contact with all potential tourists. Further, Varghese and Jose Paul (2014) conclude that DMO deals with many task categories; management, destination competency, governance, quality control, stakeholder management, infrastructural development, marketing, and eventually leads to set a benchmark that constitutes a standard of quality services and tourist products that is offered to tourists. Gržinić and Saftić (2012) explain that main precondition for destination improvement is applying an efficient system of management of a specific tourist destination, representing important fact in uniting partial interests of destination's multiple stakeholders, in order to create an integral tourist product for a specific destination. According to Volgger and Pechlaner (2014) previous research claims that DMO is capable of actively fostering collaboration between destination stakeholders which are key to ensuring destination's competitiveness. One key insight is that the effect of networking capability works through increased DMO authority also enhancing the power and acceptance of DMO. Upadhya (2014) notes that the role of DMO has traditionally been more focused on destination promotion that later grew and got expanded and shaped to facilitation which coordinates tourism service for the inbound tourists to destination. Destination management organization manages and coordinates the work of various stakeholders that have different interests. Tourist organizations on a destination level have common functions: research, marketing and development which are integrated and coordinated by destination management (Bosnić, Tubić and Stanišić, 2014). When considering problems with DMO functioning, Bieger, Beritelli and Laesser (2009) assume that current challenges require a critical budget and product-oriented regions, with rather centralized marketing and management. Therefore, the reach and boundaries of destination areas must be evaluated and, in many cases, redefined. According to WTO guidelines (2005), and mentioned by Padurean

(2010) need for government funding is necessary but they recognize the promotion as a skill-set better suited to the private sector, so future research should look into whether destination management organization can and should be outsourced to the most competent and competitive private players while the whole process is governance controlled.

3. Current model of tourist organization in Croatia

Čavlek, N. (2011 p.99) explains that the system of tourist boards at the beginning of the nineties of the last century had to change because of the new socio-political and economic relations they had established by the autonomy of Croatia. There was a need to adjust the old arrangements on new conditions. Therefore, in 1991 the Law of tourist boards has changed the existing organization and alliances which were replaced by the system of tourist boards according to the Austrian model. The Austrian National Tourist Office is ANTO. Furthermore, tourism organization branches to nine provincial tourism organizations. Regarding to Austria National Tourist Office the provincial tourism organizations were founded on the geographic-historical principle (Tirol, Upper Austria, Lower Austria, Burgenland, Carinthia, Styria, Salzburg, Vienna, and Vorarlberg). On first sight, tourist organizations of Austria correspond to the Croatian county tourist boards, and that was one of the reasons why this model was applied in Croatia, but negligible difference is that Austrian tourist organization fully functions according to the destination management model, it is harmonized to geographic and historical principles and they are all self-sufficient, which cannot be told for all Croatian tourist boards. According to that we can assume that right from the beginning, decision for applying this Austrian model had two problems which are reconsidered now when talking about DMO model; existing model was too administratively focused and insufficiently adjusted to Croatian opportunities of tourism organization. Later then, a few law corrections in 2004. and 2008. were made in order to enhance and extent the power of tourist boards, foster their productivity considering the public funding and create better collaboration between state and private sector. Current organizational structure is shown in Figure 1. Structure faithfully describes the size of bureaucratic system.

ORGANIZATION OF TOURISM IN CROATIA
· Main Office of the Croatian Tourist Board
· 20 tourist boards counties;
· 9 tourist boards areas;
· Zagreb tourist board City Council;
· 118 tourist boards cities;
· 139 tourist boards municipalities;
· 14 tourist boards small tourist posts.

Figure 1 Organization of tourism in Croatia

Source: Ministry of Tourism of the Republic of Croatia, 2015.; <http://business.croatia.hr/hr-HR/Hrvatska-turisticka-zajednica>

According to this division, organizational structure is too big, with many branches which do not always guarantee good implementation and goal achievements. Figure 2. describes main disadvantages of current model.

PROBLEMS OF EXISTING MODEL OF TOURIST BOARDS IN CROATIA
· The system is too large and irrational
· Business missions and tasks set by the existing law are not appropriate
· There is no clear division of responsibilities in tasks that are shared among the different system levels
· Inadequate coordination and control between the levels of the system
· A large number of complex tasks aimed at local levels of TZ that often surpasses their needs and opportunities;
· Main office overloaded with tasks that cannot be objectively executed (elements with tourist product development, development projects, responsibility for the diversion of resources for tourism, areas in development, etc.)
· The system is very politicized and bureaucratic
· The county has prescribed extensive tasks and assigned small budgets
· Non-standard patterns of budget spending due to the realized turnover among units at all levels - lack of standards and control.

Figure 2 Key problems of existing model of tourist boards in Croatia

Source: adopted from: "Operativni priručnik za primjenu modela destinacijske menadžment organizacije(DMO)", Ministarstvo Republike Hrvatske; Hrvatska turistička zajednica, Zagreb, 2013.

4. Applying the model of destination management in Croatia

Implementation of destination management principles in Croatia is at an insufficient level of development. Lončarić, Bolfek and Stanić (2014) notice although Croatian tourism practice still does not apply the formal model of regionalization, the world has different models of implementing tourist organizations, where the starting point for the connectivity means the existence of a full tourist product at tourist destination level. Avakumović, Čorak and associates (2008. p. 21) as main argument for destination management organization point out the independence of the administrative boundaries and according to that, a meaningful and logistically designed management system. Respecting the specific spatial, historical and other specificity or homogeneity of some unit, we obtain attractive and functional entity called tourist destination. Ministry of tourism concludes that the current system of tourist boards is not involved enough in creating and implementation of tourism policy also considering the fact that their legal responsibilities are not agreed with the implementation options. According to strategic plan of Croatian Ministry of tourism and "Operativni priručnik za primjenu modela DMO (2013, p.19) "Regional and local implementation plan of destination management concept means reorganization of current tourist boards in Croatia. The plan is to create a regional management organization for Istria, Kvarner, Dalmatia - Zadar, Dalmatia - Šibenik, Dalmatia - Split, Dubrovnik, Zagreb, Lika - Karlovac, Slavonia and central Croatia, where the biggest changes should take place. These 10 tourist regions would be divided according to the Strategic Plan of Croatian Tourism. This process would also mean reducing the number of local boards, which in this case applies to continental Croatia, while those in the coastal part mostly remain the same. The plan is to include in Central Croatia Krapina-Zagorje, Varaždin, Koprivnica-Križevci, Međimurska, Bjelovar-Bilogora, Zagrebačka and Sisak Moslavina County. RMO Slavonia would thus include Virovitica-Podravina, Požega-Slavonia, Brod-Posavina, Vukovar-Srijem County and Osijek-Baranja.

4.1. Proposed model of tourism organization

According to Croatia's Tourism Development Strategy by 2020, destination management should have the following management model in Croatia:

PROPOSED MODEL OF TOURISM ORGANIZATION
NTO (National Tourism Organization as the main body that sets rules and strategies)
RMOs (Regional Management Organizations as bodies responsible for operational activities with some strategic elements and coordination of lower order strategies between DMOs)
DMOs (Local Destination Management Organizations responsible for operational nature of tasks, except in the case of some destinations whose brand has global attractiveness and thus assume greater authority within the region)
TIC (Tourist Information Centers operating within DMO organizations as affiliates and performing the function of informative support to visitors)
DMK (Destination Management Company as a professional company that sells its services on the market, the precondition for their optimal business is the above-mentioned organization)

Figure 3. Proposed model of tourism organization in Croatia

Source: Official website of Ministry of Tourism: <http://www.mint.hr/>

Blažević, Magaš and Ivanović (2008) discuss about regional and territorial organization from 1850. and conclude there are many irregularities in regionalization in the Republic of Croatia. There is a fragmentation or an inappropriate county framework, too narrow for optimal decentralization of state functions. They also point to need for establishing tourist destination as the fundamental institutional framework for designing the concept of successful tourism development. It emphasizes the need for the delocalization of spatial content, which means that an approach to observing the region as an open system should be followed, which will encourage and not restrict inter-regional relations.

4.2. Models of forming DMO's as the main organizational units

Petrić (2011, p.192) explains that Destination Management Organizations can be organized into several models according to UNWTO (2010.) guidelines.

MODELS OF FORMING DMO'S AS THE MAIN ORGANIZATIONAL UNIT
A department of a public authority
Partnerships of various authorities / institutions of public authorities acting alone
Partnerships of various authorities / institutions of public authority with a joint management body
The body of public administration serviced by private companies
An association or a company funded from the private sector (partnerships)
A public-private partnership covering certain functions (in the form of non-profit institutions)

Figure 3 Models of DMO formation according to Petric., L. (2011.) and UNWTO (2010.)

Source: Authors

Morrison (2013 p. 34) says that there is no standardized structural template for a DMO because every destination has it's own unique character and specific historical, geographical and other determinants which represents the criteria for their constitution. Čavlek (2011. p.100) concludes that touristic organizations / tourist boards are the meeting place of the public and private interest in tourism, a place where different stakeholders meet and negotiate, cooperate and achieve common interests.

5. Expectations of applying DMO in Croatia

Aflić (2016) considers that tourist boards like DMOs would represent the body which manages development of tourist destination offerings, contributes to progress of Croatia tourism and life quality of local population, serving as a link between the stakeholders of private and public sectors. Optimum model of DMO has to be based on promotional, innovative, managerial, coordinating, organizational and informational template that would manage to perform sustainable development of destination. There is a need to expand the tasks, strengths and functions of tourist boards that supposed to be destination tourist development coordinator. According to Croatian Tourism Strategy 2020, new organization of tourism board systems as a tourism management mechanism is most important at the lower, local unit level. In order to ensure the preconditions for establishing DMO's, local tourist boards have to pass through the process of transformation on many different levels.

6. Suggestions for constituting DMO organizational model

It is very important to have management structure of destination and clarify DMP (destination management plan) which is theoretical starting point that conducts research activities and measures the effects and creates a vision of strategic plan. These measures refer to increase functionality of existing legal framework through better regulation of necessary procedures and also giving more authorizations in administrative and financial aspect. Tourist boards in Croatia have non lucrative (non-profit) character, but these regulations should be modified in order to achieve more significant financial results and better cooperation between public and private sector. Laws should be changed in procedural and functional terms because current situation implicates on development constraints, stopping the operational strategies when implementing destination management process. Each DMO must work to ensure long-term sustainable development, recognize and exploit own attractiveness potential, have a vision and goals that will be able to control and review the satisfaction of visitors and local residents by working continually to achieve competitive advantage. Croatia has to follow the standards and current process in destination management due to increased competition, increasing tourist demand and changes in consumer characteristics all in order to survive on the tourist market.

DETERMINANTS FOR CONSTITUTING SUCCESSFUL DMO
LEGAL FRAMEWORK
· adjusting organization goals with law framework
· changing lucrative (profitability) character of tourism boards
· constitution of new administrative boundaries
DEFINING TASKS
· strategic approach to managing operations
· reorganization of existing board model
· clear division of tasks and responsibilities
PROCESS OF TRANSFORMATION
· complying legal framework of organization model
· following objectives
MONITORING
· coordination between local, regional and national level

· budget control
· efficiency
· quality control

Figure 4 Authors suggestion for constituting determinants of successful DMO

Source: Authors

There is little doubt that tourism is an important generator of jobs. The cooperation between a tourism worker force, education and tourism researcher is essential. Adequate destination management development requires the understanding of lifelong learning as an essential process of business improvement and investigation in cooperative and stimulating interpersonal relationships with highlighted wellbeing and career opportunities, whereby the issue of tourism development and destination management should be a matter of continuous development.

CONCLUSION

Destination management is a key aspect of competitiveness and sustainability. Applying the concept of destination management is necessary in order to overcome the existing organizational problems and reducing uncertainty in managing operations. Destination management has better foundations to constitute more serious administrative body. Strategic approach of having destination in focus, without thinking just about the boundaries is the core of this concept. Despite of boundary frame, local tourism organization of the area has to be determined on the basis of natural, resourceful, historical and other similar features. The emphasis is on creating a product that meets economic standards while at the same time stays compatible with the natural structure characteristics of the region. Considering this fact, we can assume that destination could consist more legitimacy, including better organizational, legal and monetary linkage. DMO activities should be expanded to a broad range in order to increase operational efficiency. DMO should have leading role which can only be achieved by transformation and reorganization of existing model considering the change of many legal frameworks.

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CAN THE MICROALGA MARKET BE LONG TERM? A COMPANY PERSPECTIVE

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Abstract: This research combines the investigation on the contributions of the AlgoSolis laboratory in the development of innovations, emerging new fields and start-ups and the analysis of LLDC Algae, a company located in the West of France. Using both point of view will help to understand the opportunities and threats, as well as the key factors of success in the microalga market.

This research objective is to present the resources conditions and the necessary expertise to develop microalga transformation for different markets, to support a sustainable agriculture.

Two industrial applications seem to be more promising in our context of renewal solutions to support a low environmental impact: greenfeed for the animal feeding and green crops that propose crop supplements based on microalga. The company LLDC Algae targets the needs of both markets thanks to its expertise and to the high-performance proposal compared to traditional solutions.

We are looking for the adopters' factors to increase the implementation of these solutions.

Key words: *microalga, innovation, sustainable agriculture, case study*

1. Introduction

Microalgae are unicellular microorganisms found in aquatic environments. They are a sustainable source of biomass rich in nutrients such as proteins, lipids, vitamins and antioxidants. The microalgae market is growing rapidly, driven by increasing demand for healthy, sustainable food ingredients: they are widely considered to be one of the most environmentally and economically promising natural resources. Certain species of microalgae have extremely rapid growth rates. With an estimated number of 30,000–1,000,000 species, microalgae represent an exceptional natural resource to explore for the 21st century that combines numerous advantages, such as original metabolisms and chemical compositions, fast growth, high photosynthetic efficiency, non-competition for farmlands and tolerance to wastewaters during cultivation (Rumin et al., 2020).

They can convert CO₂ into a variety of value-added products. Microalgae are highly interesting microorganisms for CO₂ capture due to their efficient photosynthetic capabilities, rapid conversion of this gas into biomass, and ability to grow without the need for agricultural land. In addition, wastewater treatment and the production of value-added components, raw materials for aquaculture, and environmentally friendly and sustainable biofuels can also be achieved using microalgae cultures for CO₂ capture. Finally, the energy and economic costs of implementing this technique are low compared to other techniques currently being investigated. This makes the use of microalgae an even more attractive option for reducing atmospheric CO₂ levels and slowing global warming. Microalgae biotechnology is taking part to the global economy by processing valuable biomass for human-related utilisations (Fernández et al., 2021), such as bioplastic production (Chong et al., 2022), bio energies (Chong et al., 2021, Wang et al., 2021), and environmental monitoring (Peter et al., 2021). Microalgae can enrich considerably the bio economy (Fernández et al., 2021, Yong et al., 2021) thanks to the development of existing processing capability and to the proposal of new applications.

The total microalgae market is estimated to reach USD 4.6 billion by the year 2027 (Show, 2022).

This is due to the increasing awareness of the valuable functional compounds possessed by microalgae and the benefits they can provide in terms of sustainability compared to current methods of food or energy production¹. Therefore, this promotes the awareness of using microalgae biofuel as an enormous potential to displace or even replace the \$2.1 trillion fossil fuel industry (Curtin et al., 2019). Microalgae have also been introduced as a source of biofertilizer processing, biochemicals, and biochar for wastewater treatment (Khoo et al., 2021). It has many uses and can suit a wide range of industries, making it a highly valuable resource. Currently, the microalgae market seems to offer potentials, but stay with a limited number of players. We will try to answer to the following questions, as they may lead to a better understanding of the existing context. What are the opportunities and threats in the microalgae market and can be game changing? What are the key variables for the Green Crops Business Unit in the macro-environment?

It is necessary to design an economic model adapted to take both advantages of, first, technical innovation in agronomy and animal husbandry to improve yields by around 20%, and on reducing losses and waste to increase production by an additional 10 to 20% (Rastoin, 2016)². To help the development of economic viable models, we need to get some information and answer to the following questions. What are the Success Key Factors that can have an impact on the profitability? How the constraints and operation of the industrial process, optimization and limits of application, potential for exploitation can influence the sector?

“Biofertilizer” is a substance that contains living microorganisms that, when applied to seed, plant surfaces, or soil, colonize the rhizosphere or the interior of the plant and promote growth by increasing the supply or availability of primary nutrients to the host plant (Ritika et Utpal, 2014). *Chlorella* sp. was revealed to increase about 30% the wheat plant length, so it could be proposed as a probable substitute to chemical fertilizers to rise soil fertility (Rumin et al., 2020).

LLDC Algae seems to have solved a major problem, namely low sun exposure, by combining the production of microalgae with earthworm digestate. This market is still in its infancy, although yields from vegetable and wine crops are very encouraging. Numerous patents protect its industrial activities. How the case study of a company highlights major characteristics of the environment and propose management and collective interest recommendations?

1 Wood, L. (Éd.). (2022, 17 janvier). Global Microalgae Market Trajectory & Analytics Report 2022: Robust outlook for Nutraceuticals Strengthened by pandemic induced focus on immunity Drives Opportunities for Algae - ResearchAndMarkets.com. Business Wire. <https://www.businesswire.com>, le 21/05/2024

2 Le secteur des micro-algues en Méditerranée. IPEDMED, études et analyses., le 19/04/2024

This paper objective is to present a new combination of technologies implemented by a French local company that proposes a range of bio fertilizers. The adoption of such products may induce a game changing in the market, as the European regulations push farmers to use healthier agricultural practices to help the development of a more sustainable agriculture.

In this article, we will present a market analysis giving the key variables for the Green Crops Business Unit and the Success Key Factors for players. It will be followed by the methodology used to present the company and its data. We will conclude this paper by proposed recommendations.

2. Background and market analysis of microalgae

2.1. Analysis of the macro-environment and identification of key variables for the Green Crops Business Unit

Assessing the economic viability of models based on microalgae cultivation can be challenging due to the technical nature of culture selection, the diversity of applications in different markets and the type of algae used. Based on the idea that the yields obtained from micro-algae are comparable to those obtained from other solutions for supporting agricultural productivity, the analysis suggests that the large-scale development of micro-algae farming for agricultural purposes is dependent on two uncertain variables: public regulatory support, and the potential for significant technological advancement. Relying on the market for soil fertilization only, we can shape this diagram to evaluate long-term options for this market. The scenario method (Reynaud, 2001) can identify two crucial variables for designing long-term objectives in an uncertain future.

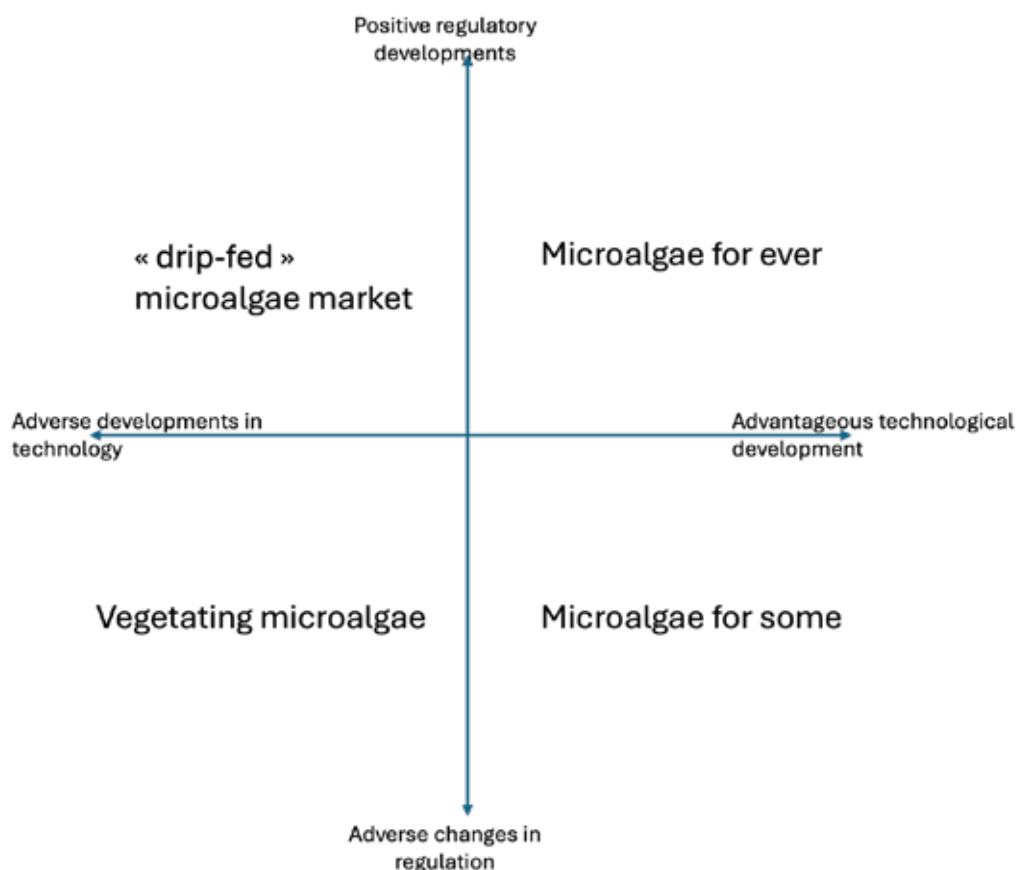


Figure 1: projection diagram using scenario method

The decrease of water supply in some geographic areas, due to climate change, combine with the global population increase are generating a water crisis that encourages the research on plant nutrition and innovative bio fertilizers, where the microalgae-based bio fertilizers appear as a realistic alternative of nutrients for crops (Rumin et al., 2020).

Tripathi et al. (2008) studied the integrated use of blue green algae bio fertilizer in the rice culture. They concluded that it has a positive impact on stress, growth, yield and mineral composition of the rice plants, and helps to reduce the high demand of nitrogen fertilizers.

Climate change is expected to intensify the existing risks for agricultural water management under climate change in Europe, particularly in regions where water scarcity is already a concern (Iglesias & Garrote, 2015). The climate change in Europe clearly encourages new solutions to save water consumption, so bio fertilizers could be one of the answers. The next part will list the major points to be lucrative.

2.2. Market overview, analysis of the profitability (Porter, 1985) and the sector strategic question (current Success Key Factors)

The following figures illustrate the market potential. However, it is important to consider the limitations of the factors to ascertain the existing profitability:

- European production of microalgae represents around 0.3 million tonnes, or 0.57% of world production in 2016 (33 million tonnes³).
- The European microalgae market generated a turnover of around €750 million in 2018⁴.
- There were 126 companies producing microalgae in the EU in 2019⁵.
- The European microalgae market is expected to grow at an annual rate of 6.4% by 2025¹.

While the technological developments and areas for improvement in the conversion of microalgae into fertilizers appear to be well under control (Osorio-Reyes et al., 2023), it is important to identify when the sector can become profitable, considering experience and economies of scale to anticipate future developments. The information can be approached by identifying key elements from the market.

Market entry barriers are our first point:

- High levels of capital investment in the construction of production units⁶
- Limited access to microalgae strains and production technologies⁷
- Economies of scale achieved by established operators⁸

Secondly, the threat from substitutes is from other plant protein sources. The question of the best solution for healthy and sustainable development is not being fully addressed today: the solutions are still in competition.

Within the industrial sector, there are few suppliers of microalgae strains and specialized equipment. The core of the industry is dependent on input suppliers of nutrients, CO₂, etc. Clients represent a fragmented market with many small players as market gardeners and cereal growers,

3 <https://sensalg.fr/la-production-dalgues-en-europe-et-la-culture-en-france/>

4 <https://www.greatitalianfoodtrade.it/fr/march%C3%A9s/la-commission-europ%C3%A9enne-propose-23-actions-pour-la-fili%C3%A8re-algues/>

5 <https://sensalg.fr/la-production-dalgues-en-europe-et-la-culture-en-france/>

6 https://www.ipemed.coop/imgedit/IPEMED_Etudes%20et%20Analyses_Rapport%20microalgues.pdf

7 <https://sensalg.fr/les-microalgues-dans-la-zone-atlantique-europeenne>

8 <https://elitepharm.fr/actualites/les-algues-et-microalgues-un-marche-en-pleine-expansion>

whose bargaining power tends to grow as their demand for healthy, natural products increases⁹. Support industries for the microalgae sector include suppliers of production equipment (photo bioreactors, harvesting systems), specialized research centres and universities¹⁰, and certification and quality control bodies.

Three main strategic groups can be identified in the microalgae market:

1. The major food and chemical groups (Cargill, DSM, BASF), which are investing in microalgae to diversify their activities¹¹.
2. Companies specializing in large-scale production of microalgae (Cyanotech, Algaenovo, Algalif, Olmix)^{12 13}.
3. Start-ups and SMEs focusing on niche applications

As compared to photo bioreactors, open raceways (especially with wastewater) are more effective for small capital investments and low power consumption in a large-scale production algal biomass.

The critical point, that was shown in many studies, is the economically feasible of algal production (Win et al., 2018).

For Costa et al. (2019), the economic viability of a bio refinery implies some key decisions, such as a substantial reduction of the current operating costs, using low-cost inputs, and maximizing the automated work for upstream processes.

Today, rivalry between companies in the sector is building and is already sensitive to differentiation strategies based on strains and production processes, while cost competition is starting to emerge for certain mass applications, rapidly leading to market consolidation through mergers and acquisitions¹⁴.

In conclusion, the key success factors today are:

- Mastery of large-scale production technologies
- Access to high-performance strains of micro-algae
- Capacity for innovation to develop new products
- Compliance with food and environmental regulations
- Positioning in high added-value segments (nutraceuticals, cosmetics)
- Partnerships with key players in the value chain¹⁵.

After defining the key success factors, we will detail the obstacles, the optimizations and limits in the industrial process.

2.3. Analysis of the sector: constraints and operation of the industrial process, optimization and limits of application, potential for exploitation

As the industrial process can encourage or limit the business development, it is central to define these parameters.

Microalgae have capacity for CO₂-fixation, so can have a significant impact to sustain

9 <https://pepswork.com/2020/08/13/agroalimentaire-micro-algues-marche-croissance/>

10 <https://sensalg.fr/les-microalgues-dans-la-zone-atlantique-europeenne>

11 <https://www.place-publique.fr/index.php/environnement/le-secteur-des-micro-algues-en>

12 <https://pepswork.com/2021/05/04/le-marche-des-algues-un-secteur-dinnovation-pour-les-marques-food/>

13 <https://olmix.com/about/>

14 <https://www.theinsightpartners.com/fr/reports/microalgae-based-products-market>

15 <https://www.greatitalianfoodtrade.it/fr/march%C3%A9s/analyse-de-sc%C3%A9narios-sur-les-microalgues-et-la-bio%C3%A9conomie-bleue-en-Europe>

earth's ecosystems and can play a role, but still underestimated in eliminating contaminants from various environments (Koller et al., 2014, Chaturvedi et Kumar, 2016).

2.3.1. Soil constraints for agricultural use

Several studies highlighted some limitations for cyanobacterial bio fertilizers in areas possibly contaminated by pesticide residues, herbicides residues, and heavy metals (i.e., nickel and copper), or in land with high salinity (He et al., 2013, Yadav et al., 2016). The salinity can modify the physiological attributes, antioxidant enzymes, and nitrogen fixing activity (Yadav and al., 2016). He et al. (2013) demonstrated that high concentration of butachlor could affect the growth, the photosynthesis activity, add stress in nitrogen-fixing cyanobacteria and induce an algae adaptive strategy.

Debnath et al. (2011) studied the effects of usually used pesticide, fungicide, and insecticide on the growth and enzymes production of four cyanobacterial species—*Nostoc ellipsosporum*, *Scytonema simplex*, *Tolypothrix tenuis*, and *Westiellopsis prolifica*. The results showed both the fungicides and insecticides at EC50 concentration would cause an inhibitory influence on the expression of nitrogenase and glutamine synthetase (GS) in all four cyanobacterial species studied.

2.3.2. Lack of Studies and information to farmers

Despite the advantages of bio-fertilizer application, the lack of awareness and knowledge in the farmers and the local level with very low production rate of algal bio-fertilizer production encounters delay in use in India (Chaturvedi et Kumar, 2016). Governments and federal agencies should promote the use of biofertilizers as eco-friendly alternatives for crop improvement (Basu et al., 2021). Basu et al. (2021) also concluded in their study that a mass public awareness is required to educate the farmers and consumers alike on the advantages of using microbe-based biofertilizers for ensuring a greener tomorrow.

Rumin et al. (2020) analyzed a corpus of 79,020 publications by authors affiliated to research institutions worldwide, especially focused on Europe and in the European Atlantic Area and containing the keywords “microalga(e)” or “phytoplankton”. Biofertilizers is one of the six major markets opportunities highlighted. The number of publications that review and study microalgae-based biofertilizers has increased in recent years and the two main countries publishing in this topic were Spain and Italy (Rumin et al., 2020). France is not listed in the hereunder table presenting the Scientific production by country for the emerging markets of biofertilizers (c).

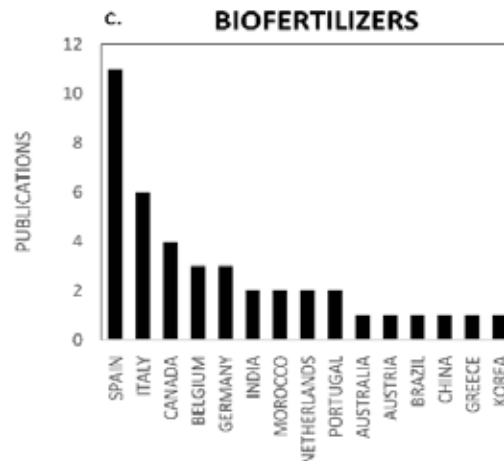


Figure 2: Number of publications on biofertilizer use by country in 2020

Source Rumin et al. (2020, p.23)

Win et al. (2018) explained that the biomass short shelf life and need for expensive cold storage can limit the development of microalgae-based biofertilizers.

Silva et De Jesús Silva (2013) analysed that the viability preservation of the dried and milled biomass was greatly enhanced using halogen lamps and subsequent ionic flocculation. Moreover, they also suggested to add akinetes as a biofertilizer after drying processes, as they have a positive impact on the storage (last several weeks when in a dried state).

Renuka et al. (2015) evaluated different formulations of a biofertilizer (after mixing with vermiculite/compost as a carrier) in wheat crop under controlled conditions. The results showed a significant increase of roots, shoots, and grains (up to 3.56 % in grains observed) and at harvest stage, a 7.4–33 % growth in plant dry weight and up to 10 % in spike weight. Renuka et al. (2015) concluded that a positive relationship existed between soil nutrient availability at midcrop stage and plant biometrical parameters at harvest stage. This research showed that the use of a biofertilizer mixed with vermiculite/compost as a carrier improved yields of wheat crop.

The growth of algae largely depends on the temperature and pH (Chaturvedi et Kumar, 2016). Silva et De Jesús Silva (2013) proposed an easy method to ensure a high germination rate by applying Cyanobacterial preservation either by air drying or drying wet Blue Green Algae (BGA) in oven at 35–40 °C for 24 h in dark.

On an economic part, Chanda et al. (2024) calculated that the use of plant nutrients through cyanobacteria biofertilizers, compared to the application synthetic fertilizers, will decrease the production cost by 12 to 15%. They also showed that the application of cyanobacteria biofertilizers can replace chemical fertilizers without any crop yield loss, help growers generate high value organic okra and stay competitive in the market. The costs for expensive organic Fe growers can be reduced as the Cyanobacteria biofertilizers can provide 2000 ppm of Fe in the soil (Chanda et al., 2024). Cyanobacteria can compensate about 50 % of recommended doses of N, P, and K (Hegazi. et al., 2010).

Algal inoculation in small quantity requires culturing in a growth media in laboratory, but for large scale commercial it may be little expensive, as for paddy fields no additional inoculation is required since once applied in paddy field it replicates in its own (Hegazi. et al., 2010). Based on different reports in the literature, Win & al. (2018) conclude that the carrier-based formulation is more suitable for N₂ fixing fertilizer and soil conditioning, while foliar-based formulation is more appropriate for germination promoting effects. However, as Chaturvedi et Kumar (2016) explained, the commercial utilization of N₂-fixing organisms in agriculture has met some

difficulties. Factors such as a suitable carrier for individual algal, soil, and climate factors and biotic and abiotic stress in the field are the main constraints for commercial use of algae as biofertilizer. Therefore, it is better to apply new methods to produce cyanobacterial mutants to discover a wider prospective of cyanobacteria (Gupta et al., 2013). Sharma et al. (2010) highlighted the prerequisite to implement multidisciplinary approaches with a multiproduct process (bio refinery) plan to optimize the benefit of cyanobacteria.

In the light of this market analysis, we question the sustainability of a business model in this context.

Is it possible to use microalgae to develop a sustainable business based on more virtuous products for agriculture?

The study of the microalgae economic environment will help to appreciate the study of LLDC Algae, that we will analyse in the following part.

3. Methodology of the presentation of the company and the data used

The study of the company LLDC Algae is including the analyse of videos, texts and the results published on the website and on the internet.

In 2008, L'Oréal asked one of its Chinese companies to replace palm oil in cosmetics. Microalgae, such as Chlorella, develops through the phenomenon of photosynthesis and was studied for a long time. It explains why LLDC Algae founder wanted to use this micro-organism. They needed to find an area capable of both supplying the energy-generating methanation unit and representing a consumption basin. Central Brittany (Loudéac) was chosen to use the waste of the agricultural production, where microalgae are still considered as pollution, but not as a potential resource ¹⁶.

Started end of 2012, LLDC Algae is a limited liability company with a share capital of 1 000 000€¹⁷. The financial report shows that the turnover and the subsidies are not covering the investments. However, in 5 years, the turnover increased of more than 150%. In 2021, the company started to get subsidised by the government for the first time. As the company director explained, this project is an opportunity to create a future activity that cannot be relocated and is ecologically virtuous. In 2021, the main shareholder has accepted a debt write-off with a return to better fortunes clause.

The concept proposed by LLDC Algae is based on the effluents from nearby livestock farms, which is sanitised and then digested by the methanizer. The methanation unit produces:

- Energy (heat, biogas, electricity) used by the site, with surplus energy returned to the grid,
- Water purified by water hyacinths and used by earthworms and chlorella culture,
- Digestate (solid residue) mixed with green waste and transformed by earthworms:
 - Percolat (liquid residue from vermiculture) is a powerful natural fertilizer
 - Humus (solid residue from vermiculture) is spread on the soil at the time of sowing
- The chlorella is grown in transparent tubes using heat and water from the methanizer and purified rainwater¹⁸.

¹⁶ LLDC Algae : la plus grande ferme de micro algues d'Europe est à Plouguenast (22). (2021, août 23). Bretagne Prospective. <https://www.bretagne-prospective.bzh/actualites/lldc-algae-la-plus-grande-ferme-de-micro-algues-deurope-est-a-plouguenast-22/>

¹⁷ <https://www.pappers.fr/entreprise/lldc-algae-la-lande-du-cran-algae-789064037>

¹⁸ <https://www.lldc-algae.com>

The production site has been designed to preserving the environment. The methanizer will produce electricity 4 times more electricity than is consumed on site. The methanizer's electrical generators (co-generation) will heat the cultivation of microalgae, as it requires additional heat, even in a temperate climate. The microalgae will absorb all the CO₂ produced on site. In the end, ecological impact of the site will be positive¹⁹.

LLDC Algae is producing chlorella that must be consumed fresh with a limited shelf life (3 weeks) once removed from its culture medium and analysed. However, at each stage comes a natural product adapted to the soil, the plant, the animal, and the human²⁰.

The growth of the business model depends on the French government, which must give its approval. For example, a prefectural decree authorises the use of 160,000 tonnes of inputs (mainly livestock effluent), which will help to turn some 5,000 hectares of waste into humus. Methanisation and the rules for the storage and use of the waste are regulated by the State²¹.

The liquid fraction of the digestate is phytopurified by macrophyte culture, while the solid fraction of the digestate is vermicomposted. The result of this process will be the production of two products: vermicompost (transformation of humus by earthworms) and a mineral fertiliser. Both products comply with the French standard. The main arguments used by LLDC Algae to increase sales are the results obtained by farmers.

4. Managerial recommendations

4.1. Technical constraints and limits to consider

Even though bio-fertilizer technology is a low-cost and eco-friendly technology, many constraints limit its application and implementation among the users; these constraints are technological, infrastructural, financial, environmental, human resources, unawareness and quality (Udemezue & Mmeremikwu, 2021). Entrepreneurs should invest more in the bio fertilizer industry and provide financial assistance for start-ups (Basu & al. 2021). Chojnacka et al. (2020) concluded that the priority directions and political determinants are important to implement such technologies. Application of potential bio fertilizers that perform well in the laboratory and greenhouse conditions often fails to deliver the expected effects on plant development in field settings (Basu and al., 2021 and Udemezue & Mmeremikwu, 2021). Different studies concluded that there are still much more efforts and collaboration between experts on plant and microbial genetics, molecular biology and ecology that are required so that sustainable microbial-based agro technologies could successfully be attained (Awasthi et al., 2019, Kour et al., 2020).

4.2. Economic and industrial factors for adoption and improvement

The following managerial recommendations are provided for the different scenarios for the development of microalgae as an agricultural fertilizer:

¹⁹ <https://www.lldc-algae.com>

²⁰ LLDC Algae : la plus grande ferme de micro algues d'Europe est à Plouguenast (22). (2021, août 23).

Bretagne Prospective. <https://www.bretagne-prospective.bzh/actualites/lldc-algae-la-plus-grande-ferme-de-micro-algues-deurope-est-a-plouguenast-22/>

²¹ LLDC ALGAE. (2021, 9 décembre). Présentation LLDC Algae [Vidéo]. YouTube. <https://www.youtube.com/watch?v=ZpKfYQTd7VA>

4.2.1. Scenario 1: Increase in demand for microalgae-based fertilizers

Recommendations:

- Invest in the expansion of production facilities according to the industrial territory configuration (nature of the existing industrial parks) to meet the increase in demand
- Propose partnerships with existing industries needing wastewater treatment for industrial symbiosis (Kalundborg model: Gulipac, 2016, Sun et al., 2024) development leading to circularity and carbon neutrality
- Optimize production processes to increase yields, profitability and symbiosis
- Develop new microalgae-based products and formulations to diversify the offering
- Strengthen research and development teams to drive continuous innovation targeting bioproduction symbiosis systems, formulation and circularity.
- Set up strategic partnerships with industrial and agricultural players to better understand market needs both in term of bioproduction and end-usage.

4.2.2. Increased competition from synthetic fertilizers

Recommendations:

- Differentiate by emphasizing the environmental benefits and sustainability of microalgae-based fertilizers
- Invest in marketing and communication campaigns to promote the benefits of microalgae
- Optimize production costs to be more price competitive
- Develop high added-value products, such as fertilizers enriched with specific nutrients
- Forge partnerships with distributors and retailers to extend the commercial reach

4.2.3. Stricter regulations on the use of fertilizers

Recommendations:

- Quickly comply with new regulations by adapting production processes and formulations
- Invest in research and development to create products that meet regulatory requirements
- Work closely with the relevant authorities to anticipate regulatory changes
- Implement enhanced traceability and quality control systems
- Communicate transparently on the company's sustainability and compliance efforts.

To sum up, the key recommendations are to be agile, innovative, customer-focused and sustainable to adapt to the various scenarios in the microalgae-based fertilizer market.

5. Presenting recommendations of collective interest

There is a clear collective and public interest in optimizing agricultural fertilizers using micro-algae. This is due to the following reasons:

5.1. Environmental sustainability

Microalgae are a source of natural and renewable fertilizers, with a reduced environmental impact compared with chemical fertilizers. Their use reduces the use of chemical inputs and preserves the quality of soils and ecosystems.

5.2. Food safety

Microalgae-based fertilizers help to improve agricultural yields in a sustainable way, thereby enhancing food security. They enable the feeding of a growing global population while preserving natural resources.

5.3. Public health

- Microalgae offer a healthier and more environmentally friendly alternative to chemical fertilizers, reducing the risk of food and water contamination.
- This has a positive impact on the health of consumers and farming communities.

5.4. Local economic development

The production and use of micro-algae-based fertilizers creates new jobs and economic opportunities, particularly in rural areas.

This contributes to local economic development and the revitalization of farming communities.

5.5. Innovation and research

The use of microalgae in agriculture stimulates innovation and research in areas such as biotechnology, green chemistry and sustainable agriculture.

This helps to advance knowledge and develop new solutions to environmental and food challenges.

In short, the collective and public interest in optimizing agricultural fertilizers using microalgae lies in the environmental, social and economic benefits it brings on a local and global scale. It is a promising way of reconciling agricultural productivity with the preservation of natural resources.

6. Conclusion, limitations and research approach

The financial capacity to invest, the government support through regulations and politics, and the progress of the research, based on a collaboration between searchers and farmers, the communication of the results to a better-informed public (consumers and farmers) are essential to assist the growth of viable businesses that are producing bio fertilizers for a more sustainable agriculture.

The study was focused on a limited liability company located in the west of France. As a result, the analysis is concentrated on this business model type, that has its strengths and weaknesses. However, it would be interesting to enlarge it and include different company categories from start-ups to big groups to confront the recommendations and check if it applies to all of it.

To conduct a marketing study with questions to farmers would outline their current knowledge about bio fertilizers and determine the obstacles and main motivations for changing their production methods (mainly going from the use of chemical fertilizers to more sustainable fertilizers).

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THE CEO'S ROLE IN CREATING A GOOD WORK ENVIRONMENT

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Abstract. The purpose of this paper is to delve into the strategies and interventions that companies can implement to improve the work environment, which in turn enhances the employees' performance. By using a descriptive-analytical method to review the existing literature, this paper demonstrates that good leadership and good culture are essential to create a positive work environment. Indeed, recent studies emphasize the importance of a good work environment to have a profitable and sustainable business. Companies require teamwork to succeed, and creating a teamwork environment requires leaders' intention. In fact, when companies run into problems, it is most likely since a negative corporate culture has been instilled in the corporation. Executives are the ones that establish said culture, but when a toxic culture is embedded into the company, removing the CEO is not enough to improve the business environment, since the toxicity has spread throughout the company. Therefore, a competent corporate leader is key to the success of any company. This means that companies should hire leaders who have the required technical qualifications, which entails a solid educational background, and the required experience to lead people in the right direction. In addition, emotional intelligence and a solid moral character are important attributes that any good leader should have. Therefore, thorough background checks should be run at a personal, professional and character level, before hiring a CEO. Some scholars claim that leadership skills are inborn talents. This paper suggests otherwise. Indeed, leadership skills should be learned. In fact, every supervisor, group leader, etc. should acquire leadership skills to lead their team in the right direction, as demonstrated herein.

Keywords: *Leadership, Good work environment, Incompetent leaders, Corporate culture, CEOs.*

1. Introduction

Companies require teamwork to succeed. Executives are the ones responsible for creating a corporate culture emphasizing teamwork in a company (Ofir & Goldschmidt, 2024). This implies having a good and positive work environment, which is essential for teams to succeed. Nevertheless, some scholars are portraying a rather gloomy picture of business leadership. They estimate that the percentage of incompetent business leaders could be as high as 60% (Hogan, et al. 2011, p.556; Randstad, 2018). This is really troublesome since executives are the ones responsible for establishing a positive corporate culture and the company's business strategy, which flows down through the entire enterprise (Belias & Kaustelios, 2014). Middle managers, in turn, are responsible for implementing and enforcing this positive culture and strategy, established at the top, by imbuing it across the entire company. This is why, when a toxic culture is embedded into the company, removing the CEO is not enough to improve the business environment, since the toxicity has spread throughout the company (Graham et al., 2022; Lazarus, 2020; Jonason et al., 2012). Therefore, hiring and training good business leaders should be a priority for any corporation (Milner et al. 2018; Fulmer et al., 2009; Kur & Bunning, 2002; Neary & O'Grady, 2000). By using an analytic-descriptive method and by

reviewing existing literature, this paper emphasizes the importance of creating a positive work environment, by hiring competent business executives with integrity, and with emotional and cognitive intelligence.

2. Leading

Good leaders are people with initiative who do not remain passive when facing an opportunity or a problem. They act by trying to solve problems and reach positive outcomes. However, they cannot accomplish it alone. Therefore, they influence and inspire others in a positive manner to help them achieve their goals, thus benefiting everyone (Benmir & Agboola, 2021; Goleman & Chemsis, 2024; Goleman, 2021; Luedi, 2022; Ofir & Goldschmidt, 2024). In addition, good leaders have the necessary knowledge and skills to undertake said tasks, along with integrity and empathy (Yazdanshenas & Mirzaei, 2023; Oginde, 2020; Amos, et al., 2017). Bachelder (2015), Popeye's successful Chief Executive Officer (CEO), adds that companies should look for leaders who have a vocation to serve all their stakeholders instead of placing their own interests above their teams' (Stone & Patterson, 2023).

Good leaders are positive role models for their team (Ofir & Goldschmidt, 2024; Koohnag et al., 2017). They are humble, knowledgeable, intelligent, hard workers, resilient, empowered, empathetic; they have emotional intelligence, a vital plan, and integrity (Ou, et al. 2018). On the other hand, people without ethics can very well lead their people into failure by seeking their own interests, instead of looking after their teams' needs (Emblemsvåg et al., 2023; Griffin et al. 2022). In addition, good leaders display the expertise required to undertake a project and lead it to success (Jaggia & Thosar, 2021). In addition, recent studies (Davison, et al., 2020) established a link between executives' personal lives and their professional lives. CEOs with reckless personal behavior, domestic violence, traffic violations or a lavish lifestyle were more likely to commit fraud in the companies they led. This is why corporations should realize a thorough professional and personal background check on the candidates they are contemplating for the CEO position.

Leaders and entrepreneurs are very much intertwined. Yet not all entrepreneurs are good leaders, but only those who undertake the required training to become good leaders. Some scholars advocate that leadership is an inborn talent (Beck & Harter, 2014). Yet, good leaders have had good mentors that helped them develop and polish their leadership skills (Raz, 2022). In addition, neuroscience could shed some light on this subject. Genetics only represent 30% of humans' lives. The remaining 70% are shaped and influenced by their surroundings (Pascual Leone et al., 2019).

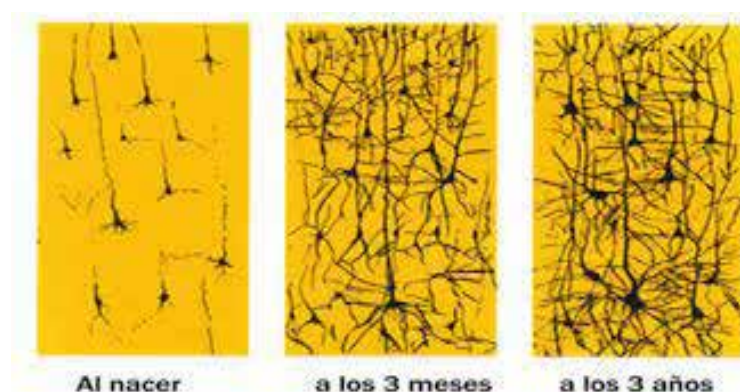


Figure 1 Three images of the creation of brain connections: At birth, at 3 months old, and at 3 years old. Source: Center on the Developing Child, 2024.

The brain is the only human organ that is not fully formed after birth. It takes around 25 years to form an adult brain (Pascual Leone et al., 2019). This is why humans are the most intelligent species in Earth. Nevertheless, they also are the most vulnerable ones, since they need a loving, caring and stimulating environment in order to develop a healthy brain. This organ develops in stages; each one linked to the previous one. Newborns are born with millions of neurons, but most of them are not interconnected (Figure 1). This is why babies do so little because most of their neurons are not connected to each other, thus most brain circuits have not been formed yet. Therefore, newborns must create millions of neurons connections to develop their brain. In fact, according to the latest studies, babies create one million connections per second (Center on the Developing Child, 2024). Connections, that are created and are reinforced by repetition and love, form the circuits that shape the child's brain. Brain architecture depends about 30% on genetics, and 70% on a loving and supportive environment. Therefore, if during the first years of life, the child is ignored, confused, abandoned, mistreated, abused...the required brain circuits for a healthy brain at each stage will not be built properly. This means that the foundations for a healthy brain are not well created, with negative physical, cognitive, and psychological consequences for life. The foundations of a healthy brain are usually compared to the foundations of a house. If they are faulty, the entire house is compromised (Center on the Developing Child, 2024).

Therefore, when people have positive, empowering, and caring environments, they can accomplish great things (Andersen, et al., 2012; Keltner, 2017; Keltner, et al., 2003). Having someone to lean on who cares is vital for success. In fact, many successful CEOs attribute their achievements to their parents' loving support and empowerment, as well as having good mentors. Family is the foundation of a successful leadership career. John Chambers is a good example. Despite his dyslexia, and his classmates making fun of him when he was young, he became CISCO's CEO, turning the company around. This was possible thanks to his father, who empowered him by teaching him not to panic in times of crisis. Kenneth Chenault is another example. Despite growing up in the brutal racial segregation era in the USA, he excelled, leading American Express into success. His father's unconditional support, and empowerment were credited for his success. Andrea Jung, a Chinese descent, is another example. Thanks to her mother who empowered her to dream big and work hard, as well as thanks to his father's empowerment, she became Avon's CEO. Indra Nooyi, an India-born woman, credits her mother's empowerment to study and learn as much as possible, for reaching the top when she became PepsiCo's successful CEO. Schools and mentors are key ingredients for success as well. Arnold Donald turned Carnival Cruise line around, the largest cruise company in the world, after becoming their CEO. His success can be traced back to this family's and school's empowerment. Despite the discrimination he suffered during the racial segregation era, his all-black boys' Catholic school empowered their students by broadcasting the message: "Gentlemen prepare to rule the world" 3 times a day (Raz, 2022). Microsoft's current CEO, Satya Nadella, is another example. He states that the biggest influence on his life has been his parents (Wall Street Journal, 2015). Therefore, people are not born leaders (Brown et al., 2023), since genetics are only responsible for 30% of human development, and human's environment can override their genetics, as stated earlier. In addition, behavioral economics, outlined in the next section, advocates that humans need a nudge to make the right decision; they need help. Therefore, any leader (team leader, project manager, boss, manager, executive, etc.) should learn how to be a good leader, and they need help to achieve it (Milner et al. 2018; Fulmer et al., 2009; Kur & Bunning, 2002; Neary & O'Grady, 2000).

Kim Scott (Amiguet, 2024) brings an interesting point to the leadership table. She introduces the concept of "Radical Candor" in management. It is a sensitive concept, because it does not

mean to put people down or shame them when making mistakes or failing. On the contrary, radical candor means to praise a job well done, but also to give a sincere, humble, and caring opinion when somebody is making a mistake or making a wrong choice. It does not mean looking the other way when somebody errs, but rather helping them, because everybody can use guidance. This might cause some tense moments. However, if it is done with care, it will be very helpful. Companies benefit when employees are engaged and when said employees feel their managers care and have their backs, as stated earlier.

3. Behavioral Economics

Behavioral economics (Thaler, 2015) brings emotions and feelings to the field of economics. It explains that humans do not always make the best decisions because of a lack of self-control, because of being influenced by others, because of laziness, etc. This is why humans are not as rational as they think they are. Thus, they need help to make the right decisions. They need help from family, friends, managers, education, government, etc., as well as from previous generations' wisdom, conveyed to the next generations through positive customs, traditions, and religion. Since feelings, emotions and decisions are influenced by others (Berger, 2016), it is very important to be surrounded by intelligent, educated, caring, loving and helpful people, with integrity and virtues, that can really help to make the best decisions. This is one of the reasons why good companies work in teams; teams that help each other. Moreover, companies should hire candidates who are team players, competent, and have integrity.

4. Pascual Leone's Findings

Pascual Leone and his colleagues (2020 and 2019) advocate the following 7 pillars to have a healthy brain, which translates into a happier, more productive, and healthier life.

1. Strong human connections
2. A vital plan
3. Exercise
4. Cognitive development & positive thoughts
5. Enough Sleep
6. Good nutrition
7. Regular check-ups.

Their research singled out loneliness as one of the most important risk factors for people's health, which affects employees' productivity. It increases the stress hormones, which impair learning and even working. On the other hand, having good relationships helps maintain a healthy brain and help live longer. Social connections are therapeutic. Having someone to lean on who cares is vital for success, as outlined in the previous section (Maciá et al., 2021).

The second pillar for a happy, healthy, and productive life is having a mission, a purpose in life: to know which path to take and why (Cattaneo et al., 2018). On the other hand, when managers only motivate their employees with economic incentives (extrinsic motivation), there will be more cheating in the company (Welsh et al., 2019). Therefore companies, besides using extrinsic motivation, should encourage their employees to have a vital plan by creating a positive corporate mission (transcendental motivation). Employees will rally around it if it resonates with them, and if it gives meaning to their work (Quinn & Thakor, 2019).

5. Toxic culture

Some scholars are portraying a rather gloomy picture of business leadership. They estimate that the percentage of incompetent business leaders could be as high as 60% of total bosses (Hogan, et al. 2011, p.556; Chamorro, 2020, p.1, Randstad, 2018). This is really troublesome, since executives are the ones responsible for establishing a positive culture in the company, and for establishing the business strategy, which flows down through the entire enterprise, affecting the companies' bottom line (Raz, 2022; Nikpour, 2017; Liu, 2016; Guiso et al., 2015). On the other hand, incompetent or toxic leaders create a negative and toxic environment. They create an environment that hinders employees' creativity and innovation. One of the reasons why there are so many incompetent managers in corporations is because employees are promoted to management positions without proper leadership training. Leadership is not an inborn talent (Brown et al., 2023). Managers and executives need to learn how to lead people to success (Minler et al., 2018; Lacerenza et al., 2017; Beer et al., 2016).

The other reason why there are so many incompetent managers in corporations is because certain traits displayed by incompetent people are overrated in leadership positions. In fact, people admire candidates who are overconfident, narcissistic, eloquent, attractive, with grandiose self-esteem, etc., instead of looking for candidates who are competent, knowledgeable, efficient, intelligent, with expertise and integrity, etc. (Cahn, 2024; Chamorro, 2020). The result is that there are 3 to 4 times more psychopaths and narcissists in corporate leadership positions than in the general population (Matos, 2017), with dreadful consequences for employees, and for the companies' viability (Rusydi, 2021; Bouncken et al., 2020; Gudmundsson et al. 2011; Hurst et al., 2019; Boddy et al., 2010).

6. Corporate Culture

A positive work environment requires a positive corporate culture, which is essential for business success. It is the core of a corporation, and it entails the following questions (Groysberg et al., 2018; Warrick, 2017; Anitha, 2016):

- What are the company's objectives?
- Does it have a purpose?
- Does it have a good product?
- Does it give good service?
- Is it a customer-orientated company?
- Does it treat their customers right?
- Does it treat their employees right?
- Is there a positive work atmosphere?
- Can employees grow personally as well as professionally in the company?

In fact, when companies run into problems, it is most likely due to the fact that a negative corporate culture has been instilled in the corporation (Liu, 2016; Guiso et al., 2015; Raz, 2022). Executives are the ones that establish said culture, but when a toxic culture is embedded into the company, removing the CEO is not enough to improve the business environment; the toxicity has already spread throughout the company (Nikpour, 2017). Boeing is a good example of this. Increasing short-term profits and the value of their stock to boost management's bonuses and investors' portfolio were the main objectives of the company. Cost cutting overshadowed safety concerns, resulting in a reduction of the quality of Boeings' parts and design. For a

while it seemed that the cost cutting policy paid off, but in 2018 and 2019, two 737 Max aircraft crashed, killing the 346 people that were aboard. Dennis Muilenburg, Boeing's CEO at that time, was forced to resign in 2020. Despite his failure as CEO, he walked away with \$62 million in compensation and pension benefits (Gregg, 2020). Dave Calhoun replaced him as Boeing's CEO, but he will step down at the end of 2024 because Boeings' negative culture remains, affecting the safety of their planes. A recent incident, where a door flew open in midair because the screws that fasten the door plug were never installed, confirms that the toxic culture is lodged within the company. This negative culture -based on maximizing profits at any cost so management, investors and executives could receive large bonuses - has cost the company over \$23 billion in losses since 2020. Boeing went from a very profitable company, with an annual net income of over \$10 billion in 2018, to being in the red thereafter (Boeing, 2024). Credit Suisse is another example. It was fined on several occasions for multiple violations, which included helping their customers evade taxes, or harboring very wealthy customers that were involved in human trafficking, corruption, and money laundering. This toxic culture, where profits were placed above the banks and their stakeholders' interests, nearly drove the bank to the verge of bankruptcy. The Swiss Central Bank had to intervene, arranging its merger with its competitor (Ma, et al. 2023).

When short-term profits are the only goal in a business, a negative culture and a toxic work environment will emerge since shareholders and managements will be the main beneficiaries. The rest of the stakeholders' wellbeing will be disregarded, thus compromising the company's long-term viability. In fact, if executives receive large incentives based on profits or on the stock value, they will be tempted to manipulate earnings to push profits up in the short-term to get those bonuses, creating a toxic environment and risking the company's long-term sustainability (Bergstresser, & Philippon, 2005; Burns & Kedia, 2004).

7. Positive Work Environment

Teamwork is key to success. There are multiple studies that single out good company culture for the success of said company (Anitha, 2014; Ashkanasy & Dorris, 2017; Bakker, 2011; Belias & Kaustelios, 2014; Fisher, 2010; Khamisa et al., 2015; Raziq & Maulabaksh, 2015). In fact, employees' engagement and productivity increase when positive connections among them are promoted. Indeed, when employees work in an environment where empathy is encouraged, they are more satisfied with their jobs, and they are better team players (Zaki, 2024). In addition, Gallup (2023) found that employees that had a caring supervisor were more engaged. Employees value empathetic managers (Hemmerdinger, 2023), since managers are responsible for 70% of employees' engagement variation, affecting the company's bottom line (Gallup, 2023). Surveys go a step further, revealing that people who have a best friend at work are more engaged (Patel & Plowman, 2022; Stevens, 2021). Moreover, employees work harder when they are happy (Oswald, Proto, & Sgroi, 2015), resulting in higher employee satisfaction, which leads to higher employee productivity and higher customer loyalty (De Neve, Krekel & Ward, 2019). In fact, when employees are happy, they give better service to customers, which in turn translates in an increase in revenues. This increase was quantified, with a ratio of 2 to 1 (Goleman, 2013, p. 109). In fact, the longest longitudinal study about happiness, conducted by the University of Harvard, concluded what makes people happier and healthier is not money, but warm human connections (Waldinger & Schulz, 2023, pp. 42,49; Waldinger et al., 2015). Therefore, creating a good work environment that promotes warm human connections pays off (Pawirosumarto et al., 2017).

López-Ibor, dean at the psychiatric department of the University Complutense of Madrid, outlines some basic attitudes to help companies and societies improve their environment. She encourages leaders to spread happiness around them, by practicing smiling because it improves their teams' wellbeing and the wellbeing of people around them. Since behaviors, emotions, feelings, and opinions are very contagious, smiling will have a positive ripple effect in the company. In addition, managers should have positive attitudes that encourage their teams to look for solutions and innovate (Sanchís, 2022). Hamilton's (2017) findings about compassion and kindness can also be applied here to improve the companies' environment, as well as to improve anybody's life (Malti, 2021; Goetz et al., 2010). By practicing kindness humans produce oxytocin and serotonin. These hormones and neurotransmitter are the glue to keep relationships together. They improve employees' performance, people's lives, and society as a whole, since they make people happier and healthier (Fryburg, 2022; Curry et al., 2018; Hamilton, 2017; Nelson et al., 2016). In addition, promoting volunteer work or helping each other is a good way to instill a sense of purpose in the workplace (Sollenberger, 2018). Therefore, corporate leaders should foster warm human connections, a sense of belonging and a mission. Moreover, business leaders should display compassion, empathy, and kindness to build a good work environment (Van Kleef et al., 2015).

8. Conclusion

Companies require teamwork to succeed. Executives are responsible for creating a teamwork culture in a company. In fact, employees are more engaged and more creative when they are happy and work in a positive work environment, which improves the company's bottom line. This implies training their managers for leadership roles or hiring good leaders to create a good work environment, a sense of belonging and a mission, which are essential for teams to succeed. In addition, good leaders should have the necessary knowledge and skills to lead teams, along with integrity and empathy. Bachelder, Popeye's successful Chief Executive Officer (CEO), adds that companies should look for leaders who have a vocation to serve all their stakeholders instead of placing their own interests above their teams'. In addition, recent studies established a link between executives' personal lives and their professional lives. CEOs with reckless personal behavior, domestic violence, traffic violations or a lavish lifestyle were more likely to commit fraud in the companies they led. This is why corporations should realize a thorough professional and personal background check on the candidates they are contemplating for the CEO position.

The longest longitudinal study about happiness concluded that what makes people happier and healthier are warm human connections. Thus, business leaders should foster a culture of warm human connections and a sense of belonging, realized by creating a safe, kind, and positive working environment. This will have a ripple effect throughout the company, increasing employees' engagement, which results in an increase in employees' productivity and customers' satisfaction, improving the company's performance. Undoubtedly, business leaders should promote, nurture and care for their employees' interrelationships by displaying compassion, empathy, and kindness. The impact of positive human connections goes beyond personal benefits, reaching the company's bottom line. Therefore, corporate leaders should foster warm human connections, a sense of belonging and a mission. Moreover, business leaders should display compassion, empathy, and kindness to build a good work environment.

Nevertheless, creating a positive work environment might not come naturally, since it requires intention, effort, curiosity, patience, discipline, motivation, etc. Yet, it should be embedded in the company's culture because "it pays off", as outlined herein.

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Track 3

Electrical Engineering,
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USE OF RASPBERRY PI COMPUTER FOR CONTROLLING A CONVEYOR BELT IN THE PRODUCTION PROCESS

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Abstract. Automation of liquid level detection systems is an essential part of modern industrial operations. This paper demonstrates the practical application of microcontroller and computer vision in the industry and automation. Model of conveyor belt for filling liquid in bottles is constructed for the purposes of this work. Fast, precise, and reliable detection of liquid level and colour in the bottle is achieved by using a Raspberry Pi, a camera, and the OpenCV library. System relies on the OpenCV library, which enables the application of advanced image processing algorithms. If the analysed liquid does not meet the predefined settings, the filling line is stopped. Once the issue is resolved and the “faulty” bottle is removed, the filling process resumes.

Key words: *Raspberry Pi, OpenCV, production process, liquid level measurement*

1. Introduction

Production processes require quality control to ensure that all products are equal to the specified specifications. This helps to establish the image of a particular brand, gain customer loyalty, and maximize profits. For example, when filling bottles, it is important to ensure that the amount of product in each bottle matches the information on the label. If there is less product in the bottle, the company may lose customers and face legal consequences. If there is more, the company loses profit by giving more than what is specified. The conventional way to ensure the correctness and consistency of the filling level involves regular checks by trained personnel. However, this method is not only labour-intensive and expensive, but also subjective. With the development in the industry, systems have been developed that use various technologies to track the filling level, such as high-frequency filling level measurement systems, infrared technology, X-ray systems...[1–3]ultrasound technology and

computer control are used to regulate fluid level in order to achieve a rapid response system that is flexible and highly accurate. Further industrial applications of the technology are indicated.”,”container-title”:”Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering”,”DOI”:”10.1243/PIME_PROC_1995_209_237_02”,”ISSN”:”0954-4089, 2041-3009”,”issue”:”2”,”journalAbbreviation”:”Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering”,”language”:”en”,”page”:”101-115”,”source”:”DOI.org (Crossref However, such systems are expensive and are mostly purchased only by large companies. To solve this problem, computers and artificial intelligence are used in many manufacturing sectors. With the development of these systems, the use of different algorithms has been proposed with the aim of finding a simple but reliable way to detect cases of overfilling or underfilling. One way is to use computer vision. Cameras and image processing systems are used to track defects, irregularities, and the like. In addition to eliminate human bias and reducing the need for labour, image processing systems speed up the production process and reduce product contact with personnel, thereby increasing hygiene standards. In this work, a liquid level tracking algorithm based on computer vision and the OpenCV library is applied.

2. Computer vision

Computer vision is a field of deep learning and artificial intelligence in which humans teach computers to see and interpret the world around them. Although humans and animals naturally solve visual challenges from a very young age, the way to enable machines to observe and interpret their environment through sight (images) remains a largely unsolved problem. The limited perception of human vision, together with the infinitely changing scenery of our dynamic world, makes computer vision very complex. Computer vision uses machine learning algorithms to recognize objects, patterns, and other information from visual data. Applications include autonomous vehicles, medical diagnostics, face recognition, image processing, etc. [4]

The beginnings of computer vision date back to the 1950s, when researchers tried to develop machines that could recognize patterns in images and analyse visual data. This period was characterized by fundamental experiments and conceptual work. During the 1960s and 1970s, researchers worked on basic image processing techniques, such as edge detection and object segmentation. The first image analysis systems were developed, although they were limited to simple applications. Computer vision experienced rapid development during the 1980s and 1990s thanks to advances in computing power and algorithms. Techniques for shape recognition, face recognition, object tracking, and similar began to be developed. Commercial applications, such as handwriting recognition systems, also became available. At the beginning of the 21st century, machine learning and deep learning became key to the development of computer vision. Advances in neural networks have enabled significantly better results in object recognition, image classification and content analysis. Applications include autonomous vehicles, face recognition on smartphones, medical diagnostics, and many others.

The principle of computer vision can be divided into three steps: image acquisition - images for analysis are captured via video or 3D technology, image processing - pre-trained “deep learning” models automatically perform a large part of this task; image understanding - the last step, in which objects from the image are recognized and classified into categories.

However, although the three steps that express the basics of computer vision seem simple, image processing and understanding through machine vision are quite complex. An image consists of a series of pixels, where a pixel is the smallest unit into which an image can be divided. Computers process images in the form of a series of pixels, where each pixel has a

set of values that represent the presence and intensity of three primary colours: red, green, and blue. All pixels are put together to form a digital image. The digital image, therefore, becomes a matrix, and Computer Vision studies this matrix. While the simplest computer vision algorithms use linear algebra to manipulate these matrices, complex applications involve operations such as convolution and down sampling through pooling. Figure 1 shows an example of how a computer “sees” an image.

Numbers in a matrix represent pixel values at specific coordinates in an image, with 255 representing a white pixel and 0 a black pixel. For larger images, the matrices are much larger. And while it is easy for a human to get an idea of an image by looking at it, looking at the pixel values shows that the pixel matrix does not give any information about the image. Therefore, the computer must perform complex calculations on these matrices and formulate relationships with neighbouring pixels to conclude that the image represents a person’s face.

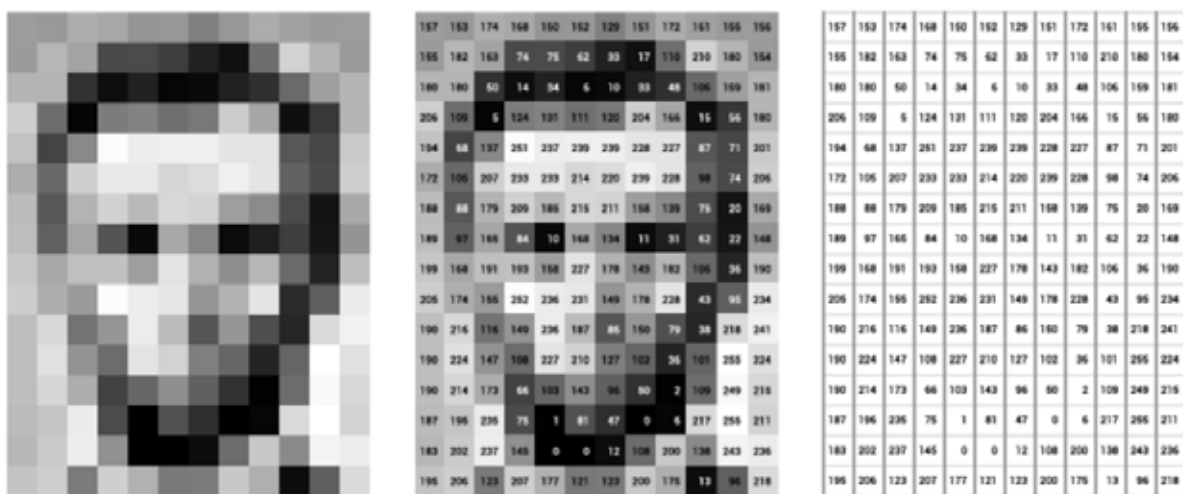


Figure 1 Matrix image display [5]

Developing algorithms for recognizing complex patterns in images brings us closer to the fact of how excellent the human mind is in natural pattern recognition.

3. OpenCV library

OpenCV (Open-Source Computer Vision Library) is an open-source library used for image processing and computer vision. It is a significant tool for both scientific research and industrial applications such as robotics, medical imaging, security, and shape recognition [6,7]. This library offers a wide range of advanced tools and functionalities, including image manipulation, object detection, motion tracking, and support for both machine learning and deep learning. OpenCV was originally developed in 1999 as a project at Intel’s research laboratory under the leadership of Gary Bradski. The goal was to create a library for working on complex computer vision tasks. The first release of OpenCV happened in 2000. While basic, this version laid the foundation for further development and adoption within the community. In 2005, OpenCV became an open-source project, allowing contributions from programmers worldwide. This significantly boosted the library’s development. Today, OpenCV offers support for Android, GPU acceleration and better integration with other libraries like TensorFlow, deep learning support with tools for working with neural networks, Vulkan API support for improved performance and optimization when working with graphics cards.

4. Hardware overview

For the project, a simple device was made whose purpose is to simulate a conveyor belt for filling bottles, shown in Figure 2 [8]. The device does not contain a part for filling the bottle, considering that the focus of the work is on detecting the level of filling of the bottle and the colour of the liquid in the bottle. The device consists of two parts: a rotating stand and an electronic circuit. Bottles with liquid are placed on the rotating stand that rotates at a speed of 1.43 rpm. The schematic diagram of the electronic circuit is shown in Figure 3. The basis of the circuit is Raspberry PI 3b+, to which PiCamera v2.1 is connected. The technical characteristics of the camera are shown in Table 1.



Figure 2 Assembly for simulating a bottle filling line

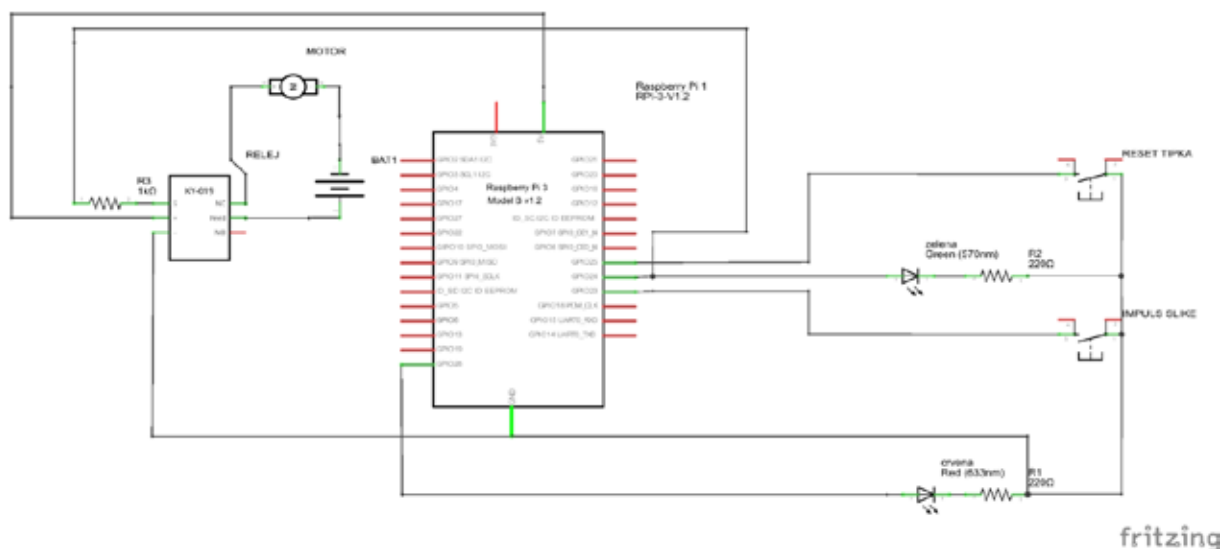


Figure 2 Electrical circuit diagram

Table 1 Technical specifications of the camera [9]

Image sensor	Sony IMX 219 PQ CMOS image sensor with module for stable focus
Image resolution (still image)	8-megapixel, 3280 x 2464
Recording resolution (motion picture)	1080p: 30fps, 720p: 60fps
Connecting to Raspberry Pi	15-pin flat cable, to a specific 15-pin MIPI serial camera interface (CSI-2).
Image controls	Automatic exposure control, automatic white balance, automatic bandpass filter, automatic 50 Hz brightness detection, automatic black calibration
Operating temperature range	-20° do 60°
Weight and dimensions	3g, 23.86 x 25 x 9mm

By turning the stand, when the bottle takes a position opposite the camera, the process of analysing the bottle is activated by a microswitch. The microcontroller stops the stand using a relay, since the motor that turns the stand is powered by a voltage of 220V. After the stand stops, the microcontroller activates the camera and captures an image of the bottle, which is further analysed. Two signal LEDs are connected to the microcontroller, showing the status of the circuit to the user. The green LED turns on in case of a positive result, i.e. if the bottle is filled to the top. The red LED lights up if the bottle is not filled to the top and remains on until the system is reactivated by the operator. The system is fully automated, except in the case when the bottle is not full, then it is necessary to restart the system by pressing a button.

5. Software overview

Two programs are created for the operation of the system: auxiliary and main. The auxiliary is used to create a sample that determine the liquid colour pattern of the “correct” bottle. The sample has a dual role: it is used to determine whether the bottle is filled with the correct liquid, and it is used to determine the liquid level in the bottle. The main program compares the colour of the sample with the bottle located on the stand. If the colour of the liquid matches the sample, the level of liquid in the bottle is measured. If the measured level corresponds to the set level, the process continues, and the next bottle is analysed. If the bottle does not match the given parameters (colour and/or liquid level), the stand stops rotating. The worker needs to remove the defective bottle and press a button to restart the system.

5.1.1. Auxiliary program

The flow diagram of the auxiliary program is shown in Figure 4.

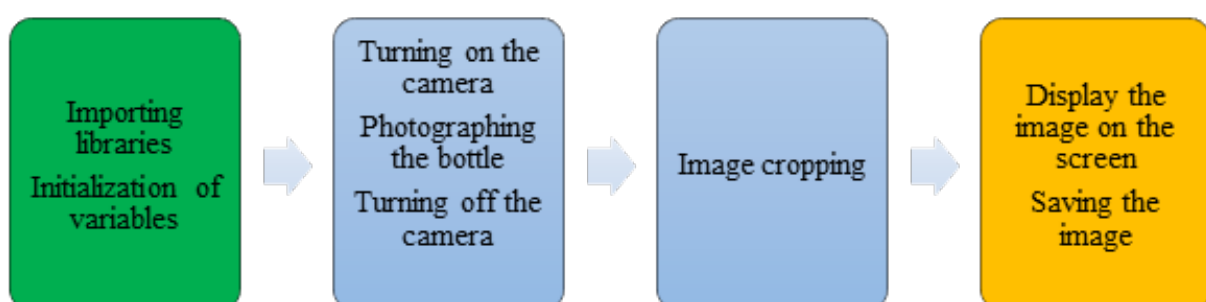


Figure 4 Utility program flow diagram

The bottle is photographed with the camera (Figure 5), and the image is cropped to the dimensions specified by the user. Care should be taken that the cropped part of the image contains only the detail of the liquid bottle. After cropping the image, the sample (Figure 6) is displayed on the screen, so that the user can check whether the sample is correct.



Figure 5 Photo of the bottle



Figure 6 Sample

5.2. The main program

The flow diagram of the main program is shown in Figure 7. At the beginning, the necessary libraries and modules are loaded, such as 'cv2' for image processing, 'numpy' for mathematical operations, 'Picamera' for taking photos with the Raspberry Pi camera, 'ImageFile' and 'Image from PIL' for image manipulation. The 'RPi.GPIO' library to use the Raspberry Pi's inputs and outputs is also loaded. In the program, the camera rotation is configured by 180 degrees (vertical image), and the resolution is set to 720x720 pixels. The number of frames (framerate) is set to 15 frames per second (fps). After loading the required libraries, the bottle sample is analysed. This is done by converting the sample image from the RGB colour space to HSV.

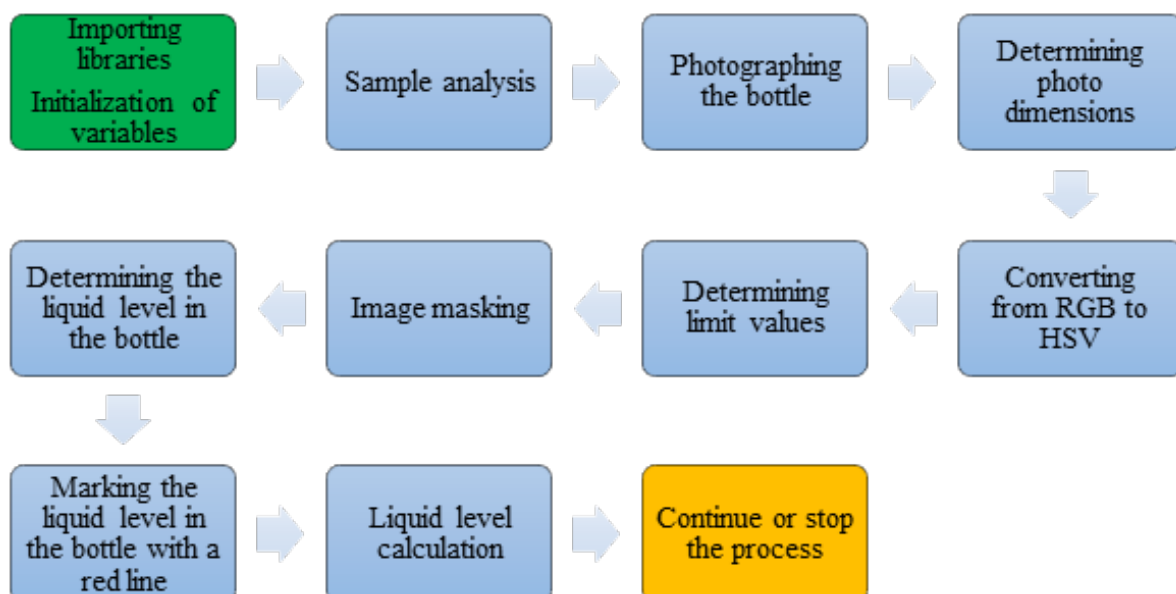


Figure 7 Flow diagram of the main program.

The HSV (hue, saturation, value) colour space is a model that represents colours similarly to the RGB (red, green, blue) colour space. Since the hue channel represents a type of colour, it is very useful in image processing tasks that require segmentation of objects based on their colour. Variation of saturation goes from unsaturated, for displaying shades of grey, to fully saturated (without white component). The value channel describes the brightness or intensity of a colour. Figure 8 shows the HSV cylinder.

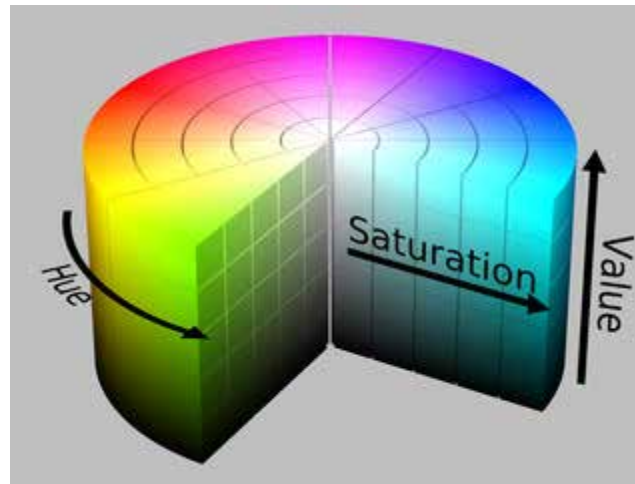


Figure 8 HSV color space [10].

After converting to HSV, the upper and lower limit value of the colour shade of the sample is determined. For the sample image shown in Figure 6, the HSV colour value is [138 91 14]. The lower limit is [135 41 0], and the upper limit is [142 141 64]. The upper and lower limits were determined experimentally, during system testing. Furthermore, a part of the program for calculating the upper and lower limit values of the sample is presented.

```
def set_threshold(sample_image):
    global hsv
    global lower
    global upper
    hsv = find_color_space(sample_image)
    lower = np.array([hsv[0][0][0]-5, hsv[0][0][1]-50, hsv[0][0][2]-50])
    upper = np.array([hsv[0][0][0]+5, hsv[0][0][1]+50, hsv[0][0][2]+50])
```

```
def find_color_space(img):
    img = cv2.imread(img)
    b, g, r = cv2.split(img)
    b = np.mean(b)
    g = np.mean(g)
    r = np.mean(r)
    li_color = np.uint8([[b,g,r ]])
    hsv = cv2.cvtColor(li_color,cv2.COLOR_BGR2HSV)
    return hsv
```

After the bottle on the stand is photographed, the dimensions of the photo (height, width, and number of channels) are determined. Since the camera takes photos in the RGB colour space, it is necessary to convert the captured photo into the HSV colour system, so that it can be compared with the sample.

This is followed by image masking, which extracts the colours in the image that correspond to the colour of the sample. Those pixels are marked in white and everything else in black. For this reason, it is necessary to correctly choose the colour of the background behind the bottle being photographed. In the created prototype, the background is white. The following code shows a part of the mask creation program.

```
img = cv2.imread(image_name)
h, w, c = img.shape
img = cv2.cvtColor(img, cv2.COLOR_BGR2HSV)
mask = cv2.inRange(img, lower, upper)
```

The masking process generates a 720*720 matrix (camera resolution). Each element represents one pixel and can have a value of 0 (black colour) or 255 (white colour).

After masking, the procedure for determining the level of liquid filling follows. This is done by checking the colour of each pixel of the image, starting from the top left pixel of the image. The pixel colour is compared to the sample colour. After finding 50 pixels in one row that correspond to the sample colour, the liquid level in the bottle is detected. This level is indicated by a horizontal red line that represents the level of filling of the bottle. Depending on the measured height, the program determines how full the bottle is (the ratio between the height of the bottle and the height of the liquid) and based on this data it is determined whether the bottle is “correct”. The algorithm is shown in Figure 9 and the parameters are determined experimentally.

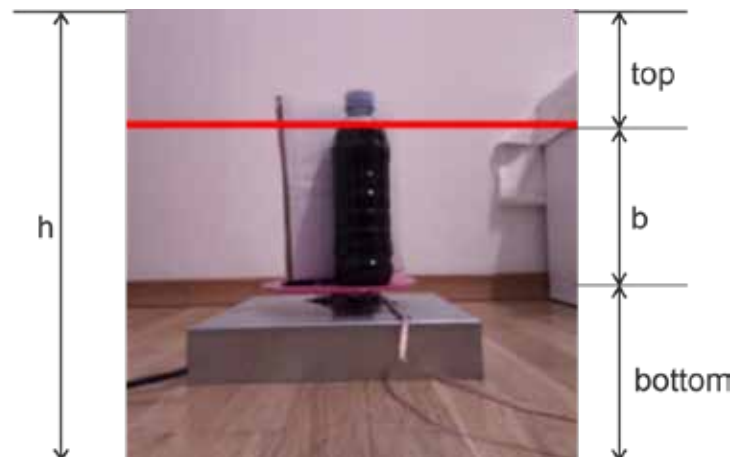


Figure 9 Graphic representation of the bottle and the algorithm

The height h is given by the resolution of the image and is 720. The liquid level of the correct bottle was determined experimentally and is marked with **top** (144), and the total amount of liquid is marked with **b** (360). The **top** and **b** values are only valid for the current camera position. If the distance between the bottle and the camera changes, it is necessary to determine the values of the variables again.

After the program calculates the liquid level (**height**), that is, how far the liquid level is from the top of the image, the percentage of the bottle's filling is calculated according to expression 1.

$$p = [(b + \text{top}) \text{height}] / b * 100 \quad [\%] \quad (1)$$

If p is greater than 98%, it is considered that the bottle is correct, and the stand continues to rotate. If p is less than 98%, the stand stops. After removing the defective bottle, the stand restarts to rotate when the operator presses a button.

The measurement procedure itself seems impractical, given that it is necessary to experimentally determine the position of the bottle in the image. However, both the stand and the camera are fixed objects, so after the initial adjustment the system works stably. The system is relatively slow because the bottle occupies only approximately 50% of the image, and the process of searching for the liquid level starts with the analysis from the top of the image, which certainly does not belong to the bottle. One of the solutions is to bring the camera closer to the bottle or to crop the image so that only the bottle remains in the image.

6. Prototype testing

For testing purposes, the bottle is filled with the drink “Cola”. Figure 10 shows a liquid sample obtained by the auxiliary program. The program describes the colour of the liquid and the colour components and expresses them numerically. Specifically, in Figure 10, the colour value is represented in the HSV colour system has the values: [138 91 14]. In this way, the relevant value is set for the system, and it will be used to recognize the level of liquid in the bottle.

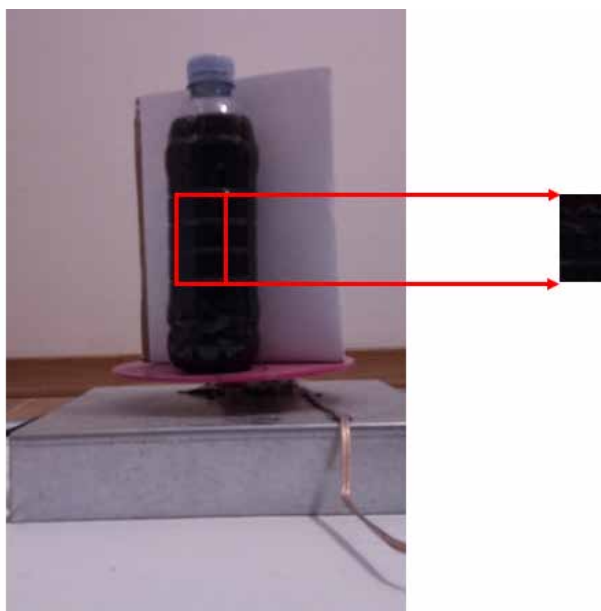


Figure 10 Taking the relevant sample

Testing process is divided into normal working conditions and extraordinary working conditions. The response speed of the system and the level of liquid in the bottle are measured. All measurements are performed four times with the same bottle. The testing is carried out under controlled conditions: the brightness of the environment must be the same for all measurements, without external influences (wind, dust, increased humidity in the air, etc.), the same liquid is in bottles on which the measurement is performed, the rotating stand is initially stopped.

6.1. A bottle filled to the top, with a suitable liquid in the bottle

The arithmetic mean of the system response speed is 2.770 s, with a standard deviation of 2.4%. The arithmetic mean of the liquid level measurement results is 99.826%, with a standard deviation of 1.4%. The bottle is 100% filled, while the system measured the bottle to be 99.826% filled on average. Figure 11 shows measuring results of a full filled bottle. As can be seen, the measurement is almost perfectly accurate. The system correctly marked the level of liquid in

the bottle with a red line. Given that the bottle is full, the system continues to work normally and checks the next bottle. Figure 12 shows how the computer sees that bottle. The white pixels in the image represent the liquid. The liquid in the right image is not correctly represented. The reason for this is that the liquid is black, and with black colour system is limited by the lower limit value of the colour shade.

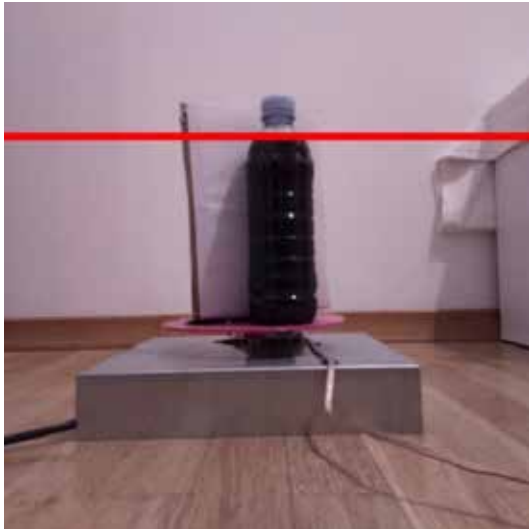


Figure 11 Measuring a full bottle

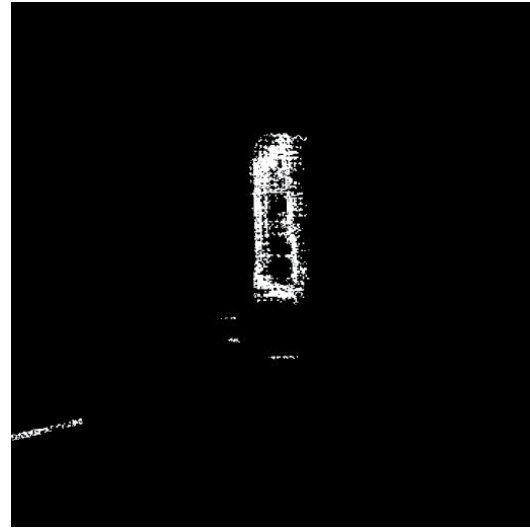


Figure 12 Image display in computer vision

6.2. A bottle that is not filled to the top, with a suitable liquid in the bottle

The arithmetic mean of the system response speed is 4.399 s, with a standard deviation of 1.0%. The arithmetic mean of the liquid level measurement results is 50.646%, with a standard deviation of the measurement results of 16.6%. The bottle is 50% full, while the system measured the bottle to be 50.646% full on average. The difference between the average measurement which is 50.646% and the actual liquid level is very low and is 0.646%. Figure 13 shows a bottle that is not filled to the top. Figure 14 shows a computer view of the bottle. The white pixels in the image represent the corresponding liquid, and there are fewer of them than when the bottle is filled to the top, which may be the reason for the difference in measurement precision and accuracy.



Figure 13 Measuring a bottle that is not filled to the top

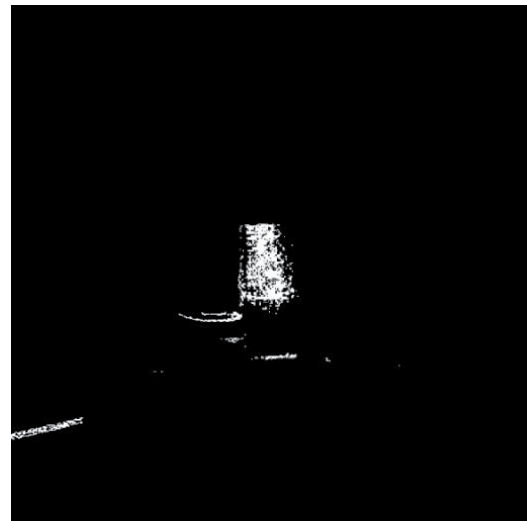


Figure 14 Image display in computer vision

If the bottle is not filled to the top, the system shows its weak side. The measurement results are significantly different from the measurement results of a fully filled bottle. The image processing speed in this case is an average of 4.399 s. This is almost two seconds more than the time required to process an image of a fully filled bottle. The accuracy of the system also decreased. The deviation between the measurement results is 16.6%, which is a difference of approximately 15% compared to the measurement results in the case of a fully filled bottle. The deviation of the accuracy of the system is within the limits of 1% and is 0.646%, while the deviation in the measurements of the fully filled bottle was less than 0.2%.

The main task of the system is to distinguish a fully filled bottle from one that is not fully filled. Despite the deviations in measurements, the system performs its task properly and very well distinguishes bottles that are correct (filled to the top) from those that are not. In this case, the bottle is not filled to the top, so the system stops the production line.

6.3. Empty stand

In the event of a failure in the production process, for example if a bottle falls off the stand due to a transfer error or if the filling device skips the bottle, an empty space will be created on the stand. The system recognizes this situation as an “empty bottle” and reacts exactly as it should: it stops the stand and alarm the operator to check the condition of the stand and restart the system manually.

The arithmetic mean of the system response speed is 7.554 s, with a standard deviation of 1.6%.

Figure 15 shows an empty stand. The line with which the system marked the liquid level is below the predicted limit, so the system stopped further operation. Figure 16 is a computer view. The computer does not recognize a liquid that correspond to the sample, it finds some similarity with the shadows on the stand. However, this is still not enough to cause an error in the system’s operation, and the system performed the task perfectly, without having previously been adapted to this situation.



Figure 15 Empty stand

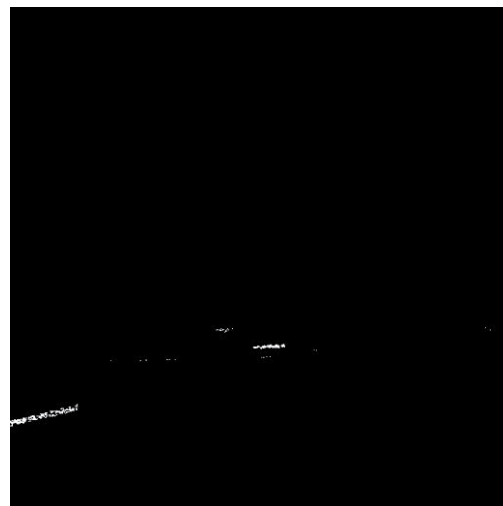


Figure 16 Image display in computer vision

6.4. Wrong liquid in the bottle

The reaction of the system in the event of an error in the production process is observed. Specifically for this example, if the filling device fills the bottle with the wrong liquid. The system recognizes this situation as an “empty bottle” and reacts correctly. System stops the stand and alarm the operator to check the condition of the stand and restart system manually.

The arithmetic mean of the system response speed is 6.819 s with a standard deviation of 7.3%.

Figure 17 shows a bottle filled with the wrong liquid. As an example, a bottle is filled with the drink “Tangerine”, which has different colour than sample with “Cola”. Figure 18 is a computer vision representation of the wrong fluid. The computer does not recognize the other liquid because it does not match the relevant sample. The picture is almost identical to picture 16, which shows the empty stand. The computer recognizes the shadow as a pattern, but the size of the shadow is not sufficient for the system to show a positive outcome. The system also handled this situation well.



Figure 17 Bottle filled with wrong liquid.

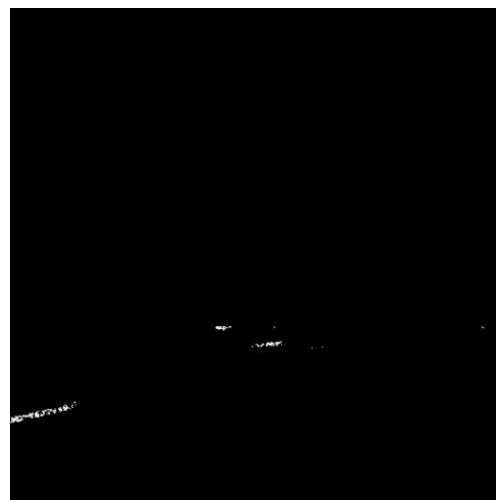


Figure 18 Image display in computer vision.

6.5. Packaging error

The reaction of the system is tested when a bottle with a label appears on the production line, but also with a different design, i.e. different packaging than the one used in normal production. During the test, the bottle is filled to the top, with the appropriate liquid that is preset in the system. If a bottle filled with the correct liquid but with the wrong design appears on the production line, the system will not be able to distinguish the packaging, which is a flaw in the system. Also, the system cannot measure the liquid level behind the label, which is an additional disadvantage.

The system correctly recognizes the liquid level in the bottle because it is the corresponding liquid predetermined in the settings. In this measurement, the label did not interfere, but it can. Figure 20 is a computer view of Figure 19. The image clearly shows that the bottle is filled with the correct liquid, but it can be seen an empty square which the area is covered by the label. The area where the label is located appears to the computer to be empty and not filled with liquid. The reason for this is the colour of the label. It differs from the relevant sample representing the “Cola”. The system is not able to measure the level of filling of the bottle if the bottle is filled to the level positioned behind the label. Also, a label of a similar colour to the “Cola” sample could lead the system to misinterpret the amount of liquid in the bottle.

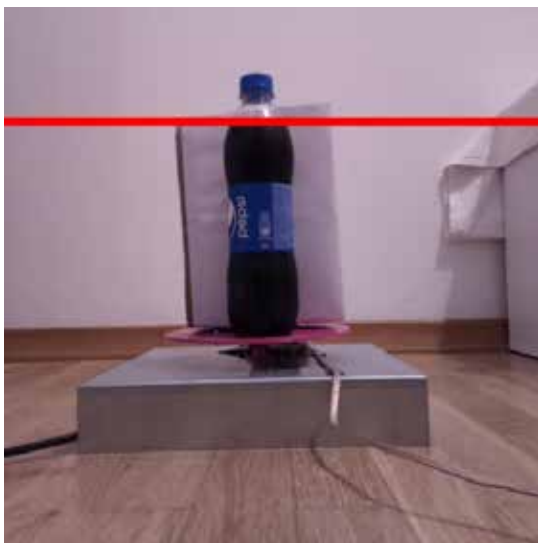


Figure 19 A bottle with a label of a different design than intended

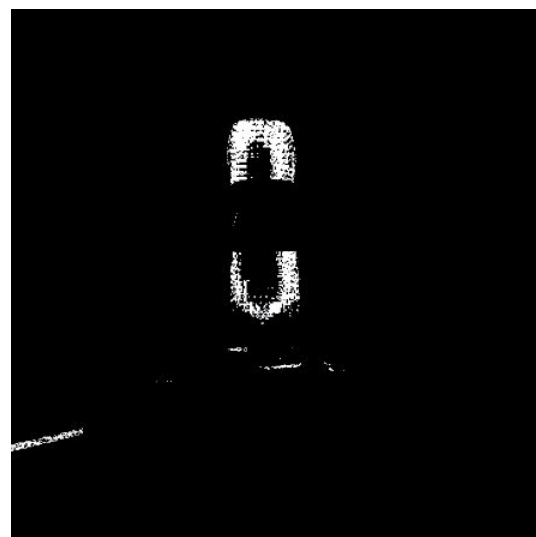


Figure 20 Image display in computer vision

7. Conclusion

Through this practical project, the connection of computer vision and electromechanical components for the automation of the liquid level detection system in the bottle was successfully demonstrated. The combination of these technologies enables fast, precise, and reliable liquid level analysis, with the potential for application in a wide range of industries. The project is based on a combination of hardware and software components. The Raspberry Pi microcontroller serves as the central unit that manages all processes, while OpenCV enables advanced image analysis. Using colour analysis, the system precisely identifies the level of liquid in the bottle. The use of physical components such as LED indicators and pushbuttons enables interaction with the user and provides visual feedback on the status of the system. This interactivity helps in the optimization of production processes, enables monitoring of the state of the bottle in real

time and reduces the need for employee intervention. In addition to industrial applications, this project has the potential for further expansion and adaptation. It can be very easily implemented in various industries, such as food, pharmaceutical and chemical. The system enables monitoring and management of production processes with greater efficiency and precision.

The tests performed showed that the system functions very precisely under normal operating conditions. Also under extraordinary operating conditions, in two out of three situations in which an attempt was made to simulate a malfunction, the system satisfied with its response. In the case of an empty production line or the wrong drink in the bottle, the system stops the line. The shortcoming that was observed during testing is the inability to recognize the packaging and interference with work that occurs because of the label on the bottle. Accordingly, all measurements are made on transparent packaging without labels. This paper highlights the importance of technologies such as Raspberry Pi and OpenCV in automation, which enables better utilization of resources and the achievement of high product quality.

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SOFTWARE AND HARDWARE SUPPORT FOR ALARM SYSTEM

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Abstract. One of the most important facilities of an object, today, are security and protection. Internet of Things (IoT) technology greatly facilitates the communication and display of various devices, as well as their management from great distances. The paper will present the development of the software and hardware of the alarm system. The system is based on an ESP32 microcontroller, which is communicated with and controlled using the Blynk application via computer or a smartphone. Such systems make it easier for the emergency services to reach the part of the building where the cause of the danger is in the shortest possible time, and remove it. They also speed up the process of evacuating people from the facility. Such systems save lives and property and are indispensable in today's world.

Key words: *IoT, ESP32, alarm system, Blynk*

1. Introduction

The purpose of an alarm system is to warn of impending or imminent danger. The system can be at the city level or at the object level. In the system of alerting and informing the population at the city level, sirens, public address devices, electronic media and SMS devices are used. Alerting the population is done with unique warning signs, which are prescribed by the Regulation on unique warning signs.

The Internet of Things (IoT) greatly facilitates the creation of “smart” monitoring, control and management systems both in industrial plants and in various household needs. IoT represents a network infrastructure in which physical and virtual devices of all kinds communicate. Device connection can be different, through different protocols. IoT provides new ways for different systems to interact with each other and thus brings new possibilities for their control, monitoring and provision of advanced services [1, 2].

The Blynk platform is one of many existing tools that offers the possibility of connecting various devices, that is, circuits, and managing them: visualization of sensor data, remote control via mobile phones and web applications, Over-The-Air firmware update, secure cloud, data

analytics, user and access management, alerts, automation and much more... The advantage of the Blynk platform is, first of all, its simplicity and reliability, so that it can be applied for, for example, simpler projects or for managing complex processes in industry. The platform is commercial, but also offers free use of some features that are sufficient in most cases to create less complex projects.

This paper describes the development of the circuit and program support of the alarm system. The system consists of a series of circuits located inside the building. The basis of the assembly is an ESP32 microcontroller to which sensors for fire, smoke, temperature and air humidity are connected. The assembly communicates using the WI-FI standard [3]. For the needs of the system, an application was developed using the Blynk platform, which enables two-way communication with the circuits, reads data from the sensors and, in case of a harmful event, activates a sound signal on the circuits for the purpose of evacuating the premises, that is, the building.

2. Hardware Support of the Alarm System

2.1. Block Diagram of the System

The block diagram of the alarm system (Figure 1) provides a simplified overview of the entire system, from which it is evident that the sensors send the read values to the ESP32 microcontroller, which processes these values and forwards them via WIFI to the Blynk cloud, to which the mobile application is connected. In case of a value change on one of the sensors, the microcontroller includes the DFPlayer mini, which plays an audible alarm using an amplifier and a speaker, while Blynk sends a notification to the user via an application and email.

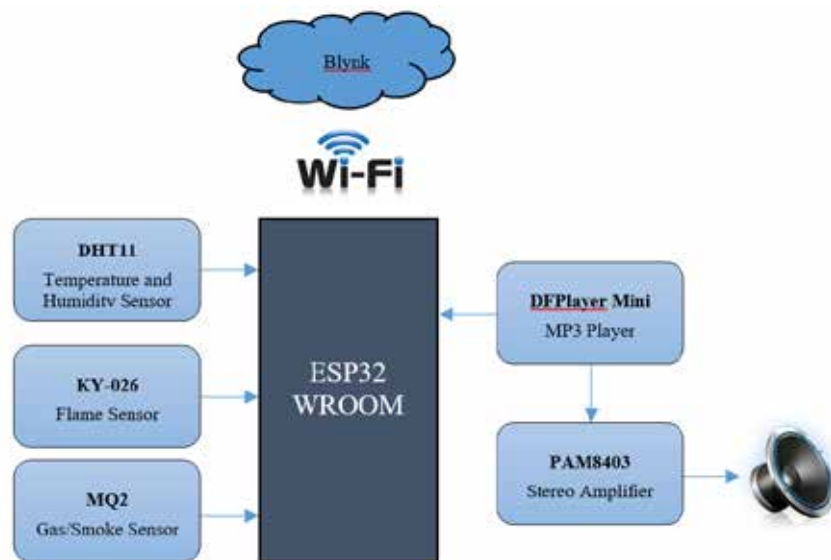


Figure 1 Block diagram of the system

2.2. System Components

The following components were used for the implementation of the project: microcontroller - ESP32 [4], air quality sensor (temperature and humidity sensor) - DHT11 [5], smoke sensor

- MQ2 [6], flame sensor - KY-026 [7], MP3 decoder - DFPlayer mini [8], audio amplifier - PAM8403 [9] and speaker.

The components of the circuit part of the system are connected according to the scheme shown in Figure 2. The electrical scheme of the system was created in the Fritzing program [10]. As can be seen from the diagram, all devices and sensors need to be supplied with a positive voltage of 5V from the ESP32 microcontroller, as well as grounding. Each sensor to send measured values to the ESP32 microcontroller needs a connection to its digital input. Thus, the DHT11 sensor is connected to digital pin D26, KY-026 to digital pin D33, and the MQ2 sensor to digital pin D35. The DFPlayer mini makes a serial connection with the ESP32 microcontroller via a "UART" interface consisting of two pins: Rx and Tx. The Rx pin is used to receive data, and the Tx pin is used to send data. In order to make a correct connection between them, it is necessary to connect the Tx pin from the microcontroller to the Rx pin of the DFPlayer via a 10k Ω resistor that serves to reduce the noise on the Rx line of the DFPlayer. It is also necessary to connect the Rx pin from the microcontroller to the Tx pin of the DFPlayer for full serial communication between them. The PAM8403 amplifier is connected to the audio output DAC_R from the DFPlayer, and the speaker is connected to the amplifier outputs provided for the speaker: +R and -R.

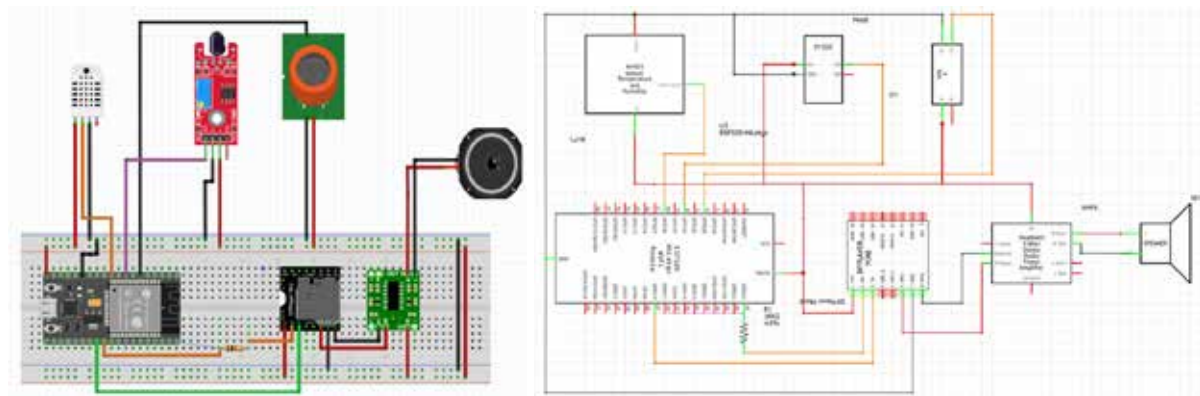


Figure 2 Electrical scheme of the system

After creating the scheme, it is necessary to arrange all the associated components on the printed circuit board in such a way that the space on the circuit board is used to the maximum, as shown in Figure 3. Drilled Vetronit was used to create the prototype. The sensors must be next to each other in order to correctly report potential hazards. After soldering all the components to each other, it is necessary to insulate the connections of the sensors with an insulating mask. Insulation is carried out as a safety and protection measure to prevent the possibility of a short circuit on the sensors themselves and thus lead to an unwanted failure on them, as well as the possibility of receiving incorrect feedback about the detected danger.

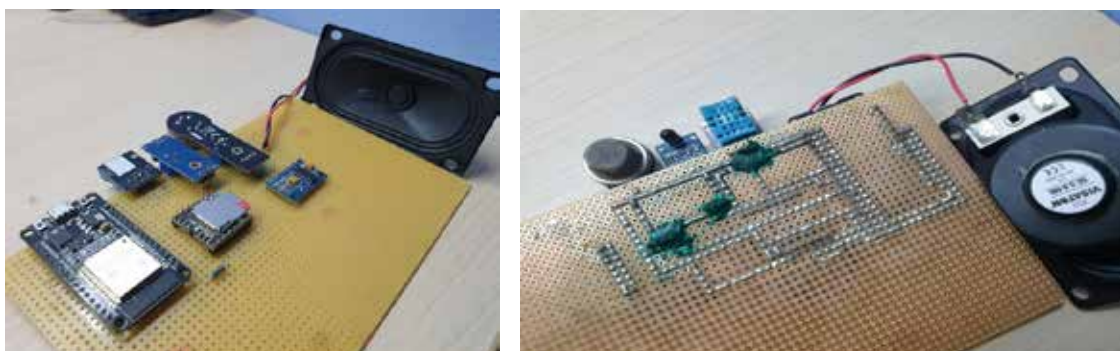


Figure 3 Printed circuit board

3. Software Support of the Alarm System

IoT or Internet of Things is a technology that is expected to enable the connection of devices and thus allow them to communicate with each other and with the user. IoT is actually a common network of all connected physical devices, i.e. a technology that facilitates communication between an application and a device.

Blynk is an IoT platform, which can be used to manage the circuit remotely, and to have real-time insight into the sensor values that are displayed via a mobile application on iOS and Android devices. The main parts of Blynk are: Blynk application, server and library. The Blynk app allows you to create a personalized interface for your projects using the various templates available when building the app. The Blynk server is responsible for all communications between the smart device and the system it wants to manage. There is the option of using Blynk Cloud or creating your own private local server. Blynk libraries enable communication with all popular platforms such as Arduino, NodeMCU and Raspberry Pi.

Figure 4 shows the Blynk interface for a mobile phone that manages the alerting system. The picture shows that the application reads four parameters (temperature, humidity, fire, smoke), and when fire is detected, it turns on the alarm using the speaker built into the device. The creation of the interface will be explained separately later. Furthermore, the process of creating the application code of the device based on the ESP32 microcontroller will be presented.



Figure 4 Blynk mobile application interface

In order to be able to control the circuitry using the Blynk application, it is necessary to use virtual pins. Virtual pins are actually a way of sending commands from the application, to the application code running on the microcontroller via the Blynk server. It is necessary to write the appropriate application code on the microcontroller, which will connect the virtual and physical pins, and thus enable device management using the Blynk interface [11].

The `BLYNK_WRITE(vPin)` function is a function that is automatically called when the device receives information from the server that the pin value has changed, which usually happens when a button is pressed in the application. Since the server sends the current value of the virtual pin to the system as a parameter, it is necessary to save it so that it can be used to perform various actions when the button in the application is turned on or off. Saving that value is done with the command `int virtual_pin_value = param.asInt();`. That command tells the code to read the value from the virtual pin and store it in a local integer variable called “virtual-pin-value”. In order to now connect the virtual pin to the physical pin, the command “pinMode”

is used, which should be executed only once at startup, so it will be placed inside “void setup()”. This is followed by the function BLYNK_WRITE(vPin) in which a condition is set where the previously saved variable “virtual-pin-value” is checked, and the command “digitalWrite(pin, value)” is used to control the physical pin.

3.1. Arduino IDE

The alarm system is programmed with the Arduino IDE (Arduino Integrated Development Environment) software package [12]. The Arduino IDE package enables easy programming in the C++ programming language. It provides compiling the program itself as well as uploading the code to the ESP32 microcontroller. The Arduino IDE comes with many programming libraries, but for this system you need to additionally install the Blynk and DFPlayer mini libraries. The program also has a Serial Monitor tool that enables communication with the microcontroller via a virtual COM port, and helps in detecting and debugging errors in the program code. Figure 5 shows the appearance of the interface of the Arduino IDE program package.



Figure 5 Arduino IDE interface

Before writing the code itself, it is necessary to connect the Arduino to the existing Blynk interface at the very beginning. This is done with the *#define* function, in the way of entering the ID, name and verification token of the Blynk interface.

The *#include* function includes the necessary program libraries for WiFi, ESP32, DHT, KAY-026, DFPlayer mini.

Using *#define*, constants are defined that do not occupy program memory on the microcontroller (constants are assigned for the digital pins of the ESP32 microcontroller to which the sensors are connected), and virtual pins connected to the Blynk server are defined.

The next step is to connect the ESP32 microcontroller to the existing WiFi network in order to communicate with the Blynk server, and to create a notification event in Blynk that will be called later.

Figure 6 shows the setting of conditions in case of increased temperature, gas leakage or open flame. If the conditions are met, a command is given to send a specific warning message to the user application and the serial monitor.

```
void temperature()
{
  if(temp > temp_alarm_threshold){
    String text = "UPOZORENJE VISOKA TEMPERATURA U PROSTORIJI KOP II 113";
    Serial.println(text);
    Blynk.logEvent(temp_event, text);
  }
  Blynk.virtualWrite(TEMPERATURE, temp);
}

void smoke()
{
  if(smoke_concentration > smoke_alarm_threshold
    String text = "DETEKTIRANO CURENJE PLINA U PROSTORIJI KOP II 113";
    Serial.println(text);
    Blynk.logEvent(gas_event, text);
  }
  Blynk.virtualWrite(SMOKE, smoke_concentration);
}

void flame
{
  if(flame_amount == 0){
    String text = "DETEKTIRANA VATRA U PROSTORIJI KOP II 113";
    Serial.println(text);
    Blynk.logEvent(fire_event, text);
  }
  Blynk.virtualWrite(FLAME, flame_amount);
}
```

Figure 6 Setting conditions in the Arduino IDE

After creating the notification, it is necessary to program the created virtual button in the application for manually turning on and off the alarm sound, and the slider for increasing and decreasing the volume, in order to enable the control of DFPlayer.

After the virtual management of DFPlayer is enabled, it is necessary to connect DFPlayer to the ESP32 microcontroller. Use `hwSerial.begin` to determine the speed, type and to which digital inputs/outputs the DFPlayer is connected to the ESP32.

In order to ensure that the system works even in case of unavailability of the Blynk application, an additional condition is set, which will trigger an alarm via DFPlayer in the event of a value disturbance on one of the sensors. DFPlayer plays the sound track stored on the SD card in DFPlayer with the help of the PAM8403 amplifier and speakers.

3.2. Blynk Platform

In order to successfully connect the devices that make up the IoT network, it is necessary that each device has a unique identifier that Blynk automatically generates when creating a new template [13]:

- *Blynk Template ID* is a unique identification mark made up of letters, automatically generated, which enables the device to be correctly associated with the corresponding device template. Template ID, i.e. device identification template, is created in the process of creating a new template so that each template has a unique identification number. The Template ID is extremely important since it is added to the microcontroller code itself (Arduino code) in order to make a proper communication and connection between the Blynk application and the microcontroller.
- *Blynk device name* is the name that is chosen when adding a new device, unlike the Template ID, it is determined arbitrarily by the user.
- *The Blynk Auth Token* is the main device identifier in the Blynk cloud, and without it it is not possible to properly connect the device and use the system. Addressing of the device, in this case the ESP32 microcontroller, is done using the Auth Token. The

Blynk Auth Token is assigned a unique 32-bit record made up of letters and numbers. The Blynk Auth Token cannot be generated “manually”, it is generated automatically when adding a new device in the Blynk application. It also needs to be added to the Arduino code as well as the Template ID and Blynk Device Name in order for the system to connect properly.

Blynk is an online platform accessed using a web browser. When creating a new template, you need to enter the system name, hardware component and connection type.

After that, it is necessary to enter the necessary addresses, firmware codes, device models and their purposes in the device template (Figure 7). Each template consists of the following data:

- Template ID - template identifier is a unique generated template identifier that ensures Blynka recognizes the type of added device and adds other template elements to it.
- General settings.
- Metadata - a “key:value” data table is associated with each device. “Keys” are immutable values while “values” are values associated with each device.
- Datastreams.
- Events.
- Web dashboard.
- Mobile dashboard.

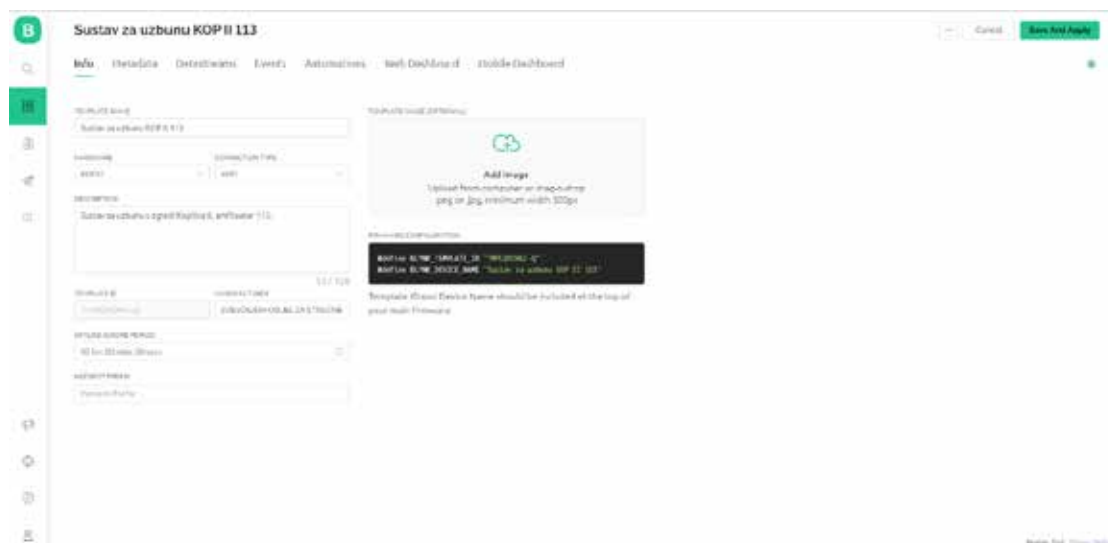


Figure 7 Device template

In the Datastreams section, the channel used to send data between the device and the Blynk cloud is defined. It is a way of structuring the data that the device receives and sends, and is used for sensor data, any telemetry or actuators [14].

To add a datastream, click on “New Datastream” and select Virtual pin. After selection, the name of the sensor is entered and the value of the virtual pin (V0,V1,V2,...) is assigned to it. A virtual pin is actually a concept used by Blynk to allow the exchange of any data between the device and the Blynk application. These are different from the analog and digital input/output (I/O) pins of the microcontroller. Virtual pins are connected to microcontroller pins to which sensors and actuators are connected when programming the microcontroller, thus ensuring communication with sensors without writing additional code. The connection procedure is performed using the Arduino IDE.

After determining the pins, the data type is selected, depending on the data read by the sensor, and the measurement unit. After that, it is necessary to define the minimum and maximum value that the sensor can read. All datastreams used in the project are shown in Figure 8.

ID	Name	Alias	Color	Pin	Data Type	Units	to Read	to Write	ID	Default Value
1	Temperature sensor	Temperature sensor	Green	V10	Integer	°C	False	0	100	0
2	Flame sensor	Flame sensor	Blue	V11	Integer	False	0	100	0	0
3	Water/gas sensor	Water/gas sensor	Red	V12	Integer	None	0	1	0	0
4	Sensor voltage	Sensor voltage	Orange	V13	Integer	V	False	0	100	0
5	Alarm	Alarm	Black	V14	Integer	False	0	1	0	0
6	General alarm	General alarm	Purple	V15	Integer	False	0	1	0	0

Figure 8 Overview of all Datastreams

Events are used for monitoring, recording and working with sensors and other device components. Events are also used to notify the user of the occurrence of an event detected by the sensor. The system can send such notifications to the selected user via push notification, email or SMS message. Events are pre-created and configured in Blynk. There are four types of events:

- Info - general information.
- Warning - a warning event, ignoring this event may cause problems.
- Critical - a critical event means urgent attention or action.
- Content - this is a special type of event, it can provide us with additional information, for example, an image, a link or additional textual information.

After selecting the name of the event, it is necessary to select the type of event, i.e. choose between four types of notification: informative, warning notification, critical and substantive notification. The event can then be described in more detail in the description with additional text and additional settings can be selected for the selected event.

The last step is to enable the notification to be sent directly to the selected user, which is very important when the system detects, for example, the appearance of a flame. In this case, the system immediately sends a notification to the user's mobile device. In the free version of Blynk used to create the project, it is possible to send push and email notifications only to the owner of the device, while in the upgraded version it is possible to send notifications to any user.

3.2.1. Creating and Editing a Web Application

In order to be able to control and read the measured results, it is necessary to create a web application, Figure 9. The web application is created using block programming and various objects are available to the designer: switches, meters, graphs, sliders, etc.

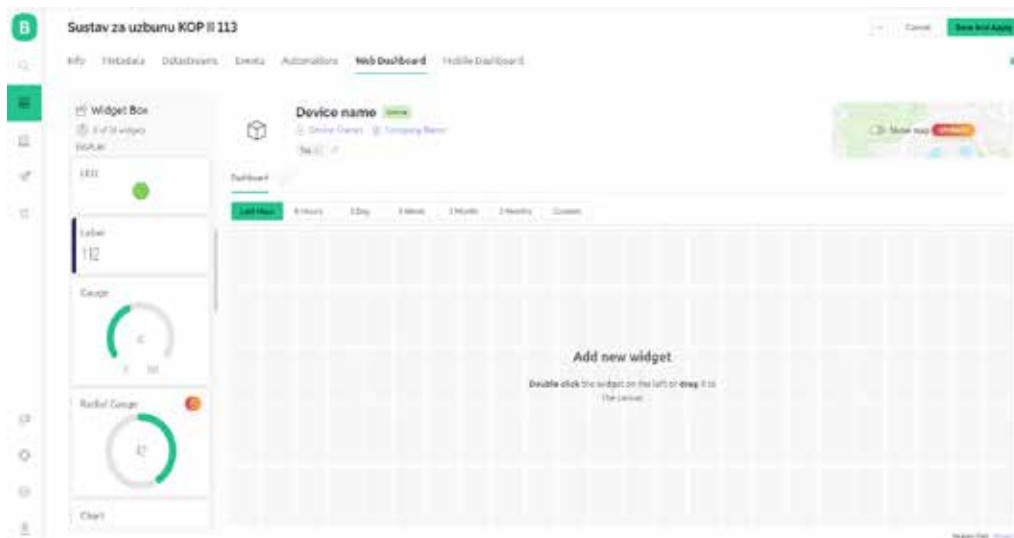


Figure 9 Single figure example

The sensor is added to the web application by selecting the desired gauge from the auxiliary menu on the left and inserting it into the control panel on the right. Once added, it is edited by adding the name of what it measures, and adding the corresponding virtual pin so that it can be connected to the desired sensor. It is then edited according to the user's wishes and saved in the control panel.

3.2.2. Creating and Editing a Mobile Application

After the web application has been created and edited, it is necessary to create a mobile application as well, which is shown in Figure 10. The advantage of the Blynk platform is precisely that it enables control and management of devices and sensors not only via the web but also using a smartphone. The process of creating a mobile application is simple and similar to the process of creating a web application.



Figure 10 Creating a Blynk application for a mobile phone

After starting the mobile application, select the device that you want to use in the application, and then add switches, gauges, graphs, sliders, etc. for the selected device. After adding and connecting all sensors with valid gauges, you can see how the application interface looks like. The basic version of Blynk (free) limits the user to using the standard interface without the ability to change the appearance of the application, and to the standard options in the application. By upgrading the application to one of the commercial versions, access to all features and add-ons is enabled and the full potential of the Blynk platform can then be used.

3.2.3. Connecting Devices to the Blynk Platform

The last step after creating the web and mobile application is connecting the device to the Blynk platform. It is necessary to select the “add new device” option in the search engine, and then select the device using the previously created template. It is also necessary to add its name.

In addition to the confirmation of the successful creation of the device, identification parameters are obtained: Blynk Template ID, Blynk Device Name and Blynk Auth Token, shown in Figure 11. The identification parameters must be added to the microcontroller code in order for the system to successfully connect the Blynk platform to the microcontroller and sensors.



Figure 11 Data for the identification of the new device

3.2.4. Edit Application, Add User Access

In order to add users in the standard version of Blynk, it is necessary to open the settings and click on the “Users” option. A new user is added by selecting “Invite new user”. Then it is necessary to enter the user’s name, email address, phone number and select the user’s authority.

It is possible to choose between three defined categories of users:

- administrator,
- employee,
- user.

Each user category is assigned different powers. These can be edited in the application settings and edited as needed.

4. System Testing

After installing the printed circuit board with soldered components, programming and creating the Blynk application, it is necessary to perform system testing in order to confirm the complete correctness of the alarm system. In order to perform the testing of each sensor and the correctness of the communication between the ESP32 microcontroller and the Blynk platform, it is necessary to test each sensor individually.

First, the testing of the DHT11 sensor, which is intended for measuring temperature and humidity, was carried out. The test was carried out in such a way that high heating of the sensor was achieved with a space heating device that increased the temperature while the humidity decreased. After the temperature rose above 50°C, the system triggered an alert alarm with

an interval of 90 seconds, and a push notification and an email notification to the system user arrived on the smart device. The content of the notification provides the user with information about what the danger is and in which room the danger is located.

After testing the temperature and humidity sensors, the next step was to test the KY-026 fire sensor. At a distance of approximately 30 centimeters, a flame was ignited, which the sensor detected in a short time, and accordingly it turned on the warning alarm. In the event that someone creates a flame inside the room, i.e. if it is not a real fire, the user can use the button in the mobile application to manually extinguish or, if necessary, turn on the alarm.

The last test of the alarm system was the test of the MQ2 sensor, which is intended for smoke and gas detection. In order to activate it, a certain amount of gas was released through the lighter, and within the application it was seen that the sensor was gradually reading the increase in gas. When the amount of gas displayed on the gauge exceeded the limit value, the system turned on the alarm, and through push and email notifications, informed the user that there was an increase in the concentration of gas in the room.

After the successful testing of each sensor individually and the communication of the mobile device with the Blynk platform, it was found that the system prototype is functioning properly, and that all the features of the system are satisfied.

5. Conclusion

This paper presents the complete process of realization of the functional circuit system for alerting. Due to its accessibility and simplicity, it can be used in households or business premises.

The advantage of the system is the low cost of production due to relatively cheap components and the possibility of using the free version of the Blynk platform, which can be used to create a fully functional system. The advantage of such a system is communication via WI-FI wireless connection, which is available everywhere today.

The created, implemented system has fire, smoke, temperature and humidity sensors. Since it is based on an ESP32 microcontroller, the system can be easily expanded with new sensors and new functionalities such as lighting control, ventilation and air conditioning systems, etc. The advantage of the Blynk platform is that it is extremely easy to use and does not require special knowledge for effective use.

The functionality of the system has been successfully tested. All devices timely and accurately notified the user of the state of the sensors via a mobile application. The sirens on the devices were successfully activated using the mobile application.

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EDUCATIONAL SYSTEM FOR AUTOMATED TESTING OF THE ELECTRIC ELEVATOR DRIVE

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Abstract. The paper describes an educational system for partially automated testing of the elevator's electric drive. The system consists of an elevator model with a three-phase cage induction motor, a control panel, a frequency converter and a dynamic test system. System control can be operated manually, remotely or automatically, using relay and PLC techniques with the SCADA system.

The electric drive of the elevator enables the operation of the induction motor in motor and brake mode, which makes it suitable for executing exercises related to electric machines, electric drives and their control and automation. The exercises that are singled out in the paper are described in terms of a theoretical presentation of the main features and an explanation of the expected results, as well as in terms of their practical performance in the system.

Furthermore, through the example of an automated induction motor heating exercise, the method of automating the mentioned exercises is described, which in the process of their execution focuses on the observation of the exercise itself, on the measured values and graphic presentations. Also, the paper introduces the elements of automation and the automation process, which are indispensable today.

Key words: *automated testing, induction motor, electric drive, elevator, PLC*

1. Introduction

In a world where new technologies appear daily, there is a need for continuous learning and following current events in the professional field. Learning through practice, i.e. through laboratory exercises on real systems, has proven to be the most effective way of learning. For such an educational method, it is necessary to design models that depict real systems as realistically as possible and are, at the same time, open and accessible for detailed analysis and understanding.

Today, the tendency to automate all processes is so pronounced that it cannot be avoided. Basic systems without elements of automation are almost impossible to find anymore and this automation trend continues to increase. Therefore, it is necessary to include automation elements in the educational models, which can also be used for more efficient analysis and

testing of the system, better observation of important actions while performing exercises and for familiarization with the system automating method.

2. Description of the educational system for automated testing of the electric elevator drive

The educational system for partially automated testing of the electric elevator drive consists of an elevator model, a control panel, a frequency converter, a dynamic test system for analyzing the operation of the drive and an autotransformer as a source.

2.1. Elevator model

The elevator model is used as an electric drive on which testing is performed. It consists of a basket that moves using sliding guides, so that it can be raised and lowered. It is connected by a steel rope via two pulleys to a rope wound drum, driven by a reducer and a three-phase squirrel-cage induction motor. The elevator travel is provided at three levels, indicated by position sensors, the highest and lowest travel points are limited by limit switches.

The motor has a built-in brake and is equipped with an encoder for measuring the motor rotation speed and determining the elevator position. Motor heating is measured by a temperature sensor built into the winding. Figure 1 shows the model of the elevator.

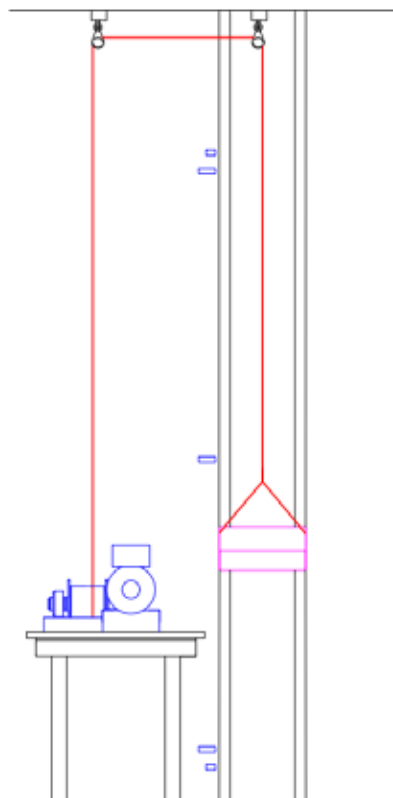


Figure 1 Elevator model

2.2. Control panel

The three-phase induction motor that drives the elevator is controlled via the control panel. It powers the motor through contactors that can be switched to change the direction of motor rotation, connect the motor windings in a star or delta, select the motor starting method and activate the brake. Figure 2 shows the control panel design. Contactors KM1 and KM2 control the direction of rotation of the electric motor. The star connection of the motor winding is made via the contactor KM6 and the delta via the contactor KM5. The selection of the motor starting method is made with the KM4 contactor for direct power supply, KM3 contactor for soft start, while KM5 and KM6 are star-delta start contactors. By connecting the frequency converter to connector S1, it is possible to start and control the motor using the mentioned converter. Contactor KM7 activates the motor brake.

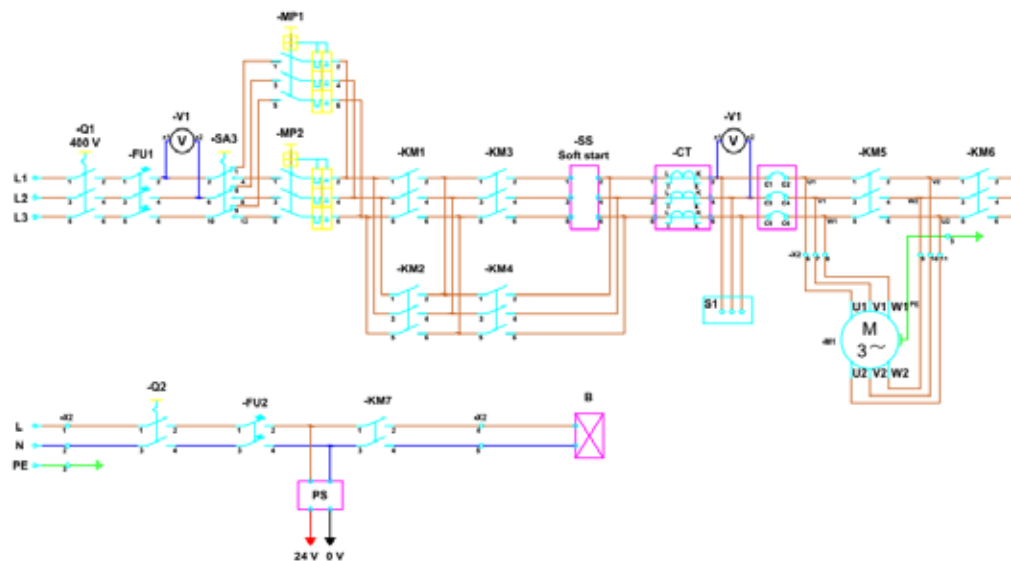


Figure 2 Control panel design

The induction motor control is performed by relay and PLC technology, and it can be executed manually, remotely and automatically. Figure 3 shows the control cabinet with associated switches, control buttons, signal lights and measuring devices.

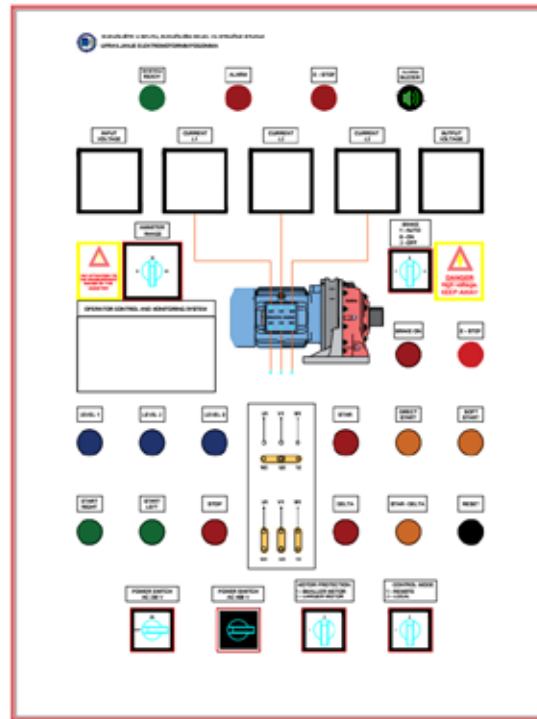


Figure 3 View of the control cabinet

2.3. Frequency converter

The frequency converter provides high-quality induction motor control, in motor and brake modes. Figure 4 shows the connection of the power lines to the terminals of the frequency converter L1, L2 and L3, the three-phase induction motor to the terminals U, V and W and the brake resistor to the terminals + and DBR. The system can optionally be equipped with thermal protection, which, in case of overload in braking mode, interrupts the control circuit, thus turning off the main power supply.

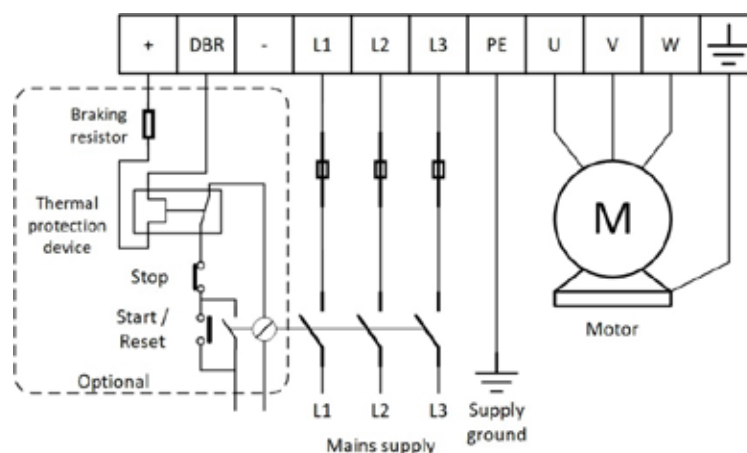


Figure 4 Frequency converter connection scheme

Control of the motor via the frequency converter can be executed locally and remotely, via the control signals shown in Figure 5. In both modes of operation, direct control of the motor, on/off turning and selecting the rotation direction can be executed via digital inputs (terminals 9-13), and speed regulation via analog inputs (terminals 1-5).

The digital inputs are activated by applying a voltage of 24V, while two analog inputs enable the regulation of the operating speed in the range of 0-10V and 4-20 mA.

In the local operating mode, the control signals are supplied via appropriate switches and potentiometers, and in the remote operating mode by sending signals from the output channels of the PLC controller.

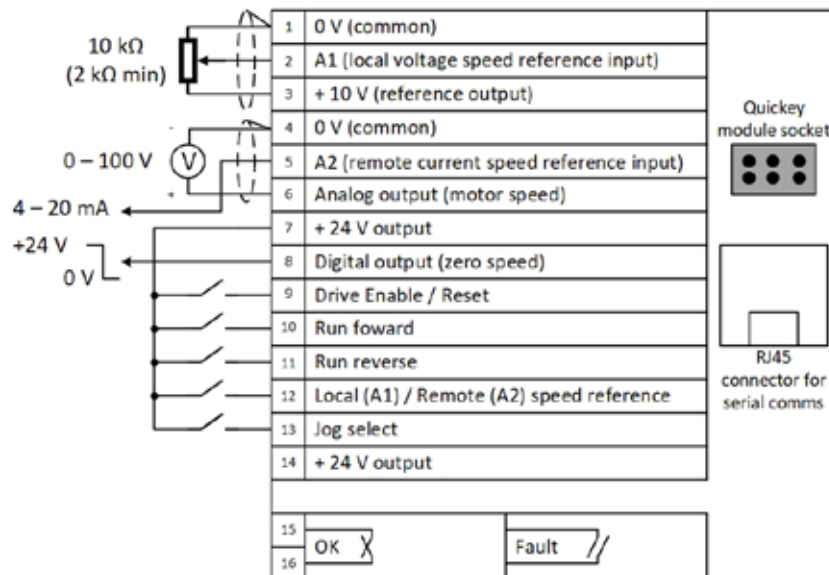


Figure 5 Control signals of the frequency converter

In order to be able to control the motor via the frequency converter, it is necessary that input 9 (*Drive Enable/Reset*) is constantly activated, and input 13 (*Jog select*) not activated.

Activating inputs 10 (*Run forward*) and 11 (*Run reverse*) starts the motor in one or the other direction.

The mode of operation as well as the motor speed regulation signal are determined by the status of the signal at input 12 (*Local A1/Remote A2 speed reference*). In local mode, this digital input is deactivated while the motor speed is adjusted by the voltage 0-10V on analog input A1 (terminals 1-3). In remote operation mode, by activating digital input 12, motor speed regulation is transferred to analog input A2 (terminals 4 and 5), which uses a current signal in the range of 4-20 mA.

The frequency converter also provides sending feedback via the digital output, terminal 8 (*Digital output (Zero speed)*) and analog output, terminals 4 and 6 (*Analog output (Motor speed)*), in voltage range 0-10V. By activating the digital output of 24V, it is signaled that the motor speed is equal to zero, while the current motor speed expressed as the number of revolutions per minute can be read on the analog output.

Remote control can also be additionally achieved via serial RJ45 communication interface, by using *ANSI EIA485* and *Modbus RTU* protocols. [5]

2.4. Dynamic test system

The dynamic test system is used for complete testing of electrical machines and electric drives. It consists of a digital control unit, brake and *Active Servo* software package. The dynamic test system is based on testing electrical machines, such as synchronous and induction motors, single-phase motors and DC motors. Exercises and measurements of motor characteristics for different types of load, as well as different motor connections, are planned. It is also possible

to achieve dynamic and static operation in all 4 quadrants, electric machine model drive that includes closed-loop torque control, speed control, inertial drive, step drive, elevator and conveyor belt.

The servo brake is used as a load and simulates linear (inertial) loads, as well as dynamic (variable) loads. It is controlled via the control panel included in this system or via a digital monitoring interface, if controlled via a computer.

The program package *Active Servo* enables the setting of various operating parameters, as well as the recording of the characteristics of the device being tested, and various real time measurements and storage of the characteristics of electrical machines. The measured values can be displayed graphically or tabularly.

Figure 6 shows the interface of the *Active Servo* program.

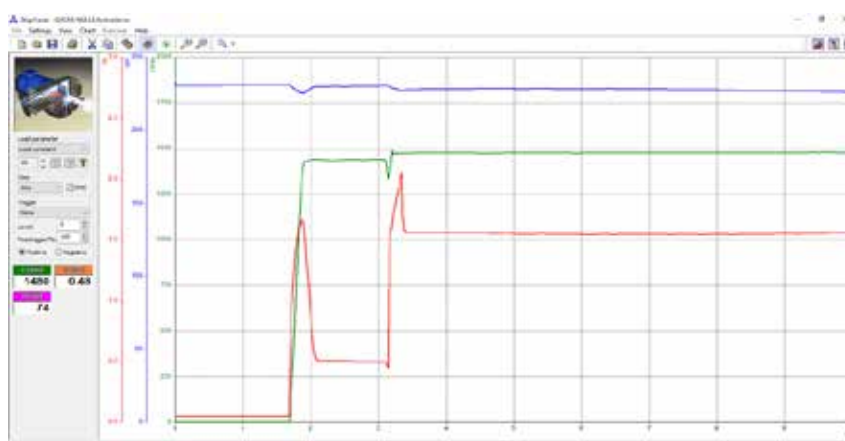


Figure 6 *Active Servo* program interface

For the motor operating mode, the system provides adjustment of the rotation speed or the load torque manually, i.e. directly on the board or in PC mode, i.e. on the computer, via the *Active Servo* program. When using the system manually, each operating point is adjusted separately, while displaying the mechanical quantities, i.e. torque and rotation speed, as well as the operating quadrant of the machine, while the measurement and monitoring of input electrical quantities is done by using measuring devices.

While using the system via computer, in the *Active Servo* program real time experiments with the adjustment of the rotational speed or torque can be performed, such as the experiment of gradually increasing the motor load from zero to the rated one, whereby the input electrical quantities can also be measured, if the power supply has been carried out and through the board. The program provides a graphical display of the interdependence of desired quantities, both measured and calculated, such as efficiency, slip, reactive power, power factor. The program also provides the comparison of multiple experiments within the same graphical interface, such as starting the motor at a nominal and reduced supply voltage.

To protect the motor, the dynamic test system provides tested machine winding temperature control measurement and stops the drive in case of overheating.

2.5. System operation principle

The elevator model is powered by a three-phase autotransformer. The power lines pass through a dynamic test system, that measures electrical quantities that can be processed and displayed graphically using the *Active Servo* program. The power supply is then led to the control panel, which can work independently or with the frequency converter. The induction

motor, as an elevator drive, is connected by a cable to the output terminals of the panel. Based on the selected action, the induction motor raises or lowers the basket, into which the desired amount of load is placed, thus regulating the motor load.

Control can be performed in manual mode, via buttons on the control cabinet, or remotely, via *SCADA* system. For the purpose of performing certain laboratory exercises, the operation of the program is pre-defined and executed automatically. By selecting the desired exercise, a short description of the exercise is displayed on the interface, as well as a request to confirm the fulfillment of the necessary requirements for performing the exercise. By starting the drive, the necessary actions are performed automatically and the required quantities are recorded and displayed graphically.

Figure 7 shows the block diagram of the system for automated electric elevator drive testing.

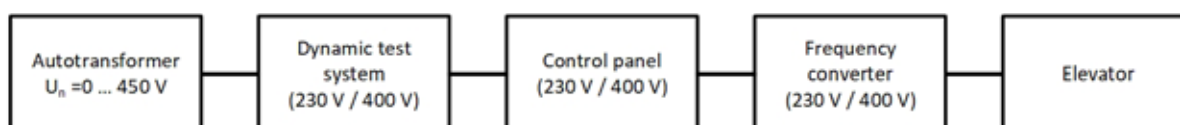


Figure 7 Block diagram of the system for automated electric elevator drive testing

3. Performance of laboratory exercises on the educational system for automated testing

A wide range of laboratory exercises related to electrical machines, electric drives and their control and automation can be devised and performed on the educational system for partially automated testing of the electric drive of the elevator. The exercises that can be performed on three-phase squirrel-cage induction motors refer to basic testings, different start-up methods, different operating modes, warm-up measurements, the testing of electric drives in their entirety and methods of drive control and automation.

3.1. Group of exercises – Basic induction motor tests

Basic test exercises for induction motors are no-load test, short-circuit test and load test. The no-load test is performed with the motor shaft unloaded and the voltage gradually increasing to the maximum nominal value. In this experiment, the total and narrow no-load operation losses are recorded, the nominal iron losses and the nominal friction and ventilation losses are determined graphically and computationally and the nominal no-load speed is determined.

The short-circuit test is performed with the locked rotor and the voltage gradually increasing to a significantly lower value than the nominal value, at which the measured current reaches the maximum nominal value. In this experiment, the dependencies of the stator current and torque on the voltage are recorded, and the starting torque and starting current are determined graphically and computationally, as well as the nominal losses in the copper of the stator and rotor and the rise in temperature of the stator winding during the experiment.

The induction motor load test is performed so that the shaft of the nominally powered unloaded motor is gradually loaded with increasing torque, while measuring the available electrical and mechanical quantities. In this way, the nominal mechanical characteristic of the motor is recorded or constructed, i.e. the dependence of the rotation speed on the load, the nominal operating point is verified and the behavior of other quantities of interest, such as stator current and voltage, power factor and efficiency, is monitored during the experiment.

3.2. Group of exercises - Starting an induction motor using different starting methods

When starting an induction motor, high starting currents occur, which can be up to 7 times the motor's rated current. The problem occurs with induction motors of higher power, when the supply network is not able to handle such currents and the protection reacts. For this reason, there are several induction motor starting methods by which the starting currents can be reduced. Direct start is used for lower power motors and is the simplest way to start an induction motor, which does not affect the starting current. Start with a star-delta switch is used for medium-power motors and is performed so that the motor starts working in a star connection, and then switches to a delta connection, which ensures a much smaller starting current, but also produces a smaller starting torque. With this design, the supply voltage should correspond to the rated voltage of the motor in the delta connection. Autotransformer start can also be used, which exhibits similar characteristics to starting with a star-delta switch. With the development of power electronics for medium and higher power motors, more advanced starting methods are being increasingly used, such as soft start and start by using a frequency converter. Examples of different starting methods for comparison are given in Figure 8 and Figure 9.

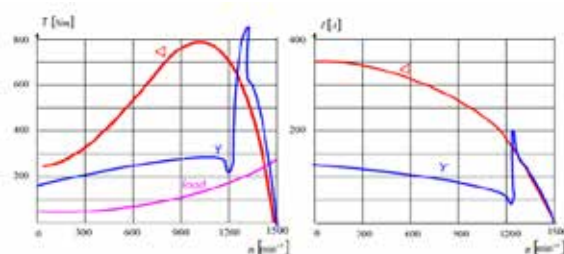


Figure 8 Starting with a star-delta switch [1]

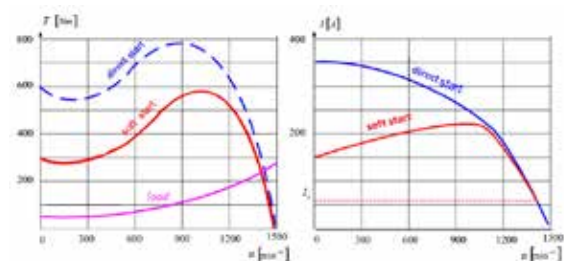


Figure 9 Starting with a soft start switch [1]

Using the testing system control panel, it is possible to start the induction motor via direct start, autotransformer, star-delta switch, soft start and frequency converter. By selecting the starting method, the system automatically starts the induction motor in the chosen way, with the measurement of electrical quantities and the display of I,U-t characteristics.

3.3. Group of exercises – Testing of an induction motor in different operating modes

An induction motor as part of the drive can operate in motor or braking mode. Motor mode of operation is achieved when the torque developed by the machine acts in the direction of motion of the drive. Figure 10 shows a sketch of the 4 quadrants for electric drives. Motor modes of operation are I. and III. quadrants, while II. and IV. quadrants present generator or brake modes. The braking modes are regenerative, reverse and dynamic braking. Since there is no possibility of adding resistance to the rotor circuit for the squirrel-cage induction motor, the application of the mentioned braking regimes is limited. Figure 11 shows a sketch of generator braking for an induction motor loaded with a potential load.

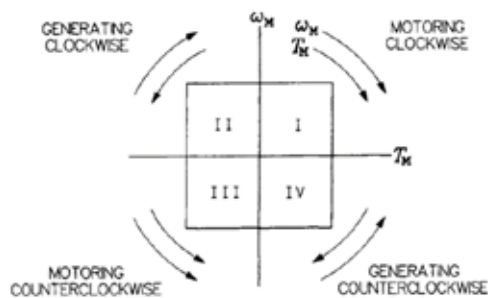


Figure 10 Operating modes [3]

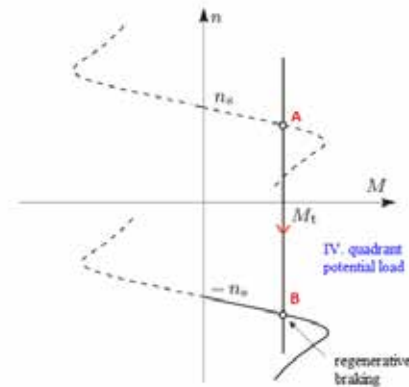


Figure 11 Regenerative braking [2]

Regenerative braking is performed in IV. quadrant, at point B, with constant super-synchronous speed. At the same time, the potential energy minus the losses is converted into electricity and returned to the grid. [4]

By measuring the electrical quantities and displaying the I,U,P,Q-t characteristics in precisely determined phases using the testing system, all modes of operation of the induction motor can be demonstrated and analyzed.

3.4. Group of exercises – Warming up an induction motor

The heating of an electric motor is in correlation to its losses, mainly the electric ones, considering that at the rated voltage the iron losses are constant, while the friction and ventilation losses depend on the rotation speed and are not always significant. The main cause of electric motor heating is long-term overload, i.e. a load higher than the nominal one. A permanent overload of only 5 to 10% can halve the life of the motor, and it should be ensured that the drive is optimally dimensioned. As dynamic regimes are often expected from the motor drive, such as take-off, acceleration, deceleration and braking, even motors intended for drives with constant load must provide a short-term overload of at least 1.6, i.e. an increase in torque compared to the nominal one of at least 60%.

A typical required minimum short-term overload for hoists and cranes is 200 to 250%. As the current that supplies the motor is proportional to the load, electrical losses also increase with the load. Permissible heating of the motor in continuous operation is determined primarily by the temperature class of the motor winding insulation (Y, A, E, B, F, H or C), that is, by the corresponding permitted temperature of the motor winding (90 to over 180°C). Already, when choosing a motor for a specific drive, in addition to the nominal load, the drive load group, from S1 to S10, is taken into account, which is defined by the type of load on the motor shaft.

The figures below show typical dependencies of motor power, power losses and motor over temperature on time for two drives of different drive groups. According to Figure 12, it can be concluded that the electric motor for the permanent drive S1 can permanently withstand loads lower than the nominal load, without the risk of overheating. It can also be concluded from Figure 13 that, for example, an electric motor in intermittent drive S4, i.e. in a drive with the influence of the transient starting response, must be allowed a rest time within each cycle, i.e. after the starting and operating at constant load time, which is defined by the very label of a drive. For example, the drive marked as S4 – 60% predicts 40% of rest time within the cycle, similar to that shown in Figure 13.

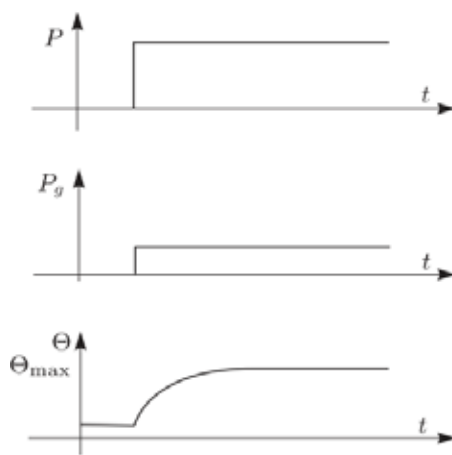


Figure 12 Permanent drive S1 [2]

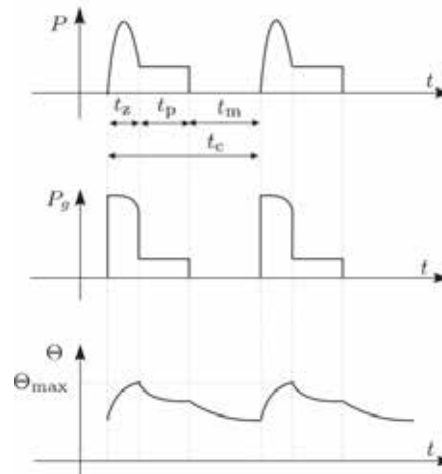


Figure 13 Drive S4 [2]

In addition to the number of motor starts in a shorter period of time, the warm-up is significantly affected by the applied starting method.

As the elevator on the test system works in continuous operation and repeatedly raises and lowers the basket with the load, the motor heats up due to the load and frequent starts and stops. By measuring the temperature and displaying the T-t characteristic, analysis and comparison can be made at different loads, with different motor starting methods and at unregulated and regulated speed.

3.5. Group of exercises - Testing of the electric elevator drive

The induction motor that runs the elevator drive can work in motor and brake modes. The analysis of the operation of the electric drive of the elevator can be carried out in different modes of operation, with static and dynamic changes in the drive and with unregulated and regulated speed. It is also possible to monitor the operation of individual elements of the elevator's electric drive, such as the induction motor, reducer, drum, basket with loads, and perform various measurements on them.

The execution of exercises on the testing system implies the analysis of static and dynamic conditions during motor operation in motor drive while lifting load, in brake drive while lowering load, while changing loads during operation and while starting and stopping the drive. Tests can also be carried out at unregulated and regulated speed, as well as along with the control of the motor rotation speed, using a frequency converter during dynamic changes in the drive. By measuring various quantities and displaying the I,U,P,Q-t and n-t characteristics, different operating conditions can be monitored.

3.6. Group of exercises - Control and automation of the electric elevator drive

The control of the electric drive of the elevator is carried out using relay and PLC techniques by direct power supply of the induction motor or by power supply via a frequency converter. Control can be set in local or remote mode. In the first case, it is done via push-buttons on the control cabinet, which is located next to the drive itself, and in the second, from a remote location via a PLC and SCADA system.

The SCADA system enables exercises execution in automated mode. On the home screen, the user can select a group of exercises to perform, and then adjust the settings for conducting

a specific exercise within the screen of each group of exercises. After starting, the exercise is performed according to the given program sequence. During the exercise, the values of certain system parameters can be monitored numerically or through graphic displays.

Using the testing system and related technical documentation, introduces the user to the elevator control plans, relay and PLC technology and methods of regulating the speed of rotation of an induction motor. During the exercises, a demonstration of local/remote and manual/automatic elevator control, operation of the elevator by call at unregulated and regulated speed and operation of the elevator according to a predefined mode of operation is performed.

The programming of the PLC for the mentioned actions was achieved by adjusting the settings of the system operation in the *SCADA* application. Through these settings, the user can define the way the motor is to be connected, the type of control, the speed of the motor in certain phases of the exercise, the motor acceleration and deceleration time when starting and stopping, operation with the motor brake, encoder calibration for defining the elevator position, alarm thresholds (e.g. temperature), etc.

4. Example of an automated exercise via a testing system

PLC control is achieved using a Siemens S7-1214C station, which, in addition to the CPU, can additionally contain up to 8 signal I/O modules and 3 communication modules.

Program management and *SCADA* application are implemented using the Siemens *TIA Portal V15* platform, in which these two functions are integrated, which simplifies the creation of the application itself.

Figure 14 shows the initial screen of the *SCADA* application used to perform automated elevator control exercises.

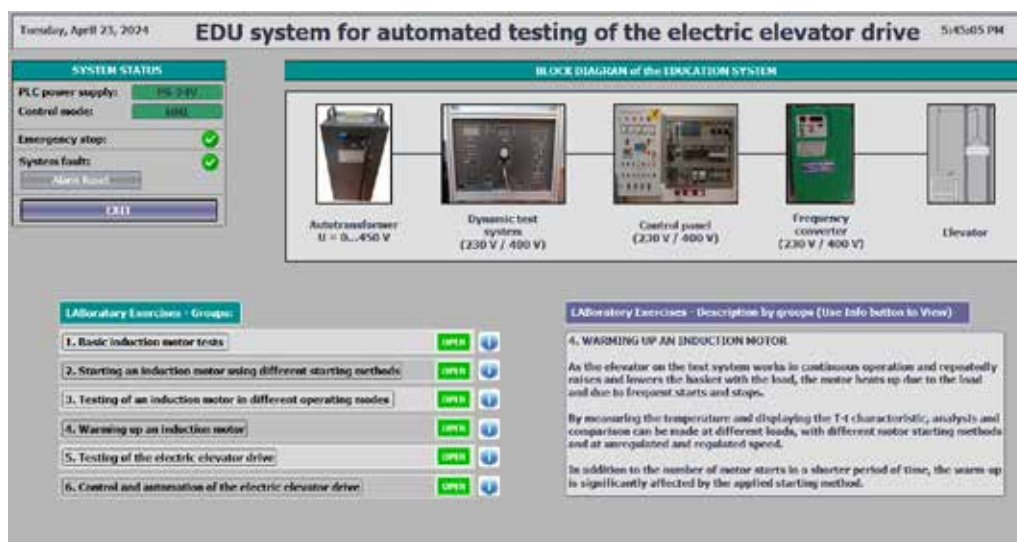


Figure 14 *SCADA* application - home screen

In the upper left corner of the *SCADA* application, general information about the status of the elevator system can be seen, such as PLC power status, control mode, emergency shutdown status and system cumulative fault signaling.

All detected errors are saved in the list of alarms, which the user can see with the date and time of their occurrence. Any error must be confirmed by the user.

The home screen contains a list of all exercise groups that can be performed. By clicking on the Info button, for each group in the lower part of the screen, a short description of the exercises that are available within the group can be seen.

The screen for performing exercises in an individual group is opened by clicking on the *OPEN* button.

Figure 15 shows the screen of the *SCADA* application for performing a group of automated exercises related to the analysis of the heating of an induction motor.

Group of exercises - *Warming up an induction motor* contains the exercises of heating up the motor:

1. during a direct start in a star connection,
2. during a direct start in a delta connection,
3. while starting using a star-delta switch,
4. during a soft start,
5. while starting using a frequency converter,
6. at different load operation,
7. at different speeds of operation,
8. at different operating modes.

To perform an individual exercise, the control mode and the motor connection method must be set first, by clicking on the *SELECT* button. The selection of an individual option is indicated by the corresponding icon. If the exercise is performed at different speeds, loads or operation modes, the parameters can be adjusted via the *SELECT* button in the additional options.

In Figure 15, the settings for exercise 1, in which the heating of the motor in an elevator drive is measured during direct start in a star connection, are set.

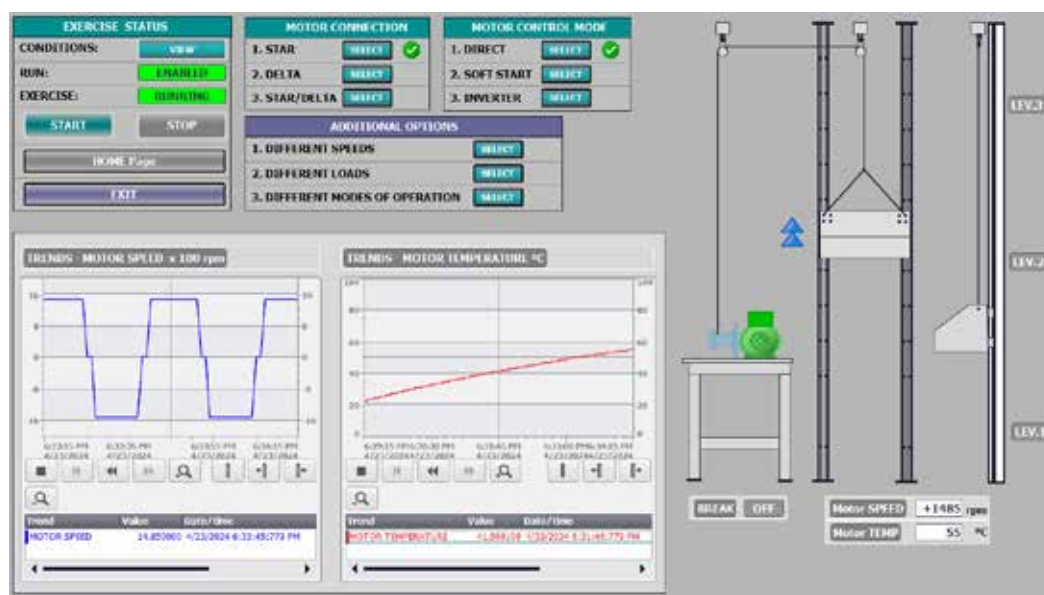


Figure 15 SCADA application – Exercise of warming up the motor during direct start in a star connection

Before starting each exercise, it is necessary to check whether all the conditions necessary for the execution of the exercise are met. For each exercise, the conditions can be recorded by clicking the *VIEW* button inside the exercise status window. This opens a new window shown in Figure 16, in which the user must confirm by clicking on the *CONFIRM* button that the conditions are met. After confirmation, the user is signaled in the exercise status window with the label *RUN ENABLED* that the exercise is ready to start.

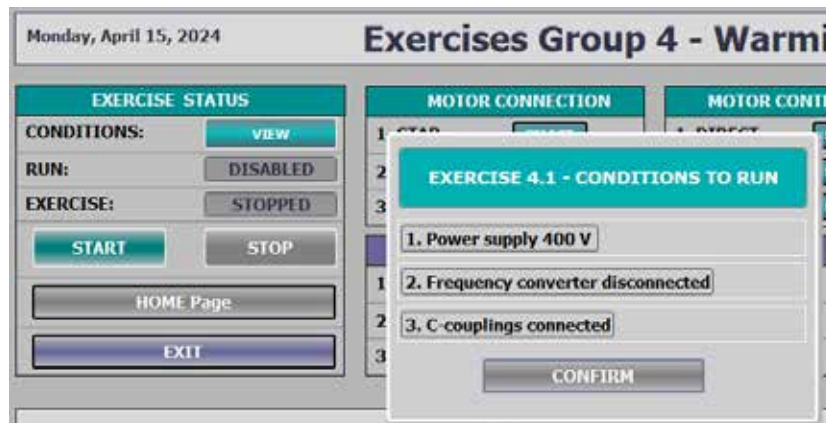


Figure 16 SCADA application – Screen for confirmation of conditions for starting exercises

The exercise is started by clicking the *START* button and stopped by clicking the *STOP* button. The exercise execution status is indicated by the labels *RUNNING* and *STOPPED* in the exercise status window.

Visualization of the operation of the elevator in the exercise is made possible through the display of the motor image (green color when the motor is running, gray when it is not), indicators of the direction of movement of the elevator, a label indicating whether the motor brake is on or off and the display of the motor speed and temperature values.

It is also possible to monitor the motor speed and temperature, through a graphic display that enables the user to analyze the data both in real time and through the saved data archive, via the built-in toolbar.

In Figure 17, the settings for exercise 5 are adjusted, in which the heating of the motor used for an elevator drive is being measured, for the case of star connected using a frequency converter for its start.

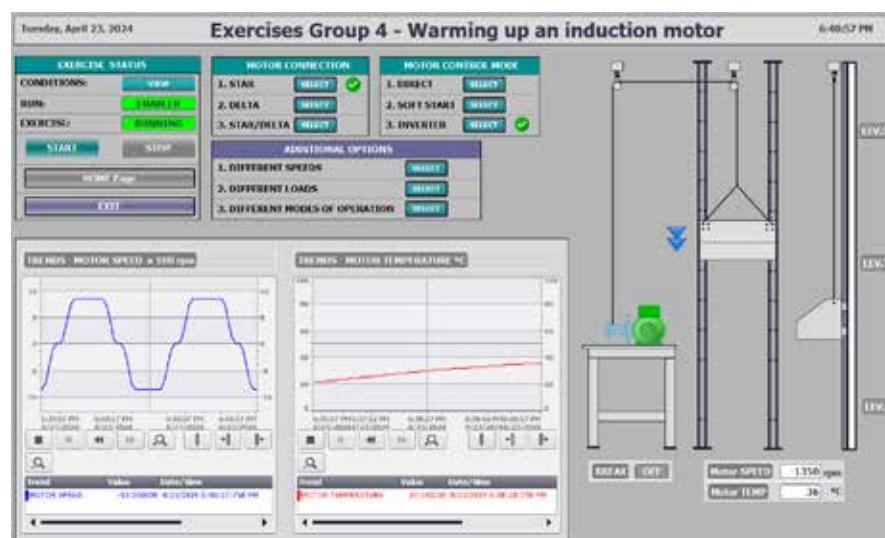


Figure 17 SCADA application – Exercise of warming up the star connected motor by frequency converter start

5. Conclusion

The educational system for automated drive testing presents a set of components that are adapted for testing and analyzing the operation of the three-phase cage induction motor and the electric drive of the elevator. The system is designed for education in the field of electric

machines, electric drives and their control and automation. It is composed of an elevator model, a control panel, a frequency converter, a dynamic test system and an autotransformer.

Using the mentioned system, it is possible to conduct a large number of exercises, of which the exercises related to the basic tests of the three-phase squirrel-cage induction motor, its start-up, different modes of operation, warm-up and testing, control and automation of the electric drive of the elevator are selected in this paper. In this way, testing and detailed analysis of the operation of the induction motor and the electric drive of the elevator can be carried out, and the students can be brought closer to a realistic system that can be found very often in practice.

By using the system, partially automated exercises are performed, which keeps the focus on essential actions and measurements, while the exercises are executed according to a predefined program. The system also offers an introduction to the automation of electric drives, which is indispensable today.

The educational system for automated testing of the elevator drive has an open concept, so it offers the possibility of upgrading and expanding in many segments. With a small upgrade related to the control of the rotor circuit, it is also possible to test slip ring induction motors, and by adding the associated converters and controllers, the system can be used for testing synchronous and DC motors.

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E-BIKE: COMBINING HUMAN AND ELECTRIC POWER

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Abstract: This paper presents an upgrade to a classic bicycle with an electric motor and a user authentication system. The upgrade consists of the following components: electric motor, ignition switch, display, accelerator, wheel speed sensor, lights, brake levers, and battery. Special attention is given to the selection of the battery, which needs to meet specific requirements such as weight, capacity, and autonomy of the e-bike. To protect against unauthorized use, the e-bike employs a user authentication system based on open-source technologies using the Arduino platform and a TFT LCD display. The system was built through a collaboration between the Vocational Technical School and the University Department of Professional Studies in Split, fostering practical skills, creativity, and a multidisciplinary approach in technical fields among students and pupils.

Keywords: *e-bike, electric motor, battery, Arduino, authentication*

1. Introduction

In recent years, there has been a significant rise in the use and acceptance of electric vehicles across various modes of transportation. Initially criticized, electric vehicles are now widely considered by consumers when purchasing new vehicles, whether it's a bicycle, scooter, car, or any other type. For this reason, our project aims to educate students and learners on converting a standard bicycle into an electric one and understanding the features while selecting the most suitable motor. This hands-on learning approach aligns with our teaching methods at the VTS (VTS, 2024) and the SOSS (SOSS, 2024), and similar practical projects have been documented in academic papers.

As the number of electric vehicles increases, safety becomes a concern. The authentication system for this vehicle is developed using open-source technology for accessibility and cost-effectiveness. Before converting a regular bicycle into an electric one, it's essential to be aware of legal requirements for electric vehicles. Electric bicycles are legally limited to a 250 W motor power and a maximum speed of 25 km/h. Additionally, the bicycle must be pedal-assist only, meaning the motor assists when pedaling. Meeting these criteria allows the bicycle to be used on public roads or bike paths without registration or a driver's license requirement.

2. E-bike drive

When selecting the bike’s drive system, we had two choices. One option was to install a motor connected to the bike’s frame, which transfers torque to the rear wheel using a chain, belt, or a rear wheel with an integrated motor. Table 1 provides a comparison of the advantages and disadvantages of both systems.

Table 1. Advantages and disadvantages of different bicycle drives

REAR WHEEL DRIVE		CENTRAL DRIVE	
ADVANTAGES	DISADVANTAGES	ADVANTAGES	DISADVANTAGES
cheaper option			more expensive option
	without gearbox	with gearbox	
	heavy rear wheel	uniform weight of the bicycle	
durability			more complex performance

In this project, the second drive model was chosen, This motor drive the 750W Motor Ebike Conversion Kit comes from the Chinese manufacturer “Bafang” (BAFANG BBS02B, 2024), Figure 1. The reason for choosing this motor is due to its features, combined with the characteristics of the entire upgrade package. With this setup which includes a gearbox, the higher bike speeds can be achieved, while with a rear-wheel motor setup, the bike’s speed is limited by the electric motor’s top speed. The engine characteristics are given in Table 2.



Figure 1. “Bafang” central motor with transmission gear

Table 2. Engine characteristics

Features of the built-in engine:	
Bafang Model	G320.1000
Power	1000 W
Speed	65 km/h
Kontroler	48V/30A
Max. moment of force	160 Nm
Efficiency	> 80%
Transmission ratio	1:21,9
Weight	6 kg

In addition to the engine itself, the upgrade kit comprises several components: an ignition switch, monitor, throttle switch, wheel rotation speed sensor, front light, and front and rear brakes, Figure 2. The ignition switch initiates the entire system and will continue to function even after the authentication module is installed and approved. The monitor displays the current speed and gear level, ranging from 1 to 9, which is a software gear level. The bike's rear wheel has six gears, allowing for hardware gear changes. This means that for each hardware gear, we can utilize a nine-step software gearbox. The monitor also indicates the battery level and current time. While this motor was selected for its "pedal assist" feature, the upgrade kit also includes a hand throttle for acceleration. Additionally, there's a front light powered by the motor system and a wheel rotation speed sensor. Moreover, the brake handles on the handlebars are linked to the engine system. Every time the electric switches are activated, they shut off the engine, especially during braking.

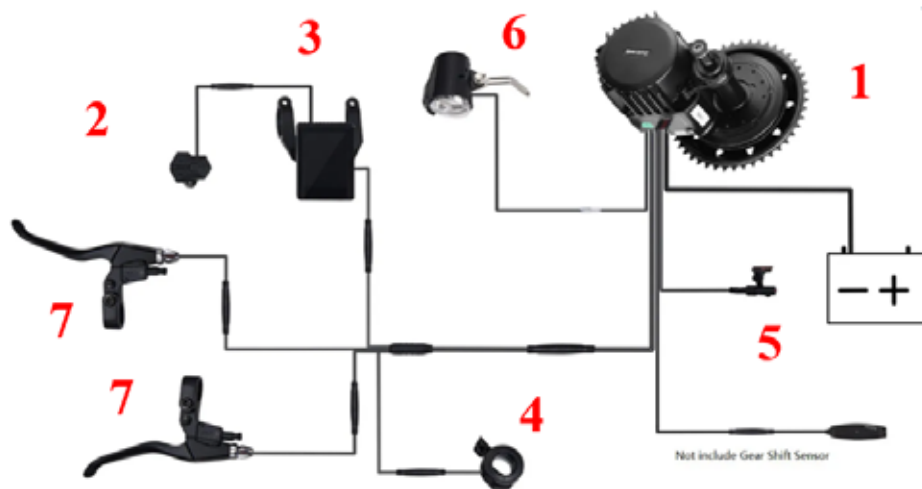


Figure 2. Built-in components

The list of built-in components:

1. Engine
2. Ignition switch
3. Monitor
4. Throttle switch
5. Rotation speed sensor
6. Front light
7. Front and rear brakes

3. Power System

When choosing a power system, several factors must be taken into account. The fundamental rule is that a battery with a higher Ah (ampere-hour) rating will offer greater range. However, a higher Ah battery also comes with more weight, which can reduce the range. Additionally, the selected assistance level on the bike plays a crucial role. A higher assistance level allows for reaching the final speed faster and with less effort, but it also consumes more energy. Moreover, energy consumption is influenced by driving intensity and terrain. Therefore, battery selection needs to be balanced. For this project, the battery of 12.5 Ah and 48 V was chosen, Figure 3.



Figure 3. Battery pack

Table 3. Battery characteristics

Battery characteristics:	
Model	PSWPOWER /(Li-Ion)
Capacity	12,5Ah
Voltage	48 V
Operating voltage	36,4V – 54,6V
Dimensions	90.3*109.4*367.4mm
Continuous discharge current	30A
Max. discharge current	60A
Maximum charging current	5A

Battery capacity is typically indicated in two ways: Wh (watt-hours) or Ah (ampere-hours). A capacity of 12.5 Ah means that theoretically, the battery can deliver 1 ampere of current for 12.5 hours. Multiplying the voltage and the capacity in Ah gives us 600 Wh, meaning this battery can power a 200 W motor for three hours, assuming the motor could run at full load for that duration. However, this calculation is theoretical and simplified because the battery consumption rate varies depending on the load. Additionally, it's important to consider the battery's safe discharge level. If the battery's lowest discharge point is at 30%, it means we can only discharge approximately 420 Wh from this battery. The discharge percentage varies depending on battery quality, with cheaper batteries discharging to 30%, while more expensive ones may discharge to 10%.

4. User authentication

The authentication module, built on the Arduino platform, is designed to confirm a user's identity by entering a pin. It uses a TFT LCD 2.4 module to display a keyboard for pin input. Once the correct pin is entered, the module activates a relay. The relay controls the ignition switch of the bike, allowing it to start. After successful authentication, the module stays connected until the bike's battery is disconnected or the module's switch is turned off.

Authentication module is shown in Figure 4, and its main components are:

1. Arduino UNO,
2. TFT LCD 2.4 module,
3. Switch,
4. Relay,
5. Case with cover,
6. 4-pin connector.



Figure 4. The authentication module

Because the bike operates at a voltage of 48 volts, it was necessary to install a voltage converter from 48V to 12V in order to power the authentication module (Regulator, 2024). Figure 5 shows the complete wiring diagram of the electrical part of the E-bike system.

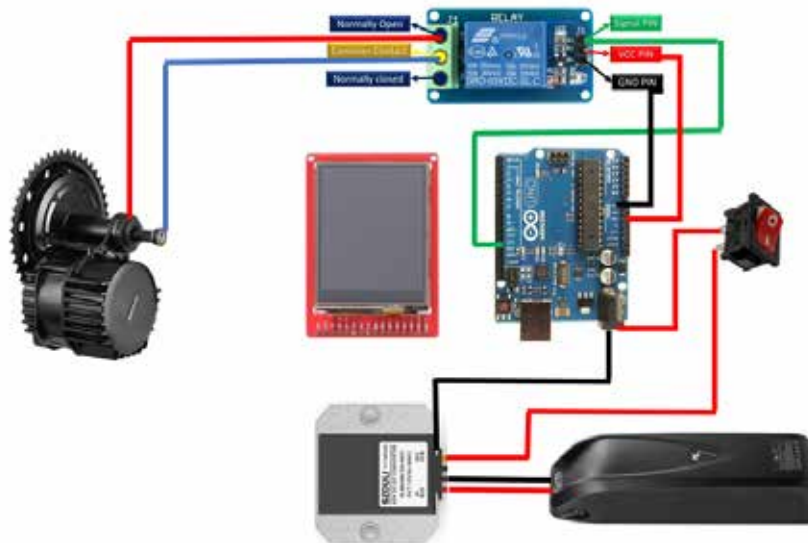


Figure 5. The wiring diagram

The 2.4-inch TFT LCD module, also known as Thin Film Transistor Liquid Crystal Display, is widely used in Arduino projects due to its practicality and touch functionality (LCD wiki, 2024). It features a color display and is sized to fit seamlessly with the Arduino Uno board, forming a compact unit. With a resolution of 240 x 320 pixels, this screen not only supports touch input but also has the capability to display images. It falls into the category of cost-effective color touch-sensitive LCD screens, making it a preferred choice for various applications. The LCD is shown in Figure 6, and its specifications are provided in Table 4. It offers excellent contrast and vibrant colors, along with a built-in microSD card slot. This TFT display boasts a strong backlight consisting of four white LED backlights and a colorful screen with 240 x 320 pixels. Additionally, it provides individual control of RGB pixels, offering significantly better resolution compared to black and white 128 x 64 screens.



Figure 6. 2.4-inch TFT LCD display

Table 4. The specification of the TFT LCD 204" display module

Name	Characteristics
Screen color	RGB 65K color
Screen size	2,4 (inch)
Screen type	TFT (Thin Film Transistor)
Driver	IC ILI9341
Resolution	320*240 (piksel)
Module interface	8-bit parallel interface
Active area	48,96*36,72 (mm)
PCB module size	72,20*52,7 (mm)
Operating temperature	-20°C~60°C
Storage temperature	-30°C~70°C
Operating voltage	5V/3.3V
Energy consumption	TBD (not determined)
Product weight	package contains 39 (g)

Table 5 shows the meaning of individual pins and their interconnection.

Table 5. The pin layout and description

LCD	Arduino UNO	Pin description	Pin purpose
LCD_RST	A4	LCD bus reset signal, reset low level	LCD control pins
LCD_CS	A3	LCD bus chip select signal, low level enabled	
LCD_RS	A2	LCD bus command / data selection signal,	
LCD_WR	A1	low level: command, high level: data	
LCD_RD	A0	LCD bus write signal	

LCD_D0	D8	LCD bus read signal	LCD data pins
LCD_D1	D9	LCD 8-bit data Bit 0	
LCD_D2	D2	LCD 8-bit data Bit 1	
LCD_D3	D3	LCD 8-bit data Bit 2	
LCD_D4	D4	LCD 8-bit data Bit 3	
LCD_D5	D5	LCD 8-bit data Bit 4	
LCD_D6	D6	LCD 8-bit data Bit 5	
LCD_D7	D7	LCD 8-bit data Bit 6	
SD_SS	D10	LCD 8-bit data Bit 7	SD card, data pins
SD_DI	D11	SD Card SPI Bus Chip Select Signal Enabled Low	
SD_DO	D12	SD_DI SD card SPI bus MOSI signal	
SD_SCK	D13	SD card SPI bus MISO signal	
GND	GND	SD card SPI bus clock signal	Power supply
5V	5V	Mass, grounding	
3,3V	3,3V	Input power supply 5V	

5. Program

The “E-bike LCD_key” program is designed for controlling the Arduino Uno microcontroller board using a 2.4 TFT LCD module equipped with the ILI9341 processor. The program utilizes a library created by Joao Lopes (Joao Lopes, 2024) and a program from IOT DESIGN PRO (IOT DESIGN PRO, 2024) which utilizes a slightly modified version of Joao Lopes’ library.

This program enables a pin (password) authentication during the startup of the E-bike. Additionally, it allows the authorized administrator user to change the pin and adding new users. After successful authentication, the Arduino Uno provides an output voltage (5V) on pin 11. Once the authentication is completed, the circuit continuously provides voltage, allowing the e-bike to be used until the power is turned off. After the power is turned off, authentication needs to be performed again for further use.

- The user procedure is given below:
- At the start after entering the PIN, confirm it by pressing the OK button
- To change the PIN, press the X button twice.
- When a dialogue box appears asking if you want to change the PIN and you need to respond with ‘YES’ or ‘NO’.
- Enter the current PIN, and if it’s correct, you can enter the desired new PIN after pressing OK.

Because the library was originally written for the SPFD5408 driver, it was necessary to configure it as follows within the program:

```
// Define the pins
#define YP A2 // must be an analog pin, use “An” notation!
#define XM A3 // must be an analog pin, use “An” notation!
#define YM 8 // can be a digital pin
#define XP 9 // can be a digital pin
```

```
// Define the colours
#define WHITE 0xFFFF //Black->White (0x0000 previous value)
#define YELLOW 0xFFE0 //Blue->Yellow (0x001F previous value)
#define CYAN 0x07FF //Red->Cyan (0xF800 previous value)
#define PINK 0xF81F //Green-> Pink (0x07E0 previous value)
#define RED 0xF800 //Cyan -> Red (0x07FF previous value)
#define GREEN 0x07E0 //Pink -> Green (0xF81F previous value)
#define BLUE 0x001F //Yellow->Blue (0xFFE0 previous value)
#define BLACK 0x0000 //White-> Black (0xFFFF previous value)
// TFT LCD calibration
#define TS_MINX 125
#define TS_MINY 905
#define TS_MAXX 965
#define TS_MAXY 85
```

In the SPFD5408_TouchScreen.cpp library, it was necessary to change code line 159 because Y coordinate is inverted in this controller.

// Old line:

```
return TSPoint(1103 - x, 1023 - y, z);
```

// New line:

```
return TSPoint(x, 1023 - y, z);
```

Figure 7 shows the complete realized E-bike.



Figure 7. E-bike

6. Conclusion

This project involves converting a standard bicycle into an e-bike using a BAFANG conversion kit. It also includes designing and installing an authentication module using open-

source Arduino technology and a TFT LCD 2.4 shield. The project was a collaboration between the Vocational Technical School and the University Department of Professional Studies at the University of Split. Because it utilizes open-source technology, there's potential for further upgrades to the authentication system. This project serves as a practical educational tool for students in technical fields, offering hands-on experience and valuable knowledge.

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APPLICATION OF AUGMENTED REALITY FOR VISUALIZATION OF IOT SENSORS

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Abstract. Internet of Things (IoT) and Augmented Reality (AR) represent two technologies that, when combined, create a potent synergy that enhances user experiences, data visualization, and operational efficiencies. IoT involves connecting devices and sensors to collect and process vast amounts of data, while AR overlays digital information onto the physical world, providing users with a visual interface to interact with digital data. Combining IoT with AR allows users to visualize IoT-generated data in real-time through AR interfaces transforming raw data into intuitive, interactive visualizations, making complex information easily accessible and understandable. This paper presents the development of an electric energy meter using the PZEM-004T sensor. The sensor is connected to an ESP32 microcontroller that collects measurement data: voltage, current, power, energy, and forwards them to an IoT platform. The AR application enables visualization of that data in 3D by directing the smartphone camera at the target image. The primary objective of this project is to enhance the user experience by leveraging augmented reality (AR) to visualize IoT sensor data in a three-dimensional (3D) space. This approach aims to move beyond the conventional two-dimensional (2D) display commonly used in IoT cloud platforms.

Key words: ESP32, Internet of Things, Augmented reality, PZEM-004T sensor, Blynk

1. Introduction

The substantial volume of data generated by the Internet of Things (IoT) presents quite a challenge for visualizing, managing, analysing, and protecting that data.

Traditional 2D data views on dashboards and cloud platforms often fail to effectively display this information. However, combination of IoT and AR enables that 2D data generated from IoT

can be viewed in 3D augmented space. While IoT devices collect real-time data, AR technology enables to superimpose this information onto the physical world in 3D.

This project demonstrates the potential of combining these two technologies by creating an AR application that enables 3D visualization of data collected in real time from PZEM-004T sensor.

2. Internet of Things and Augmented Reality

The Internet of Things (IoT) is a concept based on the connection of physical devices over the internet to do a specific task or multiple tasks, and monitoring sensor values to get real-time data [1]. IoT integrates various components, like sensors, actuators, communication protocols, and cloud computing. Sensors collect data from the surrounding environment, while actuators enable devices to perform actions based on the received data. Communication protocols facilitate the exchange of information between devices, and cloud computing provides a platform for data storage, analysis, and processing.

Augmented reality (AR) technology provides capabilities for merging the real and virtual worlds. AR creates a complex display by combining real scenes with computer-generated virtual scenes. Augmented reality enriches the real world by adding virtual elements to ordinary places, spaces, objects, or events.

AR mainly is divided into three types, marker-based, marker-less, and location-based [2]. Marker-based AR uses the recognition of specific features or markers in the real world to place virtual objects or information in specific positions. Marker-less AR does not require the recognition of specific markers but uses sensors such as the camera and motion sensors to align the virtual content with the environment. Location-based AR uses geolocation data to place virtual objects or information at specific locations in the real world, usually via GPS or other location technologies.

3. Proposed system

The proposed system uses three key components to achieve data visualization through AR: hardware, IoT cloud, and augmented reality. The PZEM-004T sensor, which measures voltage, current, power, energy consumption is connected to an ESP-WROOM-32 microcontroller that enables data processing and transmission.

The collected data from the sensor is then sent to the Blynk IoT platform for cloud storage and communication with the AR application. Developed using the Unity and Vuforia SDK, the AR application retrieves real-time sensor data from the Blynk platform and displays them on a virtual panel that appears in the real scene after the smartphone camera is pointed at the marker.

3.1. Hardware

3.1.1. ESP32 microcontroller

The ESP32-WROOM-32 module is responsible for collecting data from the sensor and transmitting it to the cloud platform. The ESP32-WROOM-32 module is a popular and powerful microcontroller module developed by Espressif Systems. It's based on the ESP32 series of chips, which integrate Wi-Fi and Bluetooth connectivity along with a dual-core processor, making it suitable for a wide range of IoT applications.

- Key features [3]:
 - Dual-core 32-bit processor with clock speeds up to 240MHz.
 - 448KB ROM, 520KB SRAM, and 4MB Flash memory.
 - Built-in Wi-Fi b/g/n transceiver.
 - 25 accessible GPIO pins for various functions.
 - Micro USB connector for power and programming.



Figure 1 ESP32 development board

3.1.2. PZEM-004T-100A sensor

The PZEM-004T sensor is a multipurpose digital meter that measures and monitors various electrical parameters, including voltage, current, power, and energy consumption.

- Key features [4]:
 - Measures voltage, current, power, power factor, and energy consumption.
 - Non-invasive CT sensor for safe installation.
 - Serial communication interface for connecting to the ESP32.
 - Wide range of applications, including consumption monitoring, efficiency analysis, and billing.



Figure 2 PZEM-004T-100A (V3.0) module

3.2. IoT Cloud Platform: Blynk

For our project, Blynk served as a user-friendly platform for sensor data management and visualization.

Blynk is a popular cloud platform designed for the IoT applications. It provides a user-friendly environment for building and managing IoT projects without the need for extensive programming knowledge. The platform supports a wide range of hardware platforms, including popular ones like Arduino, Raspberry Pi, ESP8266, and ESP32. Blynk's drag-and-drop interface simplifies the creation of custom dashboards, allowing users to visually design control interfaces with various widgets. Blynk's virtual pins (V0-V255) establish a communication link between hardware (e.g., Arduino, Raspberry Pi) and the Blynk application, allowing data transfer without requiring coding. Blynk emphasizes security through secure communication channels, user authentication, and access control features [5].

There are several reasons why we chose Blynk among other IoT platforms. Firstly, Blynk provides a database to store sensor readings so there is no need for a special SQL database. Secondly, Blynk provides a library for the Arduino IDE and third, maybe most importantly reason, Blynk provides HTTP APIs which can be used to get the sensor readings by simply calling them. This possibility has greatly facilitated the integration of AR and IoT.

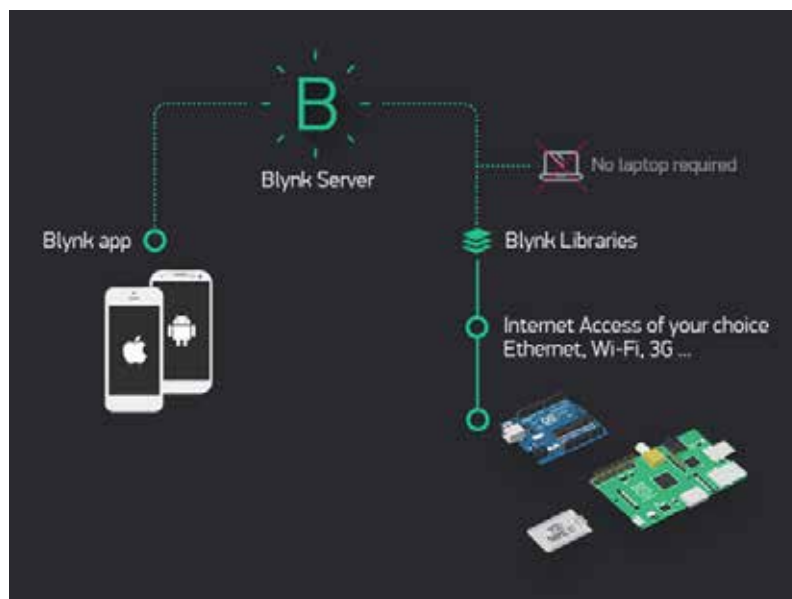


Figure 3 Blynk-Cloud Platform [5]

3.3. Augmented Reality Application: Unity + Vuforia

Unity and the Vuforia Engine SDK are two powerful tools frequently used together to create augmented reality (AR) experiences.

Unity is a widely used game development engine that provides a robust environment for creating 2D, 3D, virtual reality (VR), and AR applications across multiple platforms. It features a user-friendly interface, a powerful graphics engine, and extensive scripting capabilities using C#.

The Vuforia Engine SDK is specifically designed for AR development. Vuforia enables the creation of AR applications that can recognize and track images, objects, and environments in the real world. It provides tools and features for developing interactive and immersive

AR experiences across different platforms. Vuforia simplifies the process of recognizing and tracking real-world objects, allowing to create AR applications that overlay digital content onto physical surfaces or objects in the user's environment.

Image Targets can be created with the Vuforia Target Manager using JPG or PNG images in RGB or grayscale. The size of the input images must be 2.25 MB or less and have a minimum width of 320 pixels. Features extracted from these images are stored in a cloud or device database, of which the latter can be downloaded and packaged together with the application. Image Targets are detected based on natural features that are extracted from the target image and then compared at run time with features in the live camera image. The star rating of a target ranges between 1 and 5 stars. To ensure proper operation it is recommended to use targets with 4 or 5 stars. [6].

4. Implementation

The project involved connecting the hardware, developing software for both the IoT device and AR app.

Since different platforms are used to display measurement results, it was necessary to develop, test and upgrade the system separately for each platform [7]. The development steps are shown in Figure 4.

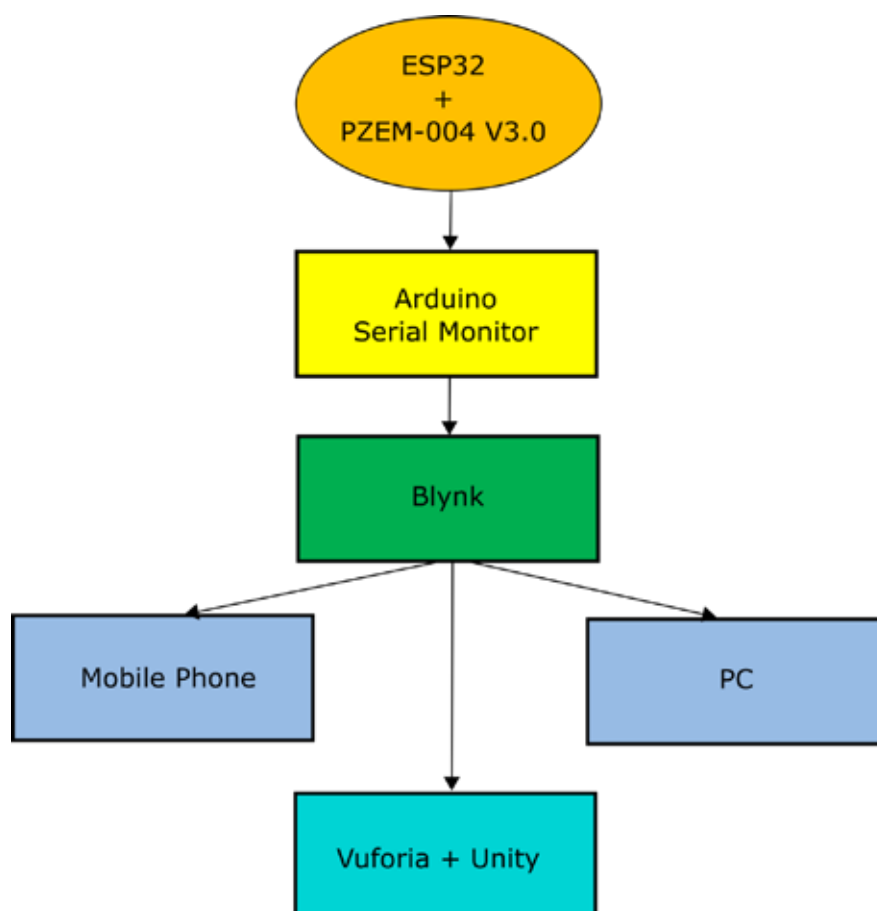


Figure 4 System development flow chart

4.1. Hardware

The initial step in project involves connecting the hardware components and verifying their functionality.

Adhering to the schematic illustrated in Figure 5, an Arduino code was written which transmits measurement results to the Serial Monitor.

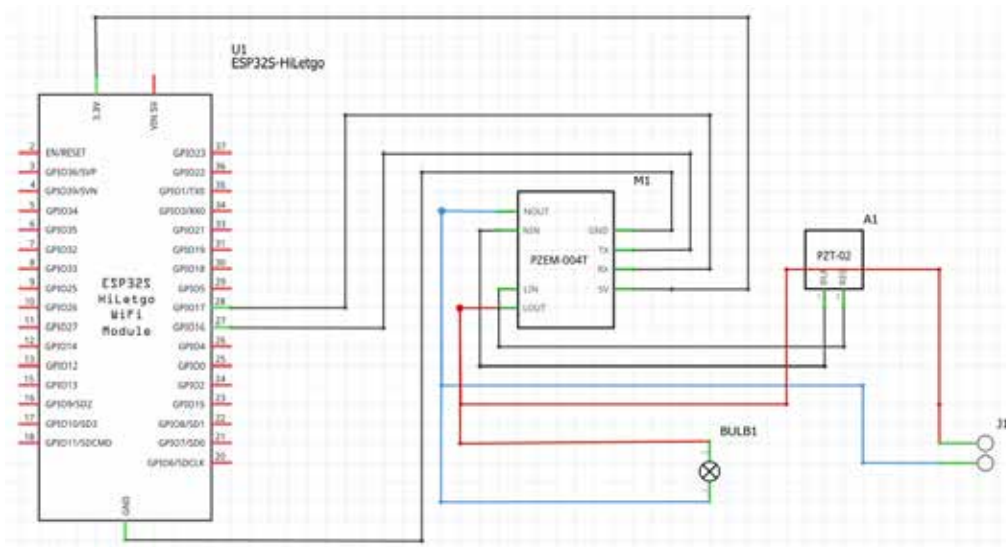


Figure 5 The circuit diagram

Notably, the PZEM004Tv30.h library is employed for establishing a connection between the ESP32 and the PZEM-004, with components linked through GPIO 16 and GPIO 17. The testing involved a 14 W LED bulb, as it shown in Figure 6. This process ensures the correctness of the circuit and lays the foundation for further development.

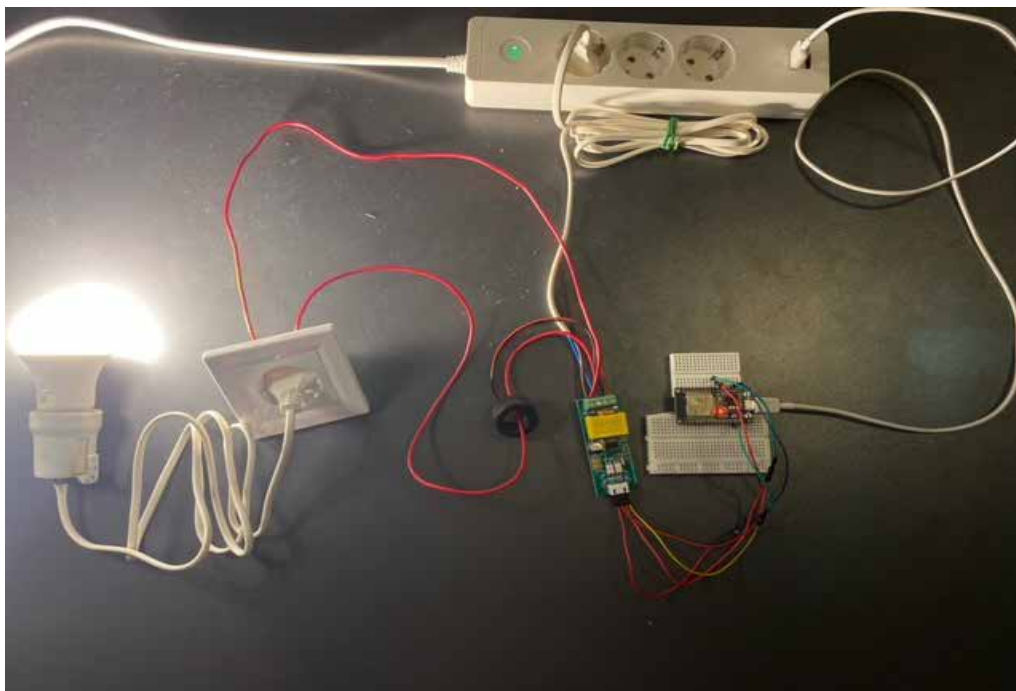


Figure 6 Checking the correctness of the circuit



Figure 7 Display of lamp power measurement on Serial Monitor

4.2. IoT cloud - Blynk

After the functionality of the circuit was verified and successfully tested, the code needed to be upgraded. Upgrading the code to display data via the Blynk platform requires adding the Blynk library to the Arduino code. This library allows the ESP32 microcontroller to communicate with the Blynk platform. After installing the Blynk application and registering, a new project has been created. Blynk assigns the authentication token needed to connect the ESP32 to the Blynk platform.

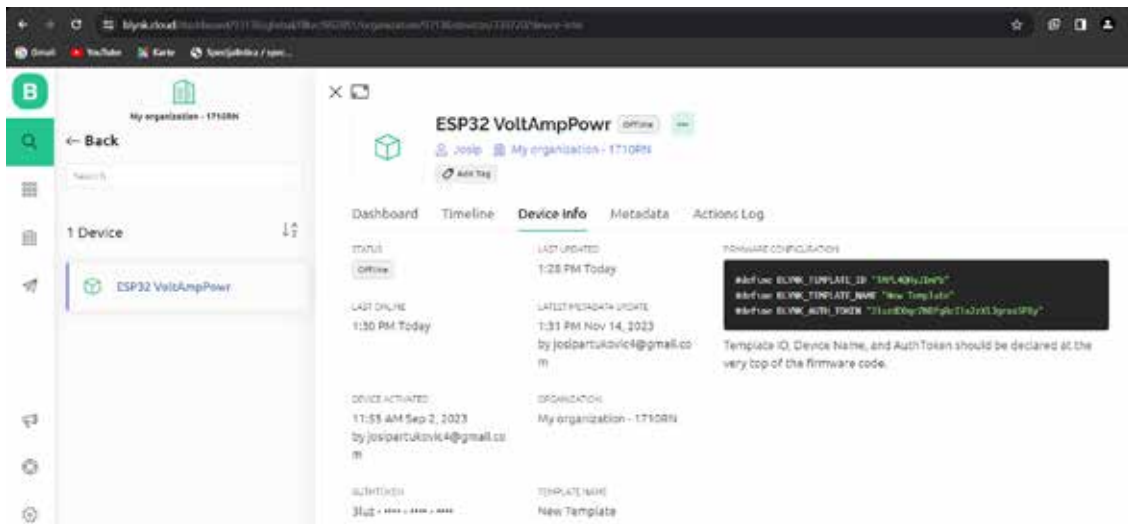


Figure 8 Blynk Device Info

In the Blynk application, four virtual pins (V0, V1, V2 and V3) are created, which represent the data flows in the Blynk platform.

4 Datastreams

Name	Pin	Data Type	Type Of Automation	Condition	Action
Voltage	V0	Integer	Sensor	<input type="checkbox"/>	<input type="checkbox"/>
Current	V1	Double	Sensor	<input type="checkbox"/>	<input type="checkbox"/>
Power	V2	Double	Sensor	<input type="checkbox"/>	<input type="checkbox"/>
Energy	V3	Double	Sensor	<input type="checkbox"/>	<input type="checkbox"/>

Figure 9 Virtual pins in Blynk

The data that the ESP32 reads from the sensor is sent to the corresponding virtual pins on the Blynk platform. Four widgets are placed on Blynk's desktop to display power, energy, current and voltage data, and are connected to the corresponding virtual pins.

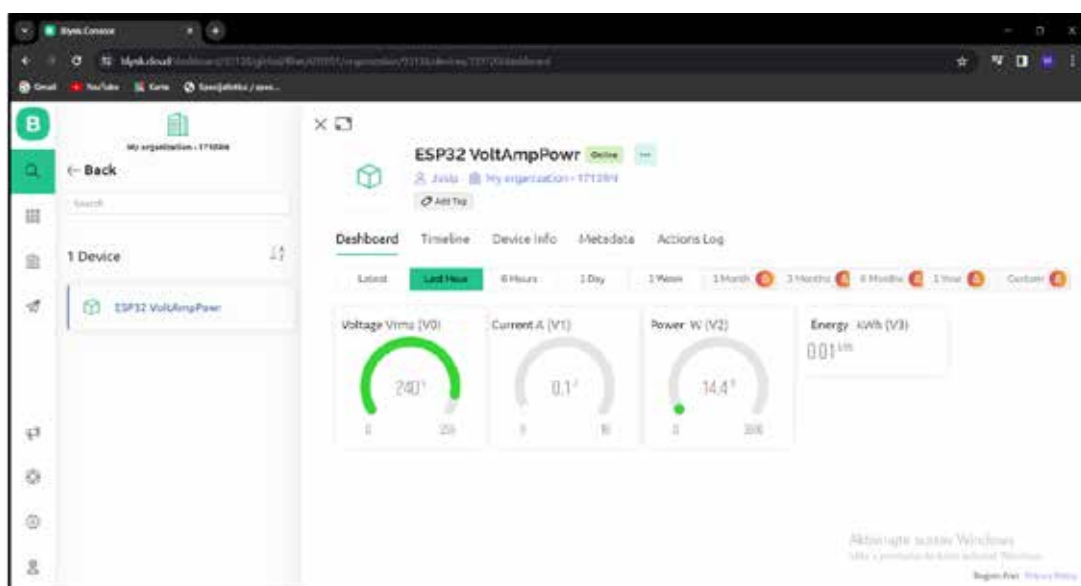


Figure 10 Blynk Dashboard on Web



Figure 11 Blynk application on mobile phone

4.3. Augmented reality app

Bridging the gap between the physical and digital world, the AR application serves as the centre piece of our data visualization system.

Ensuring precise image targets is crucial for seamless recognition by the camera and accurate overlay of virtual information. In this project, selected target image shown in Figure 12 is utilized for displaying voltage, current, power, and energy readings. The chosen target image has been assigned a 5-star rating in Vuforia, enhancing camera recognition efficiency.



Figure 12 Target image used in the project

In the Unity application, four input field objects are created to display voltage, current, power, and energy readings. Real-time data retrieval is facilitated by a virtual button object, responsible for loading sensor data in an AR environment. Integration with APIs is achieved via a C# script, connecting a virtual button and four input fields to the Blynk HTTP RESTful API. Each GET request will return the current state/value on the given Pin [5].



Figure 13 Unity

The format of API is:

https://fra1.blynk.cloud/external/api/get?token=*****&pin

Whenever the virtual button is “pressed” the corresponding APIs will be called and the value of the voltage, current, power, and energy will be displayed in real time.

Vuforia engine generates the .APK file on smartphone using the android SDK. There is no UI in the mobile application, it opens the camera directly which contains a Vuforia watermark.

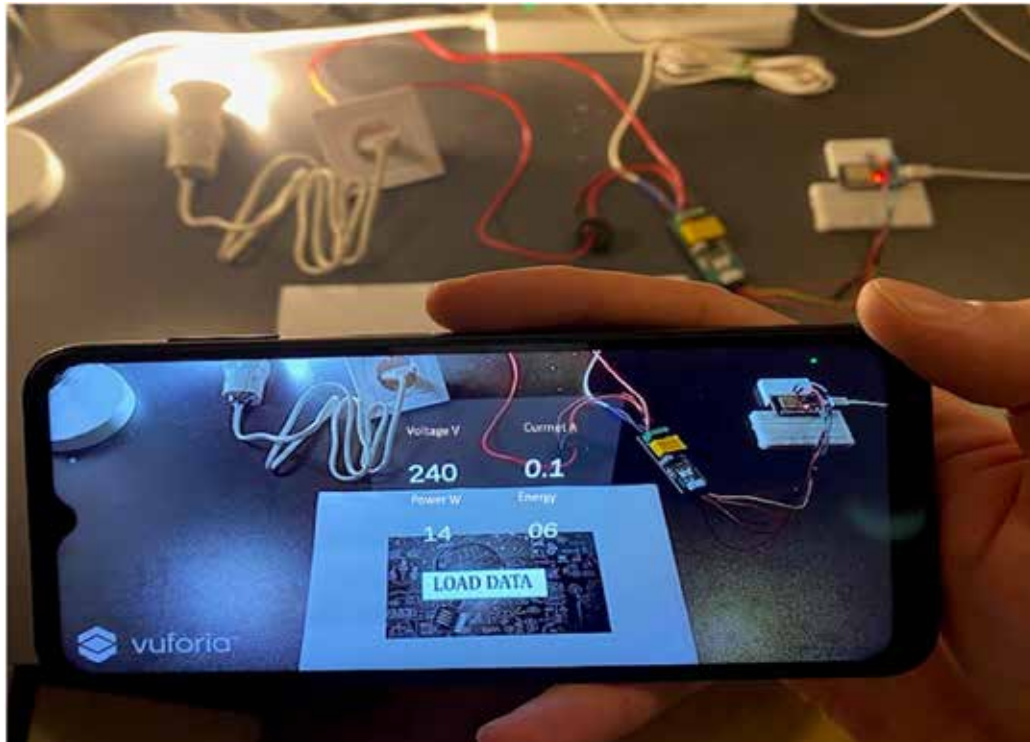


Figure 14 AR app

5. Conclusion

The integration of Internet of Things (IoT) and Augmented Reality (AR) technologies has enormous potential in the way of data visualization and user experiences. By combining IoT's ability to collect and process data with AR's ability to overlay digital information into the physical world, we gain new dimensions of interaction and understanding.

Through this practical project, an AC electricity consumption meter was successfully developed using the ESP-WROOM-32 microcontroller and the PZEM-004T sensor.

AR application developed using Unity and Vuforia SDK enables visualization of sensor data in real time in three-dimensional space, overcoming the limitations of traditional two-dimensional displays. By pointing the smartphone camera at a specific target image, users can effortlessly access the data.

As we continue to push the boundaries of innovation, this synergistic convergence holds the key to unlocking a future where the digital and physical realms seamlessly intertwine, enriching our interactions with the world around us.

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IMPLEMENTATION OF THE GAME AND THE AGENT USING MINIMAX ALGORITHM

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1. Abstract

This paper delves into the investigation, analysis, and solution of a specific algorithmic problem: the implementation of a chess engine utilizing the Minimax algorithm. The choice of chess as the focal point is due to it being both a popular game in real-world and popular case study for this type of algorithms. The primary motivation behind this endeavor is to gain a deeper understanding and mastery of search algorithms.

The main challenge encountered was the vast number of chess variants and possible states that could be reached during search. Overcoming this obstacle required numerous optimizations and special approaches, reflected in the representation of the chess board and pieces, search optimization, etc... Notably, solving this problem involved preliminary steps such as studying basic recursive algorithms and exploring search trees.

The selection of the Minimax algorithm was a logical choice, considering chess is a two-player game with fully visible state and known environment. An alternative could be Monte Carlo Tree Search algorithm, as used in Alpha-zero engine. Alpha-beta pruning was employed to enhance search depth. Simple evaluation function was implemented to count material advantage, with adjustment based on piece positions. The chess board was represented using the mailbox concept, employing 12x12 board which each square and piece represented integer value

Practically, the solution to this problem unified all required steps, starting from analyzing the theory of search algorithms, formulating theoretical solution ideas, and concluding with solution implementation in the chosen programming language (in this case, C++). As the application was designed as a command-line interface, the project also implemented a standard communication protocol. Notably, the entire project was deployed to the lichess server (open-source), utilizing the lichess server's graphical interface.

Key words: *chess, heuristic, Minimax, optimization, search*

2. Introduction

Chess, a game dating back to the 6th century in India under the name *chaturanga*, spread across Europe and China by the 15th century, becoming a popular pastime. Ancient chess differed from the modern version, with different names for pieces and rules. By the 18th century, the rules were standardized, making chess accessible to a broader audience. The game is played on a symmetrical 64-square board with pieces including pawns, bishops, rooks, knights, queens, and kings. The objective is to put the opponent's king in "*checkmate*", where it is under attack with no escape. Initial chessboard state is shown on Figure 1.



Figure 1 Initial chess-board state

The popularization of chess intensified during the Cold War, notably through matches like those between Bobby Fischer and Boris Spassky. Chess theory advanced, and with the development of chess computers in the late 1960s, mastering the game became even more complex. The first modern chess computer, *Deep Blue*, defeated world champion Garry Kasparov in 1997. It utilized IBM's supercomputer with a specialized VLSI chip for parallel algorithm processing. The computer's evaluation function relied on stored games and opening book strategies.

Early challenges of chess computers included position generalization and lack of processing power. The development of chess engines aimed to solve complex algorithmic problems. Chess engines have become an integral part of modern chess, providing players with tools for position analysis and learning from previous games. Technological advancements allow computers to simulate millions of moves per second, offering deeper insights and better strategies. The integration of chess engines into online platforms enables players worldwide to compete in real-time, regardless of geographical location. This fusion of technology and ancient game ensures that chess remains relevant and exciting in the modern era.

3. Theoretical background

3.1. Recursively solving problems

The chapter delves into the concept of problem-solving through recursion, exploring different levels of representation in Artificial Intelligence (AI) systems. It begins by contrasting atomic representations, where states are indivisible and reduced to basic elements like city names in a route-finding problem shown in figure 2, with factored representations. Factored representations break down states into variables with values, allowing for shared attributes and the representation of uncertainty. This concept is pivotal in various AI areas, including constraint satisfaction. Moving further, structured representations are discussed, emphasizing the explicit description of objects and relationships, crucial for relational databases and natural language understanding.[1]

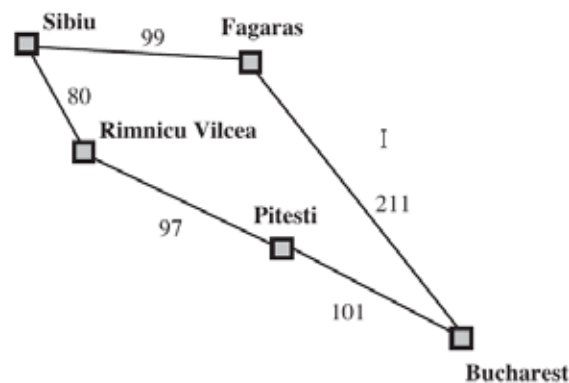


Figure 2:Route finding problem example [1]. States are depicted as towns (nodes), with lines symbolizing transitions between them.

A prime illustration of recursive problem-solving algorithms in the realm of artificial intelligence is the Minimax algorithm. Widely applied in two-player games, this algorithm operates on states that typically denote the board configuration after a player has made a move. Actions within this context represent the possible moves available to the players at any given state. The Minimax algorithm is fundamental in game theory and AI, showcasing how recursive approaches efficiently navigate decision trees to determine optimal strategies.

3.2. Minimax algorithm

The Minimax algorithm is a search algorithm used in games with two players, or in multi-agent environments. In the Minimax algorithm, each agent must consider how the decisions of the opposing agent affect the course of events. The concept of the algorithm itself is quite simple; each agent separately evaluates the state $\langle -\infty, +\infty \rangle$, and the more positive the evaluation (MAX), the better the position of the first player, while on the other hand, the more negative the evaluation (MIN), the better the position of the second player. It is important to note that the unpredictability of the decisions of the opposing agent significantly affects decision-making.

The agent chooses to transition to the next state based solely on the state at the end of the sequence (unless it encounters a terminal state earlier). Since this is a two-player game, it's clear that the second player's move follows the first player's move. The sequence length is set to 3, and the first player makes the first move. The first player first generates all actions that can be used to transition to other states. Then, it generates all the opponent's actions and then generates all actions again, so that from each opponent's state it generates all possible actions. When this is written out, it's clear that the number of states is very large, even for a very simple game. When the described data structure is visualized, it's clear that it looks like an inverted tree. This structure is called a search tree in programming. Figure 3 shows an example of such a tree for the game of chess [1].

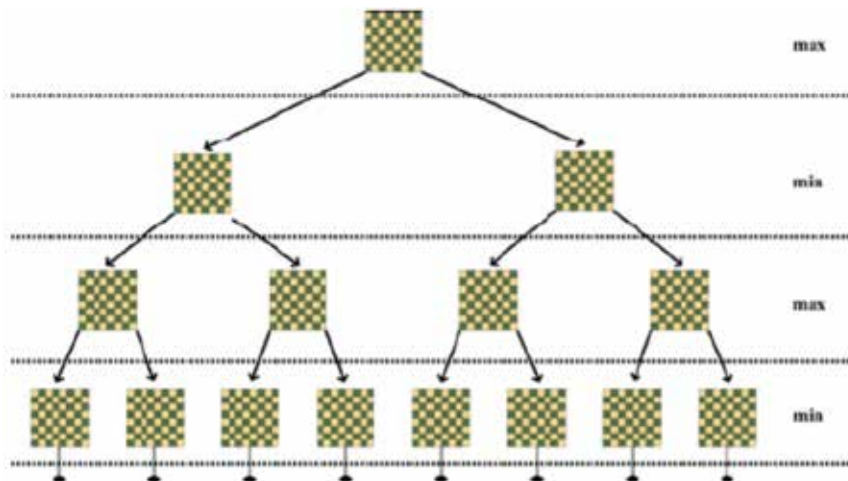


Figure 3:Minimax search tree

Formally, the entire game can be described as a search algorithm with the following states:

1. **S0** - Initial state that describes how the game is set up.
2. **player(s)** - Defines which player is making the move.
3. **result(s, a)** - Transition model, defines the outcome of the action taken by the agent.
4. **action(s)** - Set of legal actions that the agent can use to transition to the next state.
5. **test_terminality(s)** - Checks if the game is over, i.e. if the agent has reached a terminal state or a state that represents the end of the sequence.
6. **evaluation(s)** - Defines the values for a game that has reached a terminal state.

Nash equilibrium arises from the Minimax algorithm in two-player games. Minimax recursively evaluates terminal nodes, choosing the maximum or minimum values for each player's turn. This approach converges on optimal strategies assuming opponents also play optimally, aligning with Nash equilibrium. The algorithm inherently seeks stable strategies where players can't improve outcomes unilaterally.

3.3. Alpha – beta pruning

The challenge inherent in the Minimax search algorithm lies in its exponential growth of game state evaluations relative to the depth of the search tree. While the exponential nature of this growth cannot be eliminated, it can be significantly mitigated. An effective strategy to achieve this reduction involves computing the optimal minimax decision without exhaustive examination of every node within the game tree. Utilizing mentioned concept of pruning, alpha-beta pruning is introduced as a tailored technique for this purpose. When integrated into a traditional minimax tree, alpha-beta pruning retains the same optimal move while efficiently eliminating branches that do not impact the final decision.

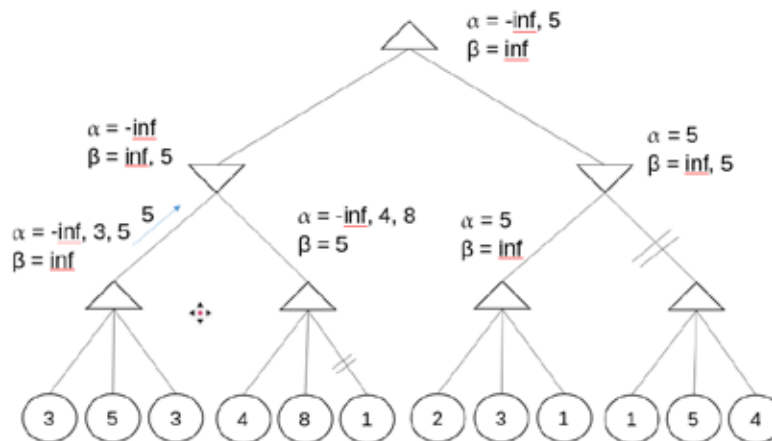


Figure 4: Example usage of alpha-beta pruning where represent MAX nodes, while represents MIN nodes

The comprehensive methodology of alpha-beta pruning is depicted in Figure 4. At the onset of tree traversal, the tracking of two key variables, conventionally denoted as α and β , becomes essential. α signifies the worst-case scenario for first player, initialized to negative infinity. Conversely, β represents the worst possible outcome for second player, initialized to positive infinity. As the search progresses, these values are propagated through parent-child nodes, updating accordingly, as depicted in Figure 4. Various α β relations serve as indicators for subtree pruning, marking sections of the tree that are deemed unreachable in the search process. In the both, MIN and MAX nodes, $\alpha \geq \beta$ is indicating that all unexplored child nodes can be pruned.

4. Implementation

4.1. Chess mechanics

Chessboard is represented employing array of integer values, corresponding to a chessboard with dimensions of 12x12. The reason for using a 12x12 board is for easier move generation. Namely, the edges of the matrix have highly negative values, while only the area of the chessboard has values ≥ 0 . Given way of chess board representation is called *mailbox representation*. Figure 5 illustrates the logical representation of the chessboard. The left part represents the squares with their corresponding values, while the right part shows the indexes of each square.

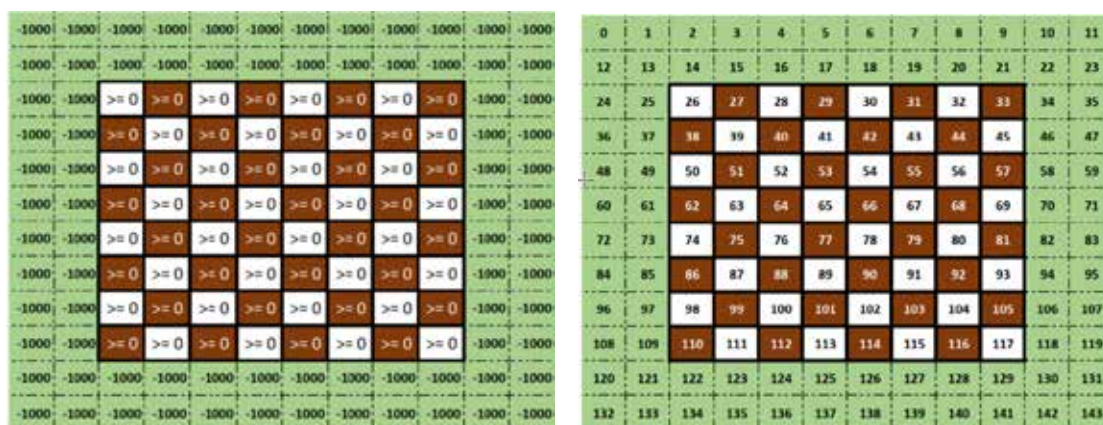


Figure 5 Chess board representation

Each chess piece is represented by a unique identifier in the form of a positive integer value using a private enumerator. In C++ language, an enumerator is a data type used to represent integer values, usually by defining the value only for the first variable, while the value of each subsequent variable of the enumerator is equal to the previous value incremented by 1 (). The reason for this representation of the pieces is that the pieces must be differentiated (for example: white bishop and black bishop), and it must be clear on which square within the chessboard each piece is located.

Generating moves is an action that occurs when a particular side must make a move. To find the best move, it is necessary to generate all possible moves that can be played from the current state. In purpose of logical representation of the move, the Move class was created. The Move class contains information's about source and destination square and additional flags for special moves (castle, en-passant, promotions). When generating each move, an object of the Move class is created, and the attributes of the mentioned array are filled in several steps:

As previously explained, each chess piece is represented by a unique identifier, while the chess board is of dimensions 12 x 12. Each pair of pieces (e.g., black and white bishop) has separate delta values that represent the value of the move that needs to be added to the index of the square on which the piece is currently located to move it to the next square (according to the rules of chess). For example can be taken bishop's movement.

Since the bishop is a piece that moves only diagonally, the mentioned array represents the necessary offset for the bishop to move to the next diagonal square (in all 4 directions). Specifically, considering the board presentation shown in figure 5, for example can be taken bishop's position on square number 89, this means that the bishop can move to squares 102, 76, 100, and 78, corresponding to diagonals. This increment of the index is repeated as long as the value of the square to which the piece moves is ≥ 0 . The explained movement representation is applicable to all other pieces on the chessboard as well.

After the destination and target squares of the Move object are filled, before filling in the other attributes, it is necessary to check whether the selected piece can move from the destination square to the target square (according to the rules of the game). According to the rules of chess, the move is not legal if the king of the side making the move is attacked by an opponent's piece (of the opposite color) after the move (if it is 'in check').

Looking into source code, it is evident that the move is added to the array of generated moves only after it is determined to be legal. This is a critical part of this practical because it requires precision and speed at the same time. Specifically, changing the position of each individual piece can endanger the king's position in various ways (open attacks, double checks, check after castling), so it is necessary after each move to start from the king in all directions to determine whether the king of the side making the move is attacked by an opponent's piece.

Since chess is a game that defines several *special* moves in its rules, it was necessary to implement a way to identify and play these moves within the game's mechanics. Generally, the method for playing a move should be quite simple, "from square X to square Y"; however, special moves complicate things, and their indicators are represented by various flags so that the move-playing function can recognize a special move and apply a specific rule.

Castling in chess involves the king and a rook of the same color exchanging positions under specific conditions: both must be on their initial squares, the king must not be in check, all squares between them must be empty, and none of the squares the king moves through can be attacked. Checking these conditions traditionally consumes significant resources during move generation. To expedite this, several flags are introduced within the position data. These flags indicate if a side has the ability to castle, making the validation process quicker by simply

verifying flag statuses and checking crucial squares for threats. The castle flag is initially true and changes to false when the king or rook moves.

En passant is a unique pawn move in chess. When an opponent's pawn moves two squares forward and lands beside a pawn of the opposite color, the rules allow the capturing pawn to move diagonally forward and capture the opponent's pawn (if the square is empty). This rule applies only on the immediate move following the opponent's pawn's two-square advance. Implementation involves an integer flag for each side, initially set to 0, updated to a positive integer value if all conditions are met. This flag resets after the opponent's move.

Chess's "promotion" rule allows a pawn reaching the opposite board edge to be replaced by any piece of the same color. This counts as 4 separate moves, as the pawn can promote to a knight, bishop, queen, or rook. Implementation uses two flags: a boolean for promotion readiness and an integer for the promoted piece type. Additionally, programmatically defined arrays list eligible pieces for promotion for each side.

In the game of chess, two terminal states can be reached: checkmate and stalemate. Checkmate occurs when the king is under threat by an opponent's piece, with no available squares to move to or pieces to interpose, resulting in a win for the attacking side. Stalemate, similar to checkmate, denotes a draw, but the king's square is not directly threatened by an opponent's piece. These conditions are crucial within the execution of the Minimax algorithm.

Checkmates follow a similar pattern, checking for available moves for the current player. If no moves are available, an additional check is made to determine if the player's king is under attack.

4.2. Minimax Search

The Minimax algorithm represents a central part of the practical section of the work. As mentioned earlier, the agent's decision to transition to the next state is based on the algorithm, which in this case is the recursive Minimax algorithm. Additionally, all other methods needed to transition to the next state are called from the Minimax algorithm.

The Minimax method is called at the moment of searching for the best response move. Specifically, the 'search' method generates all available moves using the move generation method and for each move, it calls the 'minimax' method that generates the aforementioned search tree (see figure 3).

Since Minimax is a recursive algorithm, the first step is to check if the state currently being processed is a terminal state. The number of terminal states depends on the game for which Minimax is implemented. In the case of chess, it is necessary to check several terminal states.

According to mentioned, the first case of a terminal state occurs when the side to move has no legal moves available. This scenario can be explained in two ways: "checkmate" or "stalemate". Both states are described in previous chapters.

On the other hand, the second case of checking the terminal state verifies if the search has reached the end of the sequence, and if it has, the "search" method returns the static state evaluation at the end of the sequence.

```
int maxi( int depth ) {
    if ( depth == 0 ) return evaluate();
    int max = -oo;
    for ( all moves) {
        score = mini( depth - 1 );
        if( score > max )
            max = score;
    }
    return max;
}
int mini( int depth ) {
    if ( depth == 0 ) return evaluate();
    int min = +oo;
    for ( all moves) {
        score = maxi( depth - 1 );
        if( score < min )
            min = score;
    }
    return min;
}
```

Output 1: Minimax algorithm pseudo code [3]

Pseudo code of the minimax algorithm, divided into two mutually recursive functions, which call each other until a specified depth is reached.

Since Minimax is a generic algorithm (as it is visible from output 1), not adapted solely for chess but for most two-player games, it was necessary to implement a special evaluation function based on which Minimax makes decisions about moves. In Minimax used for games between two players, such as chess, the following rule applies: positive values of the evaluation function indicate an advantage for the player with white pieces, while negative values indicate an advantage for the player with black pieces.

As previously described, looking in the source code it is evident that evaluation occurs only at the end of the sequence, except in cases when a terminal state is reached earlier. The created engine utilizes advanced evaluation. Advanced evaluation not only considers the value of the piece itself but also takes into account the piece's position on the board according to the game's principles.

4.3. Communication protocol

4.3.1. Deploying to Lichess server

In light of the preceding discussion regarding the terminal-based nature of the application, it became imperative to establish a connection with a Graphical User Interface (GUI). Notably, various applications facilitating GUI access to the terminal-based chess engine application are available online, including Winboard, Arena, and Lichess.[2]

Lichess, being an open-source application with a hosted server, offers a cost-free avenue for deploying chess engines onto web servers. The deployment process for a chess engine onto the

Lichess server involves several sequential steps. The initial step entails cloning an open-source Python script designed to serve as a proxy between the locally executed chess engine and the graphical user interface (GUI) on the Lichess server, as outlined in Figure 6.[2]

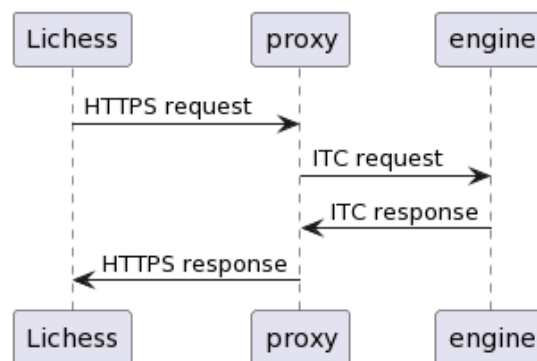


Figure 6: Illustrating the communication process between a chess engine and the Lichess server, detailing the sequence of API requests and responses for move generation and game state updates.

As depicted in the diagram, one facet of the communication involves internet-based communication (HTTPS), while the other side employs Inter-Process Communication (IPC). The implementation of IPC necessitated the development of a Terminal User Interface (TUI).[2]

The Terminal User Interface (TUI) serves the function of managing Command Line Interface (CLI) commands, which in turn initiate specific actions within the chess engine. It is imperative that the TUI adheres to predefined rules to ensure the accurate execution of these commands and actions. These rules are encapsulated within what is termed as the ‘communication protocol’. The communication protocol can be likened to a dictionary, comprising pairs of CLI commands and their corresponding actions. This meticulous approach guarantees the appropriate action for every individual CLI command that may originate from the Lichess server. Figure 7 provides a comprehensive depiction of the entire logical flow within this framework[2]

Among the two popular communication protocols, Winboard/Xboard and UCI, the Winboard protocol has been selected due to its simplicity. In the operation of the Winboard protocol, file descriptors are employed for communication. Specifically, it utilizes STDIN for reading, STDOUT for writing, and STDERR for reporting error messages. This includes errors associated with irregular engine behavior or program crashes.[2]

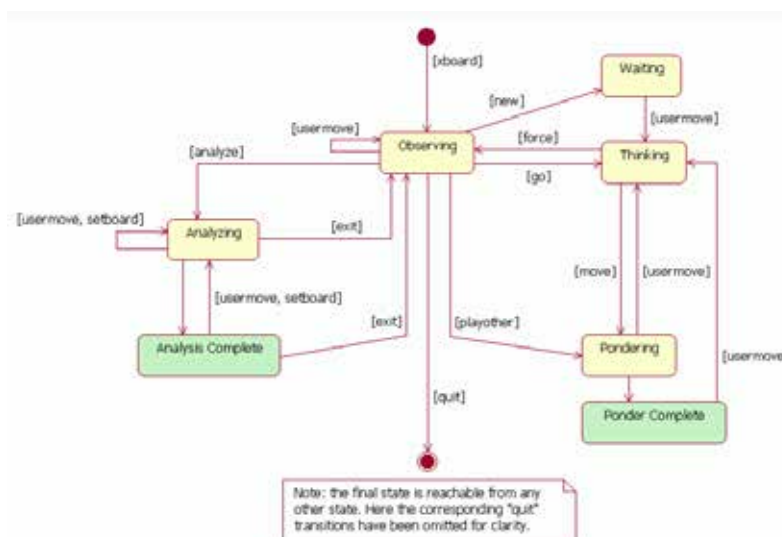


Figure 7: Interaction sequence between the chess engine and GUI, illustrating the states of the engine, the XBoard interface, and the exchange of commands according to the protocol [3]

5. Testing and evaluation

Since move generation is the most complex part of this work, testing the functionality of move detection is also quite intricate. The moves are generated within the Minimax algorithm itself, which is recursive. Consequently, detecting irregularities becomes challenging due to multiple recursive calls on the program stack.

Irregularities were detected using an automated technique of comparison. Specifically, for the practical purposes of this work, a dedicated proxy software was created. This software compares the output result of the tested engine to the output of a verified engine (in this case, *Stockfish*) for the same input. It was sufficient to generate a large number of positions in Forsyth-Edwards Notation (FEN) format, and then send each of them through both engines. If the number of generated nodes by both engines (at a specified depth) did not match, it indicated an irregularity. The diagram in Figure 8 illustrates the working principle.

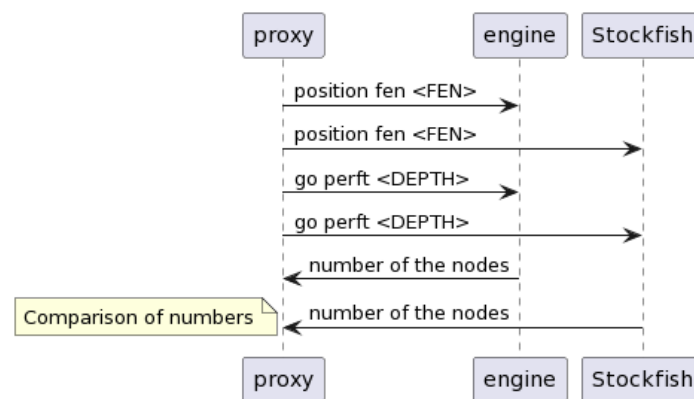


Figure 8: Diagram illustrating the proxy script workflow for detecting irregularities by comparing the number of generated nodes at a specified depth between the tested engine and Stockfish using positions in FEN format.

The proxy program was developed using the Python programming language, utilizing the *Subprocess* module, which needed to be installed as an external library. The program operates on the principle of running both engines as background (daemon) processes, sending positions in FEN format and a command to calculate the number of nodes to their standard inputs, and then reading and comparing the results from their standard outputs.

FEN format is the standard format for representing a chess position, including castling rights, en passant captures, and other important parameters in a textual form. It is important to note that the created engine supports importing positions from the FEN format and exporting positions to the FEN format.

This method was primarily employed to address discrepancies in generated node counts when testing a chess engine with predefined positions and expected outcomes.

6. Conclusion

This paper provides an overview of designing and developing a chess engine, completed by appropriate theoretical foundations and explanations. The presented chess engine has the capability to generate, process, and evaluate approximately 150,000 nodes per second (NPS), as well as the ability to import and export states in the Forsyth-Edwards Notation (FEN) format.

The creation of this paper is primarily significant for understanding the practical application of algorithms. The practical part of the thesis completes the entire process of approaching the problem, conceptual problem-solving, creating algorithms based on conceptual solutions, and

implementing the solution using the specified technology. Working on algorithm implementation gives important insight into practical aspects of search algorithms. Furthermore, to complete the engine, a deep understanding of the structure of program memory and the interpretation of program instructions within the processor were required.

In the practical implementation detailed in this thesis, the horizon effect problem remained unresolved. The primary obstacle to its resolution is the necessity of augmenting search depth, a challenge that can be addressed through the introduction of quiescence search. Furthermore, an important enhancement involves the incorporation of 'Zobrist keys' as a component of dynamic programming, serving to improve search speed and augment search depth.

As previously mentioned, the created engine has been deployed on the Lichess server, where it actively plays chess every day. User experiences are positive in terms of the stability of the application and the speed of move execution, which does not exceed 7 seconds. So far, the engine has achieved a 70% win rate from the total number of played games.

In conclusion, the implementation of alpha-beta pruning significantly enhances the efficiency of the chess engine by eliminating a substantial percentage of nodes at a given depth compared to the traditional minimax algorithm. This optimization not only reduces the computational complexity but also accelerates the decision-making process, allowing for deeper search within the same time constraints. Future improvements can focus on refining the scoring heuristics to further enhance the engine's performance. By integrating more sophisticated evaluation functions and adaptive techniques, the engine can achieve more accurate assessments of positions, ultimately leading to stronger gameplay.

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DESIGN OF EXPERIMENTAL TEST RIG FOR POLYMER GEARS

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Abstract. With the beginning of the production of synthetic polymers, a more significant application of polymers in mechanical constructions and structural elements began. Polymers are increasingly replacing metals, especially steel, which also applies to the most important machine elements for motion and power transmission - gears. The reason for this is the lower cost and faster production of polymer gears compared to metal, as well as the suitable mechanical properties of polymer gearboxes, especially with lower transmitted loads and speed. Polymer gears are manufactured by injection moulding and conventional processes such as cutting, but more recently by additive processes. The main disadvantage of polymer gears is the lack of standards and empirical values for their design, so they must be tested under conditions that are as similar as possible to operating conditions. Another problem is heating and the associated increased wear due to the poor thermal conductivity of polymers. Due to the wide range of polymers used for the manufacture of gears, with different structures, mechanical and tribological properties and a large number of parameters that influence their properties and behaviour, it is necessary to carry out experimental investigation on polymer gears.

Key words: *polymers, gears, additive manufacturing, gear test*

1. Introduction

Historical epochs were often named after the materials that had the greatest influence on the development of society and technology at that time. We can therefore say that we are living in the age of polymers, or more precisely plastics. Although the production of polymeric semi-finished products and products began in the 19th century when natural polymeric materials such as rubber were used, the development of synthetic polymers in the middle of the 20th century enabled their application in various areas of life. In 1950, plastics production amounted to around one million tons, while in 2004 it had already reached 224 million tons. For comparison: In 2007, annual steel production was around 1300 million tons, whereas in 1950 it was around 100 million tons [1]. Looking at the behavior of polymers at elevated temperatures, they are divided into elastomers, thermosets and plastomers, with thermosets and plastomers being referred to as plastics. Polymer products are simple and easy to process, they are stable at low temperatures, have a low specific mass, are not susceptible to corrosion and dampen shocks and vibrations well, and the manufacture of polymer products is very attractive in terms of energy.

Their biggest disadvantage is the stability of their structure and properties at high temperatures and a low coefficient of thermal conductivity, which causes them to heat up quickly. However, due to the wide range of polymer materials with different properties, it is possible to find a polymer that meets the conditions for specific construction requirements. For these reasons, it is obvious why polymer products are increasingly used today in various construction elements, but also in entire structures with high safety and reliability requirements. One such construction element is the spur gear, the most commonly used element of power and motion transmission. They are often used because they can transmit large loads and rotational speeds with a low dead weight, so their performance is very compact, and they are usually made of steel. Due to rapid technological development, steel gears are now increasingly being replaced by those made of polymers, which, due to their mechanical, rheological and thermal properties, can meet the requirements to which gears are exposed during their work. Gear wheels are subjected to dynamic loads, as the direction and amount of the load changes as the teeth pass through the line of action. The root of the tooth is subject to bending, while the side of the tooth is subject to high contact stresses. It is therefore necessary to know and understand the behaviour of polymer gears in order to determine their load capacity and service life. Polymer gears are manufactured by injection moulding, which is equivalent to die casting for metals, conventional cutting processes such as milling, MAAG or Fellows, and nowadays more and more with additive technology processes, whereby three-dimensional printing (3D printing), fused deposition modelling (FDM or FFF) and stereolithography (SLA) are to be distinguished. Additive processes are only about 30 years old and still under development, but due to the short production time, the low cost of the device, the adaptability of the process and the increasing quality of the products, they are becoming more and more accepted and could be the future of polymer gear production. Recently, efforts have been made to increase the precision of additive manufacturing devices in order to produce objects that require high dimensional accuracy without additional post-processing [2]. The most commonly used materials for polymer gears are polyoxymethylene (POM), polyamides (PA), also known as nylon, acrylic butadiene styrene (ABS), polypropylene (PP), polycarbonate (PC) and polyether ether ketone (PEEK). The almost unlimited number of polymer types with different properties that can be produced makes it difficult to standardize the calculation and design of plastic gears, which limits their application to some extent. There is a lack of standards, norms and empirical values for the reliable calculation and design of polymer gears, with the exception of recommendations [3, 4], which are limited to a few polymer types. Therefore, it is necessary to investigate polymer gears experimentally, under conditions as close to operational conditions as possible, which would lead to their standardization in the future and ultimately to a larger, more reliable and more efficient application.

2. Gear test rigs

In order to study polymer gears under conditions as close to operating conditions as possible, equipment must be used that is capable of exposing the gears to different conditions. There are two basic types of gearbox test rigs, non-mechanically closed loop test rigs and mechanically closed loop test rigs [5]. With these test rigs, it is possible to investigate the behaviour of polymer gears under different loads and speeds, their lifespan, wear, heating, the influence of lubrication, efficiency, etc. The most important properties, advantages and disadvantages of the test rigs mentioned are described below.

2.1. Non-mechanically closed loop test rig

Non-mechanically closed test rigs are simple and have fewer parts compared to mechanically closed loop test rigs. Non-mechanically closed test rigs contain a drive motor, a tested polymer gear pair and a driven motor. The drive motor is usually an electric motor, synchronous (DC) or asynchronous (AC), which is easy to control and can be used in a wide speed range, while the driven motors are usually brakes, mechanical, hydraulic or magnetic and can also be an electric asynchronous motor operating in generator mode. Devices for measuring the torque and speed are installed on the input and output shafts of the gearbox, while the device for measuring the temperature, vibration, noise, etc. of the polymer gears is installed around the polymer gears under investigation or in the housing, if present. Figure 1 shows an example of a non-mechanically closed loop test rig with a schematic view and the main components.

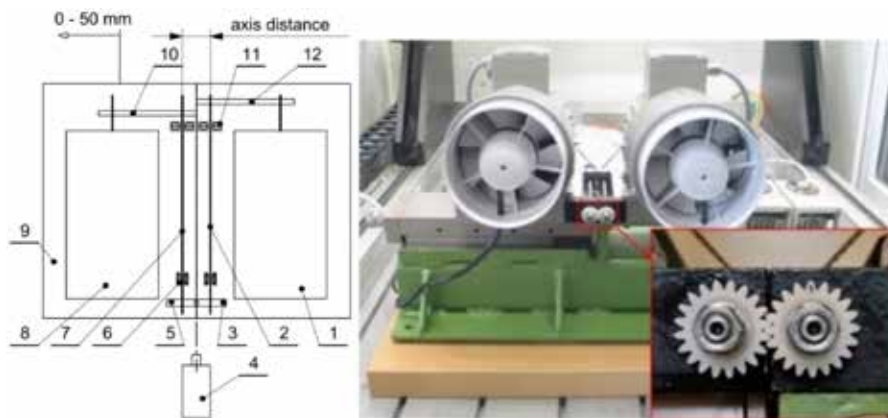


Figure 1 Non-mechanically closed test rig [6]

The power is transmitted from the driving electric asynchronous motor (1), which is controlled by the frequency converter, via the toothed belt (12) to the drive shaft (2), to which the drive gear (3) is attached. The drive gear (3) is paired with an identical driven gear (5) located on the output shaft (7), which is connected via a toothed belt (10) to the electric asynchronous motor (8), which operates as a brake motor (generator). The seat of the drive shaft (11) is located on the stationary part, and the seat of the driven shaft (6) is located on the movable part (9) of the two-part base on which the testing rig is located. The two-part base is used to easily adjust the centre distance of the tested gears. The temperature of the tested polymer gears is measured using a thermal imaging camera (4) and the torque is measured with torque measuring device (8). The simplicity of execution and the possibility of testing polymer gears of different dimensions on the same device thanks to the easy adjustment of the centre distance are the main advantages of these test rigs. The disadvantage of these test rigs is that all the energy generated by the drive motor is converted into heat and is therefore lost. In addition, a drive motor with the same power as the driven motor must be installed for the test, which can significantly increase the cost of the test, which is not the case with mechanically closed loop test rigs.

2.2. Mechanically closed loop test rig

In order to reduce the power required to test gear drives, especially metal gears, mechanically closed loop test rigs are used. A larger number of parts affects the slightly higher initial cost of testing, but if you are testing gear pairs for higher power transmission, the investment is economically legitimate. Mechanically closed loop test rigs have been used for a long time, e.g. the FZG test rig for testing oil and gear lubricants, but they can also be used for testing

polymer gears. The schematic view of such a test rig is shown in Figure 2 and consists of an electric motor (1) driving two pairs of gears (2) and (7) as well as (3) and (4), the driving gears being connected by a continuous shaft, while the driven gears are connected by a two-piece shaft having coupling flanges (5) and (6) at their connection. When one of the flanges is rotated by an angle in relation to the other and fixed in this state, a torsional moment is created in the system that is proportional to the realized deformation of the sections of the two-part shaft. By connecting the flanges in such a loaded system, the entire system with the gear pairs is previously loaded with a certain torsional moment. When we reach an angular velocity with the drive motor, each of the two pairs of gears transmits power in relation to the described method.

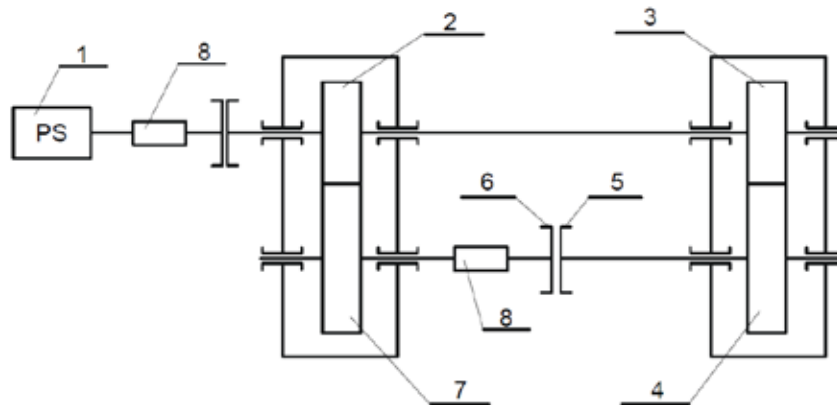


Figure 2 Mechanically closed loop test rig scheme [7]

The torque is achieved with a load clutch. Considering that load clutches have many parts and their design is quite complex, they are less reliable and more expensive. Since the gear housing is loaded with the sum of the torques on the driving and driven gears, i.e. the shaft, the gears can be loaded by the torque acting on the housing. Normally, the torque is transmitted to the housing via a lever and a weight suspended at the end of the lever. In this way, much less power is required from the drive motor and less power circulates in the system than in non-mechanically closed loop test rigs. The electric motor is controlled by a frequency converter, data and measurements are collected on a computer and the temperatures of the gears are measured with an infrared thermal camera. Such devices can work with constant and variable loads. Their main disadvantage is that the gear pairs are started and stopped at maximum load. Another disadvantage is the internal dynamic forces that cause vibrations and the problem of maintaining a constant torque due to wear of the polymer gears, which can be avoided by choosing a suitable design solution. Figure 3 shows an example of a pair of polymer gears being examined in a mechanically closed loop test rig.



Figure 3 Mechanically closed loop polymer gear testing rig [7]

3. Polymer gears testing methodology and equipment

Considering all the above-mentioned advantages and disadvantages of non-mechanically and mechanically closed loop gear testing rigs, and considering the requirements, the field of interest and the desired parameters of the investigation of polymer gear pairs, an in-house test rig was designed and built. The non-mechanically closed loop test rig was chosen due to the ease of assembly and the ability to adjust the centre distance between gears, which allows the testing of gears of different sizes and shapes. Figure 4 shows a schematic representation of the non-mechanically closed loop test rig developed in-house, with details of the most important components.

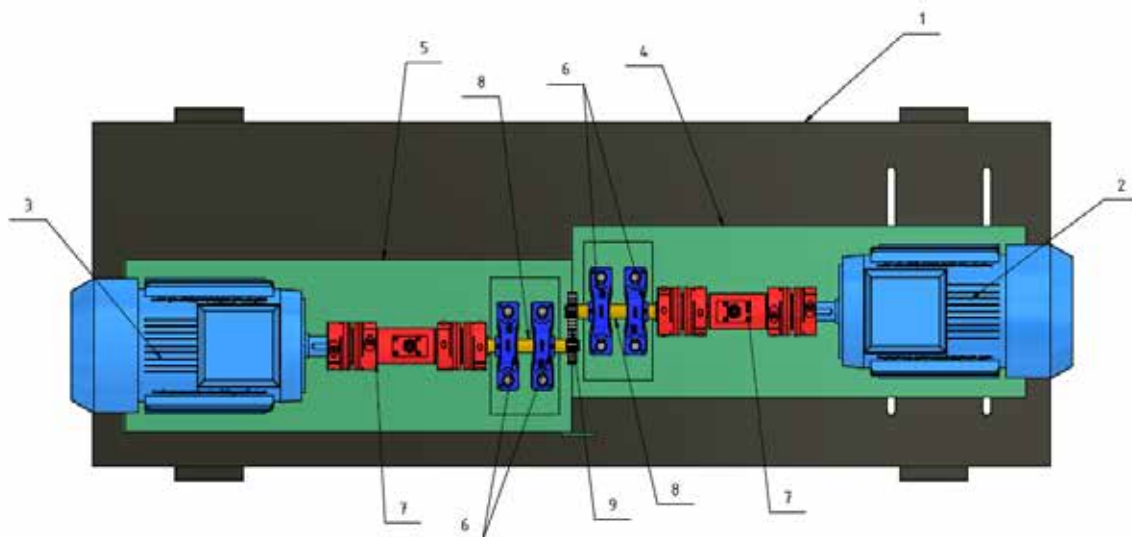


Figure 4 Schematic representation of the in-house designed non-mechanically closed loop test rig

A stand was originally made for such a test rig, on which the motors and other associated components will stand. The stand (1) has been calculated and designed from the point of view of rigidity in order to avoid unwanted vibrations during operation and possibly the occurrence of resonances. The stand is provided with slots that allow the axial alignment of the block (4) on which the driving motor (2) is located and the radial alignment of the block (5) on which the generator (3) is located with the associated transmission elements. The slots are precisely

manufactured so that the gears can mesh correctly. Two separate blocks are mounted on the stand, each consisting of a 10 mm thick steel plate and a 100 mm x 100 mm x 100 mm square steel bar machined to the final size and shape so that the shafts (8) to which the polymer gears (9) are connected, the bearings (6) and the output shaft of the motor/generator are coaxial. The plate and the bars are welded together. The holes for the bolts securing the bearings and the holes for the bolts securing the motor/generator to the blocks are then produced by precision CNC machining. The edges of the steel plate are manufactured with a strict requirement for perpendicularity to allow the test gears to mesh correctly, to avoid pitch or yaw misalignment. An electric motor/generator, bearings, torque sensors with couplings (7) and shafts are attached to each individual block. They are not affected when a new set of tested gears is replaced, ensuring the accuracy, reliability and repeatability of the test. Seipee three-phase asynchronous electric motors with a nominal power of 3 kW and a nominal rotational speed of 1430 rpm at a mains frequency of 50 Hz were selected for the test rig. The driving motor and the driven motor, the generator, are identical and the generator is connected to an Altivar regenerative unit with EMC filter with a nominal power of 15 kW. When the electric motor operates in generator mode, current is induced in it, which is converted into heat and additionally heats up the electric motor. A regenerative unit is therefore installed to feed the same current back into the generator. In this way, a more efficient cycle has been achieved as the system needs to draw less power from the mains. Both the motor and the generator are controlled and regulated by Schneider ATV 930 frequency converters with a nominal power of 3 kW. Figure 5 shows the selected frequency converter and the regenerative unit.



Figure 5 Schneider ATV 930 frequency converter (left) and Altivar regenerative unit (right)

To maintain the desired torque and speed during the test, a Dataflex 16/50 dynamic torque sensor with the corresponding Radex NC26 steel laminae coupling, both manufactured by KTR, is installed between the motor/generator and the shaft (Figure 6). The torque measuring range of the torque sensor is 50 Nm (range 1) with an accuracy of $\pm 0.1\%$, or 10 Nm (range 2) with an accuracy of ± 0.2 . Beside torque, sensor provides rotational speed information with the maximum measuring rotational speed of 10000 rpm. All the information is sent to DF 02 connector box that provides all the inputs and outputs of the torque sensor and features a scalable frequency/voltage converter. Torque output voltage is between -10 V and 10V, depending on the direction of the rotation and thus the torque, while output speed is between 0 V and 10 V (scalable). The Radex NC26 flexible coupling can compensate for axial displacements of up to 1.6 mm, radial displacements of up to 0.3 mm and angular displacements of up to 1° . Although

only one torsion metre is required, two are installed, one on each block, so that the efficiency of the polymer gear pair can be calculated immediately. The result of the ratio between output and input torque is the efficiency of the gear pair efficiency, only the losses in the bearing units need to be taken into account.



Figure 6 Torque sensor Dataflex 16/50 with steel laminae coupling Radex NC26

SKF SY 20 TF plummer block units made of cast iron with an extended inner ring and set screw locking, with basic dynamic load rating of 12.7 kN and a limiting speed of 8500 rpm were used for mounting. The entire test rig is regulated, controlled and automated by a Siemens LOGO! 8.3 PLC unit and the associated software from Siemens. The software makes it possible to store all measured parameters on the computer. During the testing of the polymer gears, it is possible to measure the bulk temperature of the gears with two infrared thermal imaging cameras. The infrared thermal imaging camera Hikvision DS-2TD2637-10/P (Figure 7) is mounted on the wall and monitors the temperature of the driven gear and allows measurements in the range of -20°C to 150°C with an accuracy of $\pm 8^{\circ}\text{C}$. The portable infrared thermal imaging camera FLIR E6 with an accuracy of $\pm 2^{\circ}\text{C}$ and a measuring range of -20°C to 550°C is used to measure the bulk temperature of the driving gear (Figure 8). Considering that polymer gears are not suitable for temperatures above 120°C , as they become soft and power transmission is no longer possible, both cameras can be used for measurement.



Figure 7 Hikvision DS-2TD2637-10/P



Figure 8 FLIR E6

In addition, a noise level metre was placed on the test rig, and a temperature and humidity metre were set up in the laboratory where the tests will be carried out (Figure 9). The Testo 816-1 sound level metre, which has a measuring range of 30 dB to 130 dB with an accuracy of ± 1.4 dB and an integrated memory with the option of storing up to 31,000 measured values,

was used for the noise measurement. Data acquisition and processing is possible with the aid of special Testo software. The Testo 175 H1 with data logger is used to measure relative humidity and air temperature. The temperature measurement range extends from -20°C to 55°C with an accuracy of $\pm 0.4^{\circ}\text{C}$, while the accuracy of the relative humidity measurement is ± 1 RH.



Figure 9 Testo 816-1 (left) and Testo 175 H1 (right)

Finally, the assembled in-house developed non-mechanically closed loop test rig for polymer gears is shown in Figure 10.



Figure 10 In-house assembled non-mechanically closed loop test rig for polymer gears

4. Conclusion

Metal gears have been extensively researched and developed, and it is possible to design them with great reliability, taking into account load capacity, wear, lubrication, damage types and fatigue limits. Due to the large number of different polymer materials used for the production of gears and the lack of experimental parameters and data, as well as the absence of standards or

norms, the reliable design and construction of polymer gears is a major challenge for engineers and manufacturers. Currently, various recommendations and guidelines can be used for the design of polymer gears, but those only cover some of the most commonly used polymers such as polyoxymethylene (POM) also known as acetal, and polyamides (PA 6 and PA 66) known as Nylon 6 and Nylon 66. In order to gain new insights, it is necessary to perform experimental tests on real polymer gears which can be carried out on non-mechanically and mechanically closed loop test rigs. Non-mechanically closed-loop test rigs are more consistent and allow flexibility during testing. They are more suitable for testing polymer gears as polymer gears generally transmit lower loads. With the help of such test rigs, it is possible to test the influence of geometric, mechanical, rheological and thermal properties on the service life and performance of polymer gears at different loads and speeds. It is also possible to gain insights into the wear mechanisms and damage types of polymer gears as well as the temperature changes during their operation. Research can also be extended by adding various measuring instruments such as thermal imaging cameras, sound level metres, precision scales, etc., which can contribute to the standardisation of polymer gears.

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GENERIC PRINT LAYOUT AND DATA GENERATION FOR ACCOUNTING REPORTING

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Abstract. Creating data reports for various applications can be time consuming and it is often done by software developers which is not an optimal allocation of their skills and time. Considering this, database and reporting tool vendors through the past decade have developed reporting tools (Oracle BI Publisher, Microsoft Power BI and other) that are supposed to delegate most of reporting to end-user. Although advertised as easy to use, those reporting tools require quite a few skill sets that many users don't have. This paper proposes and demonstrates the concept, design and use of generic report print layout and data generation (collection) for a set of reports used in accounting. Criteria and the process of data collection, grouping and sorting, report header, footer and body content are stored in database objects thus reducing developer's time to add or change report and allowing user interface to be made as an option. The realization of this concept is done in Oracle environment using standard SQL database objects, syntax, procedures (or procedures that are common) and basic report design features. Implementation of the concept is demonstrated, but not restricted, to accounting data set reporting.

Key words: *reports, data generation, generic layout, accounting*

1. Introduction

Changing business environment, business process automation, followed by a broad spectrum of software applications, and growing data generation have induced the need for quick and suitable data reporting. Over the past decade, database and reporting tools vendors have developed reporting tools advertised as "easy to use", thus delegating much of the reporting workload to the end-user. Unfortunately, not many end-users have time and/or skills to design and maintain required data sets, layouts, and data sources needed to produce requested reports. Thus, most of the data collection, report data model, and design is carried out by software developers, whose time and knowledge could be allocated more efficiently.

This paper will demonstrate the concept using design and use of generic report print layout and data generation (collection) for a set of reports used in accounting. It explains how the selection of columns, as well as the processes of data collection, grouping, and sorting, and the organization of the report's header, footer, and body are stored in database objects, thereby reducing the time developers spend adding or modifying reports. The concept is demonstrated within an Oracle environment using standard SQL [1] database objects, syntax, procedures (or procedures that are common) and basic report design features. It can be easily used on any other RDBMS* and reporting environment. The implementation of the concept is demonstrated, but not restricted, to accounting data set reporting.

This paper is structured as follows. Chapter 2 explains the concept of data collection for this specific purpose and dynamic query generation.

Chapter 3 describes the concept, design of the adjusted report layout and the accompanying database structure. Conclusions and suggestions for future improvements are presented in Chapter 4.

2. Data collection and dynamic query generation

In database reporting, the creation of SQL queries that can adjust to different data needs is crucial. This flexible query creation is known as dynamic SQL [2], a method that allows the creation of SQL commands that change according to the data they collect, group, or aggregate. In addition, it is important to define database objects that store detailed information about the columns holding business data and their characteristics within a report. For this reason, the table IZVJ_KOL was created (Table 1). It documents important details about each column, such as the user column position (KOLONA), grouping status (GRUPIRANJE), the type of column indicating whether it is a regular or an aggregate column (KOL_VRSTA), and the type of aggregate function (AGR_VRSTA).

Table 1 Table IZVJ_KOL

❖ COLUMN_NAME	❖ DATA_TYPE	❖ NULLABLE	DATA_DEFAULT	❖ COLUMN_ID	❖ COMMENTS
BR_IZVJEST	NUMBER	No	(null)	1	(null)
KOLONA	NUMBER	No	(null)	2	(null)
NAZIV	VARCHAR2 (1000 BYTE)	Yes	(null)	3	(null)
OPIS	VARCHAR2 (1000 BYTE)	Yes	(null)	4	(null)
GRUPIRANJE	VARCHAR2 (1 BYTE)	Yes	(null)	5	(null)
KOL_VRSTA	VARCHAR2 (1 BYTE)	Yes	(null)	6	A-agregat; K-"obična" kolona;
AGR_VRSTA	VARCHAR2 (10 BYTE)	Yes	(null)	7	vrsta agregata SUM, MAX, ...
NAPOMENA	VARCHAR2 (1000 BYTE)	Yes	(null)	8	(null)
IZVJ_KOL_ID	NUMBER (38,0)	No	(null)	9	(null)

The creation of a dynamic SQL query is achieved by several loop iterations over the table IZVJ_KOL. In the first loop, the grouping part of the query is stored in a string variable (Listing 1). Standard columns (Listing 2) and aggregate clauses (Listing 3) are generated in subsequent loops. Finally, all parts are concatenated into a single string variable (Listing 4), which forms the SQL query to be executed for collecting data for the specific report.

```

declare
    i integer:=0;
begin
    for c_kol1 in (select naziv,grupiranje,kol_vrsta, agr_vrsta, opis from izvj_
kol where br_izvjest=P_IZVJESTAJ_ID order by kolona)
    loop
        CASE c_kol1.kol_vrsta
            WHEN 'K' THEN
                if c_kol1.grupiranje = 'D' then
                    if i=0 then
                        i:=i+1;
                        p_group_by_prvi:=c_kol1.naziv;
                        p_group_by :=p_group_by || c_kol1.naziv ||',';
                        continue;
                    end if;
                    p_group_by_bez_prvi :=p_group_by_bez_prvi || c_kol1.naziv ||',';
                    p_group_by :=p_group_by || c_kol1.naziv ||',';
                    end if;
                ELSE null;
            END CASE;
        end loop;
    end;
    p_group_by := SUBSTR(p_group_by, 0, LENGTH(p_group_by) - 1); -- otkidaj zadnji
zareza

```

Listing 1 Oracle PL/SQL code excerpt - SQL query generation – GROUP BY clause

```

for c_kol in (select naziv,grupiranje,kol_vrsta, agr_vrsta, opis from izvj_kol
where br_izvjest=P_IZVJESTAJ_ID order by kolona)
loop
    CASE c_kol.kol_vrsta
        WHEN 'K' THEN
            if c_kol.grupiranje <>'D' or c_kol.grupiranje is null then
                p_kol:=p_kol || c_kol.naziv ||',';
                p_opis:=p_opis || ' ' || c_kol.opis || ' ','';
                brojac_kol:=brojac_kol+1;
            elsif c_kol.grupiranje = 'D' then
                -- ako je kolona ista prethodnoj i sljedećoj stavi NULL, ako je NULL stavi
                -- uk. inače 0
                p_kol:=p_kol||' DECODE('||c_kol.naziv||',(LAG('||c_kol.naziv||')
OVER (ORDER BY '||p_group_by||')),
DECODE('||c_kol.naziv||',(LEAD('||c_kol.naziv||')
OVER (ORDER BY '||p_group_by||')),NULL,
DECODE('||c_kol.naziv||',NULL,NULL,' uk.'''||
||c_kol.naziv||')),'||c_kol.naziv||'),'';
                p_opis:=p_opis || ' ' || c_kol.opis || ' ','';
                brojac_kol:=brojac_kol+1;
            end if;
        ELSE null;
    END CASE;
end loop;

```

Listing 2 Oracle PL/SQL code excerpt - SQL query generation – SELECT clause (standard columns)

```

for c_kol2 in (select naziv,grupiranje,kol_vrsta, agr_vrsta, opis from izv_j_kol
               where br_izvjest=P_IZVJESTAJ_ID order by kolona)
loop
  CASE c_kol2.kol_vrsta
    WHEN 'A' THEN
      p_kol:=p_kol || 'ROUND(NVL('||c_kol2.agr_vrsta||'('||c_kol2.
naziv||'),0),2),';
      p_opis:=p_opis || ' ' '|| c_kol2.opis || ' ',';
      brojac_kol:=brojac_kol+1;
    ELSE null;
  END CASE;
end loop;

```

Listing 3 Oracle PL/SQL code excerpt - SQL query generation – SELECT clause (aggregate columns)

```

query := 'SELECT '||p_select||' FROM '|| p_tabl || ' '|| p_where|| ' '|| p_
group_by;

```

Listing 4 Oracle PL/SQL code excerpt - SQL query generation – clause concatenation

3. Concept and design of report layout and accompanying database objects

3.1. Database objects

The system is designed to accommodate various parts of a report as needed. To keep things simple and based on user requests, only page and report footers/headers are implemented. The layout for each part of the report is stored in the IZVJ_DIO table. This setup allows users or developers to modify or add new sections to the report layout as new needs arise.

The structure of the IZVJ_DIO table, which stores the layout information for report sections, is shown in Table 2. This design facilitates easy updates to accommodate user needs. Table 3 presents examples of the data within the IZVJ_DIO table, demonstrating the correspondence between the data and each report segment.

Table 2 IZVJ_DIO table design

❖ COLUMN_NAME	❖ DATA_TYPE	❖ NULLABLE	DATA_DEFA...	❖ COLUMN_ID	❖ COMMENTS
IZVJ_DIO_ID	NUMBER(38,0)	No	(null)	1 (null)	
OZNAKA	VARCHAR2(30 BYTE)	Yes	(null)	2 (null)	
OPIS	VARCHAR2(200 BYTE)	Yes	(null)	3 (null)	

Table 3 IZVJ_DIO table data

❖ IZVJ_DIO_ID	❖ OZNAKA	❖ OPIS
1	ZAG_IZVJ	Zaglavlje izvještaja
2	ZAG_STR	Zaglavlje stranice
3	SADRZ	Sadržaj
4	PODN_STR	Podnožje stranice
5	PODN_IZVJ	Podnožje izvještaja
6	PARAMS	Parametri

To ensure that each section of the report is filled with the appropriate data, all information, including header, footer, and content, is placed into a temporary table named IZVJ_TEMP. Each entry in this table is linked to a specific part of the report by a report part ID, known as IZVJ_DIO_ID. This ID is then used within data collection queries to organize the report content.

The construction of a report is a multi-step process that involves the insertion of distinct data segments into the database. Listing 5 outlines the insertion of the report header data, which includes information that appears at the beginning of the report. Following this, Listing 6 details the process for inputting page header data, which, unlike the report header, repeats at the top of each page.

```

/***** ZAGLAVLJE IZVJESTAJA *****/
select izvj_dio_id into P_IZVJESTAJ_DIO_ID from izvj_dio where oznaka='ZAG_
IZVJ';
select naziv_izvj into v_naziv_izvj from izvjesca where izvjesca_id=P_
IZVJESTAJ_ID;
select pogon_zbirno,naziv_pog_zbirno into v_pogon_zb, v_naziv_pz
from pogon_zbirno where br_zbirno=
(select br_zbirno from pogon where br_pogon = P_BR_POGON and rownum=1);
select naziv_pog into v_naziv_pg from pogon where br_pogon=P_BR_POGON;
select username, ime, prezime into v_username, v_ime, v_prezime
from korisnik where korisnik_id=P_USER;

INSERT INTO IZVJ_TEMP
(SELECT P_APP_ID ,P_SESSION_ID,P_USER,P_IZVJESTAJ_ID,P_IZVJESTAJ_DIO_ID,NULL
/*red*/, v_username, v_naziv_izvj,to_char(sysdate, 'dd.mm.yyyy
hh24:mi'),
NULL, NULL, NULL, NULL,NULL, NULL, NULL, NULL, NULL, NULL, NULL,
NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL,
NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL,
NULL from dual);
INSERT INTO IZVJ_TEMP
(SELECT P_APP_ID ,P_SESSION_ID,P_USER,P_IZVJESTAJ_ID,P_IZVJESTAJ_DIO_ID,NULL
/*red*/,v_pogon_zb, v_naziv_pz, v_naziv_pg, NULL, NULL, NULL, NULL,
NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL,
NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL,
NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL, NULL,
NULL from dual);
/*****

```

Listing 5 Inserting report header data


```

/***** ZAGLAVLJE STRANICE *****/
BEGIN
  select izvj_dio_id into P_IZVJESTAJ_DIO_ID from izvj_dio where oznaka='ZAG_
STR';

  INSERT INTO IZVJ_TEMP
  (SELECT  app_id,    session_id,    korisnik_id,izvjestaj_id, P_IZVJESTAJ_
DIO_ID,
        NULL/*RED*/,    opis_1,    opis_2,    opis_3,    opis_4,
        opis_5,    opis_6,    opis_7,    opis_8,    opis_9,    opis_10,    opis_11,
        opis_12,    opis_13,    opis_14,    opis_15,    opis_16,
        opis_17,    opis_18,    opis_19,    opis_20, NULL,    NULL,    NULL,
        NULL,    NULL,    NULL,    NULL,    NULL,    NULL,    NULL,    NULL,
        NULL,    NULL,    NULL,    NULL,    NULL,    NULL,    NULL,    NULL
  FROM    izvj_temp
  WHERE app_id= P_APP_ID AND SESSION_ID=P_SESSION_ID AND KORISNIK_ID = P_USER
  AND IZVJESTAJ_ID=P_IZVJESTAJ_ID AND IZVJ_DIO_ID=
(select izvj_dio_id  from izvj_dio where oznaka='SADRZ') AND  ROWNUM=1);
  COMMIT;
  END;
/*****

```

Listing 6 Inserting page header data

The final stage involves the insertion of the main content into the report. The code in Listing 7 sequentially retrieves data from a query and inserts each piece into the IZVJ_TEMP table. This process repeats until all relevant data has been transferred, ensuring the table is populated with the necessary information for report generation.

```

open c_ref for query;
loop
  fetch c_ref into row_tblizv;
  exit when c_ref%NOTFOUND;
  insert into IZVJ_TEMP values row_tblizv;
  commit;
  null;
end loop;

```

Listing 7 Inserting content data

3.2. Report layout and data model

The report layout and data model have been designed to align with the underlying concept that is implemented through database objects. A generic layout consists of report and page header/footer, while the main content area is divided into twenty columns to meet current and anticipated needs. The report data model compiles a single report from various data sources stored in IZVJ_TEMP, distinguishing specific reports by application ID, username, report ID, and session ID.

Figure 1 illustrates the structure of the generic report data model, while Listing 8 presents the query used for extracting content data.

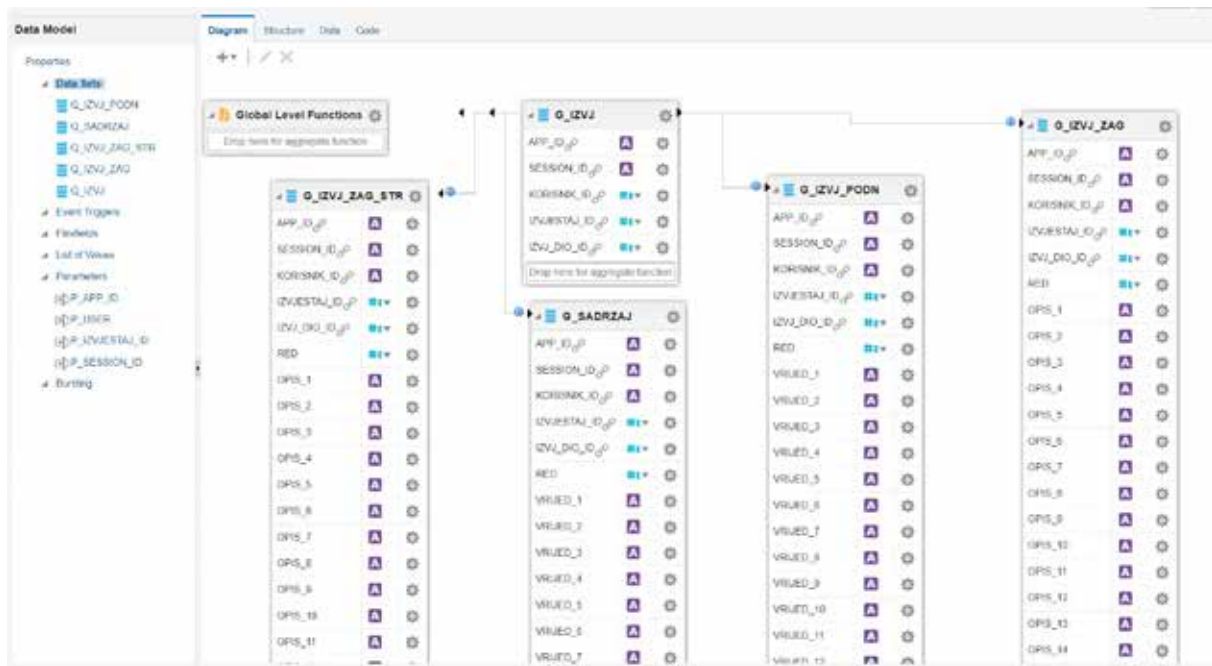


Figure 1 Generic report data model

```
SELECT
    app_id, session_id, korisnik_id, izvjestaj_id, izvj_dio_id,
    red, vrijed_1, vrijed_2, vrijed_3, vrijed_4, vrijed_5,
    vrijed_6, vrijed_7, vrijed_8,
    NVL(REPLACE(vrijed_9,',','.'),' ') vrijed_9,
    NVL(REPLACE(vrijed_10,',','.'),' ') vrijed_10,
    NVL(REPLACE(vrijed_11,',','.'),' ') vrijed_11,
    NVL(REPLACE(vrijed_12,',','.'),' ') vrijed_12,
    NVL(REPLACE(vrijed_13,',','.'),' ') vrijed_13,
    NVL(REPLACE(vrijed_14,',','.'),' ') vrijed_14,
    NVL(REPLACE(vrijed_15,',','.'),' ') vrijed_15,
    NVL(REPLACE(vrijed_16,',','.'),' ') vrijed_16,
    NVL(REPLACE(vrijed_17,',','.'),' ') vrijed_17,
    NVL(REPLACE(vrijed_18,',','.'),' ') vrijed_18,
    NVL(REPLACE(vrijed_19,',','.'),' ') vrijed_19,
    NVL(REPLACE(vrijed_20,',','.'),' ') vrijed_20
FROM
    izvj_temp
WHERE
    izvj_dio_id = (select izvj_dio_id from izvj_dio where oznaka='SADRZ')
ORDER BY RED
```

Listing 8 Data model query (content)

3.3. Design and illustrations of report layouts

This section provides a visual overview of the report layout and samples used within our system. The diversity in the design reflects the system's adaptability to various informational needs and presentation styles.

The design of the report layout is simple and mirrors the logic by which individual parts of the report are created in the database tables (Figure 2). The first part represents the report header

(G_IZVJ_ZAG), followed by the page header (F OPIS_1 ... OPIS_12 E) and report content (F VRIJED_1 ... VRIJED_12 E) in the central part. The last part represents the footer of the report (F VRIJED_1 ... vrijed_12 E). This template is the same for all generated reports regardless of the number of displayed columns and grouping, and it does not require any maintenance or modification.

<?foreach3 IDV_ZAG?>				<?OPIS_2?>				<?OPIS_3?>			
<?end foreach3?>											
F OPIS_1	OPIS_2	OPIS_3	OPIS_4	OPIS_5	OPIS_6	OPIS_7	OPIS_8	OPIS_9	OPIS_10	OPIS_11	OPIS_12 E
F VRIJED_1	VRIJED_2	VRIJED_3	VRIJED_4	VRIJED_5	VRIJED_6	VRIJED_7	VRIJED_8	VRIJED_9	VRIJED_10	VRIJED_11	VRIJED_12 E

F VRIJED_1	VRIJED_2	VRIJED_3	VRIJED_4	VRIJED_5	VRIJED_6	VRIJED_7	VRIJED_8	VRIJED_9	VRIJED_10	VRIJED_11	vrijed_12 E
------------	----------	----------	----------	----------	----------	----------	----------	----------	-----------	-----------	-------------

Figure 2 Report layout (Word template)

The appearance of the report depends on the number of selected columns for display as well as the level of data grouping. At the end of each data group for which we have selected grouping, the total is displayed (Figure 2, Figure 3)

IPOSIC				Rekapitulacija No. 1				28.03.2024 07:31			
CIET 2024				Generic print layout				and data generation			
Područje	Objekt	Gr.rad.	Jed.				Poč.st	Ulag.	Akt.	Saldo	
uk.0003027	00030279	7	001				0,00	1.234.121,17	0,00	1.234.121,17	
		uk.7					0,00	1.234.121,17	0,00	1.234.121,17	
		16	002				0,00	54,00	-54,00	108,00	
		uk.16					0,00	54,00	-54,00	108,00	
	uk.0003027	1	002				0,00	1.234.175,17	-54,00	1.234.229,17	
		uk.1					0,00	33,00	0,00	33,00	
		7	002				0,00	492,00	0,00	492,00	
		uk.7					0,00	492,00	0,00	492,00	
	00050161	16	001				0,00	9.879,00	0,00	9.879,00	
			002				0,00	10.973,00	0,00	10.973,00	
		uk.16					0,00	20.852,00	0,00	20.852,00	
							0,00	21.377,00	0,00	21.377,00	
	uk.0005016	1	002				0,00	123.456,00	0,00	123.456,00	
		uk.1					0,00	123.456,00	0,00	123.456,00	
							0,00	123.456,00	0,00	123.456,00	
							543,00	0,00	0,00	543,00	
	uk.0005016	1	002				543,00	0,00	0,00	543,00	
		uk.1					0,00	908,00	0,00	908,00	
		16	001				0,00	23,00	0,00	23,00	
		uk.16					0,00	931,00	0,00	931,00	
	uk.00050184						543,00	931,00	0,00	1.474,00	
		00070333	2	003			0,00	3.577,65	-3.577,65	7.155,30	
		uk.2					0,00	3.577,65	-3.577,65	7.155,30	
		16	003				0,00	11.122,80	0,00	11.122,80	
	uk.0007033	uk.16					0,00	11.122,80	0,00	11.122,80	
							0,00	14.700,45	-3.577,65	18.278,10	
		00100434	1	001			0,00	345,00	0,00	345,00	
			002				0,00	1.320,00	0,00	1.320,00	
	uk.0007033		003				876,00	0,00	0,00	876,00	
		uk.1					876,00	1.665,00	0,00	2.541,00	
		16	001				55,00	912,00	0,00	967,00	

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Figure 3 Report example 1 (first page)

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CIET 2024

Rekapitulacija No. 1

Generic print layout ...

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and data generation ...

Područje	Objekt	Gr. rad.	Jed.	Poč. st.	Ulag.	Akt.	Saldo
	uk. 4022000			0,00	180,00	0,00	180,00
	4022000347	72	404	0,00	90,00	0,00	90,00
		uk. 72		0,00	90,00	0,00	90,00
	uk. 4022000			0,00	90,00	0,00	90,00
	4022000347	108	102	0,00	90,00	0,00	90,00
		uk. 108		0,00	90,00	0,00	90,00
	uk. 4022000			0,00	90,00	0,00	90,00
	4022000349	72	102	0,00	480,00	0,00	480,00
		uk. 72		0,00	480,00	0,00	480,00
	uk. 4022000			0,00	480,00	0,00	480,00
	4022000350	72	404	0,00	180,00	0,00	180,00
		uk. 72		0,00	180,00	0,00	180,00
	uk. 4022000			0,00	180,00	0,00	180,00
uk. 4022				3.771.162,61	2.245.918.191,5	21.086.088,18	2.228.603.265,94
Sveukupno				3.771.162,61	2.245.918.191,51	21.086.088,18	2.228.603.265,94

Figure 4 Report example 1 (last page)

Regardless of the number of displayed columns, the number of grouped columns, the arrangement of grouping and the type of aggregate functions used, the report layout, the data source from the reporting system, as well as the program code remain the same and do not require programmer involvement for modifying an existing report or creating a new one (Figure 4, Figure 5).

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CIET 2024

Rekapitulacija No.2

Generic print layout ...

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and data generation ...

Područje	Šifra objekta	Poč. st.	Ulag.	Akt.	Saldo
	05201301	7.848,36	0,00	3.924,18	3.924,18
	10202104	136.000,00	0,00	0,00	136.000,00
	20201901	207.200,00	0,00	0,00	207.200,00
	20201902	53.000,00	0,00	0,00	53.000,00
	20202005	12.712.348,00	2.146.574,00	8.502.748,00	6.356.174,00
	20202006	1.680.644,52	286.570,00	0,00	1.967.214,52
	20202007	19.500,00	212.490,00	212.490,00	19.500,00
	20202101	0,00	2.139.928,00	0,00	2.139.928,00
	20202103	48.000,00	67.100,00	0,00	115.100,00
	20202104	32.000,00	327.190,00	327.190,00	32.000,00
	20202105	0,00	183.544,00	0,00	183.544,00
	20202106	0,00	178.200,00	178.200,00	0,00
	20202112	0,00	51.800,00	0,00	51.800,00
	5586008	750.300,00	0,00	251.800,00	498.500,00
uk. 4022		15.646.840,88	5.593.396,00	9.476.352,18	11.763.884,70
Sveukupno		15.646.840,88	5.593.396,00	9.476.352,18	11.763.884,70

Figure 5 Report example 2

The user simply selects the type of report and parameters, and the process for executing the chosen report (with predefined columns for display, grouping arrangement, and aggregate functions used) is carried out using database logic that generates records for the reporting system, which, using the layout design, ultimately displays the report, as shown in Figure 6.

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Rekapitulacija No.3

28.03.2024 08:19

CIET 2024

Generic print layout ...

and data generation ...

Područje	Objekt	Jedinica	Grupa radova	Aktivnost	Početno stanje	Ulaganje	Aktiviranje	Saldo
			24	221YU	0,00	48.100,00	0,00	48.100,00
			uk.24		0,00	48.100,00	0,00	48.100,00
		uk.003			0,00	183.544,00	0,00	183.544,00
	uk.2020210				0,00	183.544,00	0,00	183.544,00
	20202106	003	10	221YL	0,00	178.200,00	178.200,00	0,00
			uk.10		0,00	178.200,00	178.200,00	0,00
		uk.003			0,00	178.200,00	178.200,00	0,00
	uk.2020210				0,00	178.200,00	178.200,00	0,00
	20202112	003	9	221YU	0,00	51.800,00	0,00	51.800,00
			uk.9		0,00	51.800,00	0,00	51.800,00
		uk.003			0,00	51.800,00	0,00	51.800,00
	uk.2020211				0,00	51.800,00	0,00	51.800,00
	558008	003	9	222YS	207.200,00	0,00	0,00	207.200,00
			uk.9		207.200,00	0,00	0,00	207.200,00
			11	231Y	19.500,00	0,00	0,00	19.500,00
			uk.11		19.500,00	0,00	0,00	19.500,00
			23	231Y	20.000,00	0,00	0,00	20.000,00
			uk.23		20.000,00	0,00	0,00	20.000,00
			24	212	503.600,00	0,00	251.800,00	251.800,00
			uk.24		503.600,00	0,00	251.800,00	251.800,00
		uk.003			750.300,00	0,00	251.800,00	498.500,00
	uk.558008				750.300,00	0,00	251.800,00	498.500,00
uk.558008					15.646.840,88	5.593.396,00	9.476.352,18	11.763.884,70
Sveukupno					15.646.840,88	5.593.396,00	9.476.352,18	11.763.884,70

Figure 6 Report example 3

4. Conclusion

The concept of delegating the selection of report columns, along with the processes of data collection, grouping, sorting, and generating report content to database objects, has been validated to reduce the time developers spend on modifying or adding reports. Although this system has been implemented in an Oracle environment, its foundation on standard SQL objects, syntax, and procedure, as well as basic report design feature, ensures that it can be easily adapted to other RDBMS and reporting environments.

Future improvements may include a visual report design tool and an application interface that will allow users to independently create and modify the content of reports, further minimizing the need for developer intervention.

REFERENCES

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CHALLENGES OF AN IMPLEMENTATION OF THE FC JUNAK FOOTBALL FIELD LIGHTING PROJECT

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Abstract. The paper presents a proposal for a lighting project for the football field of FC Junak from Sinj, with 20 optimally positioned and aimed DALI controllable LED floodlights, mounted on four proposed newly designed lighting poles, which would meet the requirements for competitions, and with the possibility of powering only six floodlights per pole, which is enough for lighting during training.

The presentation of the appearance of the designed lighting poles, the optical, mechanical and light-technical properties of the selected floodlights and an example of the cost sheet are given. Illumination calculations were performed and analysed in the Dialux program, for both cases of use, for competitions and public events and for training. Designed technical-light solutions for football field lighting are shown via tables, floor plans and spatially for both cases. An estimate of the annual consumption of electricity is given.

The execution of the project would be significant for the city of Sinj and its surroundings, which would provide new generations with a functional football field, and potentially provide its citizens with a newly lit space for attractive, not only sporting, but also cultural, artistic and other events. This would allow the city of Sinj to join the current renovation and construction process of sports infrastructure in the Republic of Croatia.

Since the project is estimated at 750000 euros, which is a large expenditure for an investor, it was proposed to apply for a tender for co-financing the construction, renovation, maintenance, equipping and reconstruction of sports buildings by the Ministry of Tourism and Sports. The option of a cheaper project, with less reliable floodlights from the Chinese market, was also taken into account and a comparison with the proposed project was given. Due to environmental standards, only LED floodlight lighting was taken into account for both cases.

Key words: *electrical lighting, football field, FC Junak, LED floodlights, Dialux*

1. Introduction

NK Junak Sinj is a football club from Sinj, founded in 1916. With a rich tradition spanning over a century, the club boasts more than 250 trophies from various competitions, a testament to its long-standing success. [1] While it previously competed in the 2nd Croatian football league, NK Junak Sinj currently finds itself in the 3rd league. However, the club's aspirations remain focused on further development and progress.

NK Junak Sinj attracts numerous talented young athletes from Sinj and the surrounding areas, who are drawn to the club's strong reputation. Their home ground is the City Stadium Sinj, opened in 2006 and located just outside the city centre, next to the famous Sinj Hippodrome. The stadium boasts a capacity of 3096 seats. [2] While currently equipped with only a few

floodlights, as shown in Figure 1, this lighting is inadequate for night games or professional competitions requiring television broadcasts.



Figure 1 Current lighting of the FC Junak football field [3]

The lighting project of the FC Junak football field was created with the aim of starting investments in the sports life of Sinj and additionally motivating young people to live in Sinj, play sports and strengthen sportsmanship and competitiveness. The project provides for 4 lighting poles with 20 floodlights on each pole. The planned poles are placed in the corners of the playground, they are 20 metres high, with floodlight supports tilted by 15° , according to the design standards for football field lighting, and with ladders for climbing, that is, for access to the floodlights and their maintenance. Maintenance of floodlight lighting also includes periodic cleaning, because it is recommended for high-quality indoor and outdoor lighting to clean the fittings and optics when the light flux drops by 10% or less.

The provided floodlights are of LED technology and DALI (Digital Addressable Lighting Interface) controllable, which means that group and individual control of lamps is possible. For elementary use of lighting control, two modes of operation are provided: playground lighting for competitions, with all 80 floodlights turned on and an average illumination of over 1000 lx, and playground lighting for training, with 24 floodlights turned on and an average illumination of over 200 lx. Uniformity U_0 , the quotient of minimum and average illuminance on the football field ground, is also high in both cases, i.e. over 70% for training and over 80% for competitions, which was achieved by carefully positioning and directing each individual floodlight in the Dialux 4 software.

Dialux 4 software is free, easy to install, extremely fast and ideal for designing floodlight lighting, as it offers a tabular overview in the form of a floodlight table, in which coordinates and inclinations can be manually entered and altered, as well as the tilting angles or aiming points of a floodlight or group of floodlights. As well as by the tabular input, the position and the aiming of the designed lighting can be verified on the fly in a floor plan and in a simple three-dimensional view, which gives designers excellent control and transparency of their designing process. There is also a more advanced, 3D version of Dialux named Dialux EVO, which is also free to use and has many additional visual and design options, such as the input of floor plans made in CAD programmes, but it is a software that requires a higher quality user's computer, in terms of a greater working memory and a stronger processor.

2. FC Junak football field proposed floodlight lighting

This project proposes a lighting design using 80 floodlights, each rated at 1500 W, mounted on 4 poles. The design offers two lighting modes: one for competitions and television broadcasts with all floodlights on, and another for training with a selection of floodlights turned on.

2.1. The lighting poles

The project utilises 4 poles positioned according to established design practices, as outlined in Figure 2. The optimal placement involves extending two diagonals of the playing field beyond its boundaries. From the center of each shorter side, a smaller line is drawn towards the corresponding diagonal, forming a 15° to 20° angle with it. The intersection points of these lines with the extended diagonals define the pole positions, labelled A, B, C, and D. The height of each pole should be at least one-third of the distance (L) from the pole to the centre of the playground.

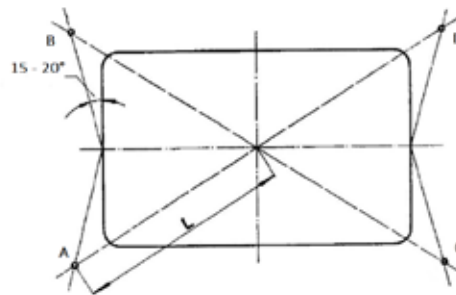


Figure 2 Principle of defining the pole positions [4]

The dimensions and characteristics of the poles proposed in this project are given in Figure 3.

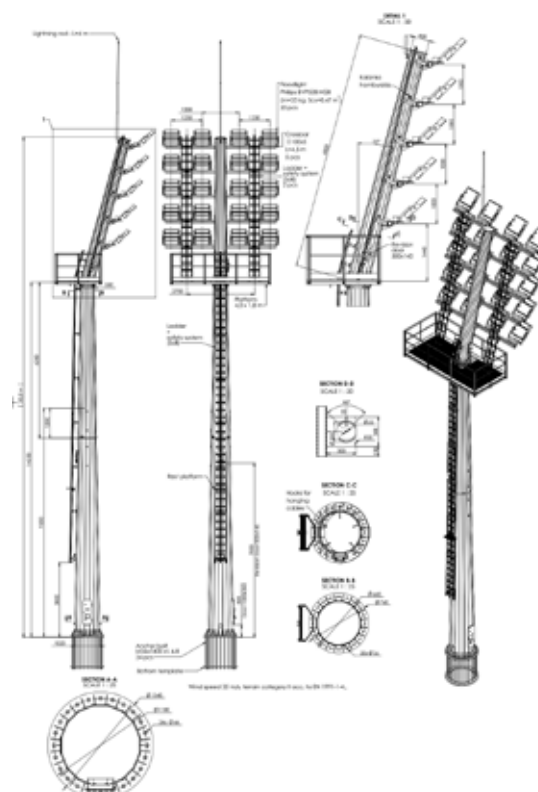


Figure 3 Proposed floodlight pole

Reinforced concrete poles provided for the installation of lighting fixtures are 20 metres high, with built-in ladders leading to the platform at a height of about 15 metres, with additional ladders that allow access to the LED floodlights, in this way enabling the installation and service of the floodlights. The ladder has a built-in rest platform, as well as a safety system to prevent falls. The floodlights are to be mounted on a console tilted 15° in relation to the pole column, in the form of 5 groups of 4 floodlights, mounted at different mounting heights, defined by

the project and indicated in the pole specifications. The poles are designed to be installed on previously made foundations with installed mounting screws.

2.2. The floodlights

The main technical data for the floodlights proposed in this project are given in Table 1.

Table 1 Floodlight technical data [5]

Maximum system power	1500 W
Effective luminous flux	195850 lm
Lamp efficiency	130 lm/W
Light colour temperature	4000 K
Colour rendering index	Ra \geq 70
Ingress Protection rating	IP66
IK rating	IK08
Temperature operating area	-40 °C to +50 °C
Dimensions	737x695x128 mm
Mass	35.5 kg
Maximum wind impact area	Scx 0.512 m ²

As shown in Table 1, the proposed floodlight provides a high efficiency of 130 lm/W. The luminous flux is nearly 200000 lumens and other parameters listed in the table meet the requirements for outdoor football field lighting. The housing and support of the floodlight are made of cast aluminium, and the optical cover is made of UV-stable polycarbonate. The lamp has integrated voltage protection of 10 kV and Class I electrical protection. The drawing current is limited to a maximum of 20 A with a duration of 0.160 ms. The lamp is ENEC certified and supports the DALI communication interface. The DALI system regulates the lighting so that each lamp is assigned a separate IP address, thus enabling individual control of the lamps. This makes it possible to turn on, turn off and adjust each lamp separately, so the control over the lighting system is greater and more flexible. A picture of the proposed floodlight is provided in Figure 4.



Figure 4 Proposed floodlight [5]

Figures 5, 6, and 7 show an overview of the lighting data and optics provided in Dialux for the three floodlight variants used in the project, with the noted number of pieces for television broadcast lighting for each type used.

60 Pieces

PHILIPS BVP528 S4 1xLED2220/740 OUT T25 50K LHP1710Q
Article No.:
Luminous flux (Luminaire): 195888 lm
Luminous flux (Lamps): 222600 lm
Luminaire Wattage: 1500.0 W
Luminaire classification according to CIE: 100
CIE flux code: 93 97 100 100 88
Fitting: 1 x LED2220/740 OUT T25 50K (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.

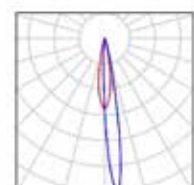


Figure 5 Proposed floodlight - Type 1

16 Pieces PHILIPS BVP528 S6 1xLED2220/740 OUT T25 50K LHP1710Q
Article No.:
Luminous flux (Luminaire): 195888 lm
Luminous flux (Lamps): 222600 lm
Luminaire Wattage: 1500.0 W
Luminaire classification according to CIE: 100
CIE flux code: 92 97 100 100 88
Fitting: 1 x LED2220/740 OUT T25 50K (Correction Factor 1.000).

See our luminaire catalog for an
image of the luminaire.

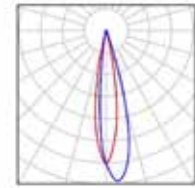


Figure 6 Proposed floodlight - Type 2

4 Pieces PHILIPS BVP528 S8 1xLED2220/740 OUT T25 50K LHP1710W
Article No.:
Luminous flux (Luminaire): 195888 lm
Luminous flux (Lamps): 222600 lm
Luminaire Wattage: 1500.0 W
Luminaire classification according to CIE: 100
CIE flux code: 88 96 99 100 88
Fitting: 1 x LED2220/740 OUT T25 50K (Correction Factor 1.000).

See our luminaire catalog for an
image of the luminaire.

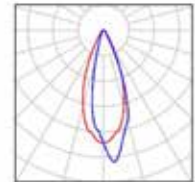


Figure 7 Proposed floodlight - Type 3

It can be noted that all of the floodlights have the same rated power and luminous flux. The photometric characteristics, which show the luminous intensity values and distribution are slightly different, each type was chosen for a specific mounting position and tilt angle.

2.3. The investment costs

The investment costs proposed by the project are given in Table 2

Table 2 Proposed investment costs

	Description of the item	Pieces	Price per piece €	Total price €
1	Delivery and installation of LED floodlights (minimum 1500W, 130 lm/W, 195850 lm, CRI \geq 70, 100000 hours lifespan, DALI ballast, -40°C to +50°C operation, IP66/IK08 protection, Class I electrical protection, 10 kV surge protection, max dimensions 737x695x128 mm)	80	4000.00	320000.00
2	Delivery and installation of light pole with ladder (20 m column height to platform, +15° inclined head for 20 floodlights, certified Söll anti-fall system according to EN 353-1, hot-dip galvanized according to EN1461, wind zone calculation 35m/s, terrain category II)	4	70000.00	280000.00
TOTAL WITHOUT VAT:				600000.00
PDV 25%:				150000.00
TOTAL WITH VAT:				750000.00

It can be noted that total investment costs are set at 750000 euros.

3. Lighting designs

Two separate lighting regimes are proposed in this project, one for the training and one for the more significant events, like television broadcasts and competitions, where the lighting requirements are harder to meet.

3.1. Lighting design for television broadcasts and competitions

For a proposed lighting design of FC Junak football field for television broadcasts and competitions, the floor plan of the football field with the illuminance distribution is shown in Figure 8 and the positions and aiming points of the floodlights are shown in Figure 9.

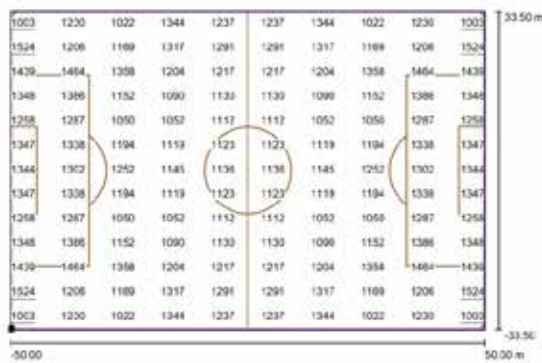


Figure 8 Design I – Floor plan

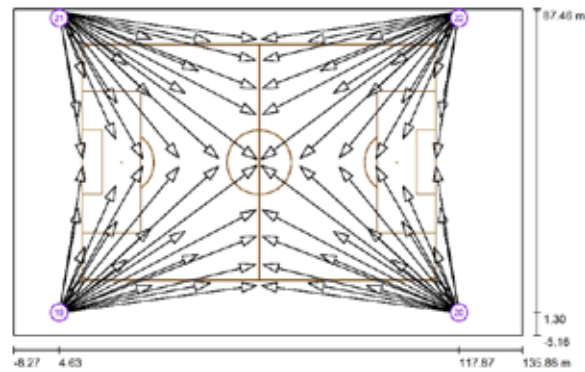


Figure 9 Design I - Floodlights

To achieve an average illumination of a 1000 lx minimum, all floodlights were used at all heights, groups of four floodlights at five different heights between 18 and 20 meters. With the floodlights with aiming points defined in this way, the average illuminance for competitions and TV broadcasts reached 1233 lx, with a uniformity of 0.81, which is shown in the Dialux simulation results overview in Figure 10.

Results overview

No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	$u0$	E_{min} / E_{max}	E_{hm} / E_m	H [m]	Camera
1	perpendicular	1233	1003	1524	0.81	0.66	/	0.000	/

E_{hm} / E_m = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

Figure 10 Lighting design for television broadcasts and competitions – results overview

Figure 11 presents a 3D night view of the designed lighting and the Figure 12 presents a 3D view of illuminance distribution, named *False colour rendering*.



Figure 11 3D view

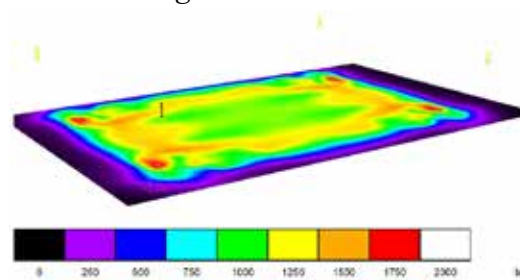


Figure 12 False colour rendering

3.2. Lighting design for training

For a proposed lighting design of FC Junak football field for training a goal was to achieve average illumination of at least 200 lx. Floor plan of the football field is shown in Figure 13. Only six floodlights were used on each pole, with aiming points defined as shown in Figure 14.

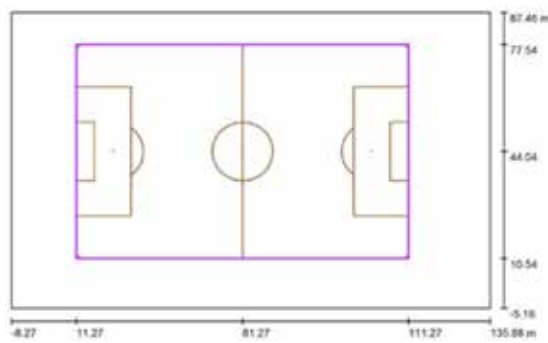


Figure 13 Design II – Floor plan

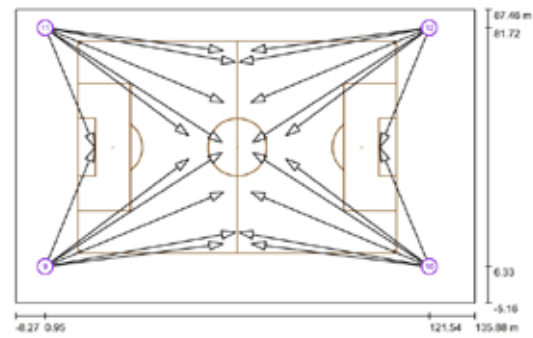


Figure 14 Design II - Floodlights

The 24 floodlights used in a simulation provided illuminance calculation results as shown in a Dialux simulation results overview in Figure 15.

Results overview

No.	Type	E_{av} [lx]	E_{min} [lx]	E_{max} [lx]	$u0$	E_{min} / E_{max}	$E_{h,m} / E_m$	H [m]	Camera
1	perpendicular	281	202	406	0.72	0.50	/	0.000	/

$E_{h,m} / E_m$ = Relationship between middle horizontal and vertical illuminance, H = Measuring Height

Figure 15 Lighting design for training – results overview

It can be noted that with the floodlights with aiming points defined in this way, the average illuminance for training reached 281 lx, with a uniformity of 0.72.

3.3. Energy consumption estimation

The installed power for the planned 80 floodlights with an individual power of 1500 W, as well as the power for competition lighting and TV broadcasts, amounts to:

$$80 \cdot 1500 = 120000 \text{ [W]} = 120 \text{ [kW]} \quad (1)$$

With such a working regime planned 10 times a year for 6 hours, the total annual consumption of electricity for lighting for competitions and TV broadcasts amounts to:

$$120 \text{ [kW]} \cdot 60 \text{ [h]} = 7200 \text{ [kWh]} \quad (2)$$

Considering the price of the HEP Lux tariff model, the model for public lighting, the annual electricity costs for lighting for competitions are:

$$7200 \text{ [kWh]} \cdot 0.4235 \left[\frac{\text{€}}{\text{kWh}} \right] = 3049.2 \text{ [€]} \quad (3)$$

The total power used during training, when 24 floodlights are used, amounts to:

$$24 \cdot 1500 \text{ [W]} = 36000 \text{ [W]} = 36 \text{ [kW]} \quad (4)$$

With a working regime scheduled for 2 times a day for 2 hours, of which once in the evening, 6 days a week, the total annual consumption of electricity for lighting training amounts to:

$$36 \text{ [kW]} \cdot 12 \text{ [h]} \cdot 52 = 22\,464 \text{ [kWh]} \quad (5)$$

Therefore, the annual electricity costs for training lighting are:

$$22464 \text{ [kWh]} \cdot 0.4235 \left[\frac{\text{€}}{\text{kWh}} \right] = 9513.5 \text{ [€]} \quad (6)$$

The total annual electricity costs are the sum of the annual costs for training and competitions and they amount to:

$$3049.2 \text{ [€]} + 9513.5 \text{ [€]} = 12562.7 \text{ [€]} \quad (7)$$

4. Project implementation challenges

As the investment costs proposed by the project are high, the possibility of using cheaper floodlights, which would be ordered from China, was considered. Although there are floodlights on the market with similar characteristics and half the price, it is difficult to verify the authenticity of the specified data without an *ies* or *LDT* file of the product, which would be passed through the Dialux simulation.

Never the less, a simulation was made with one floodlight made in China, which had the *ies* file accessible online, with similar dimensions as the floodlight proposed by the project and of identical power of 1500 W. The simulation was made for a more demanding mode of operation of the lighting of the football field for television filming and competitions. The floodlights mounting positions and aiming points were taken as for the floodlights proposed in the project and are shown in Figure 16, while the illumination results presented as *False colour rendering* are given in Figure 17.

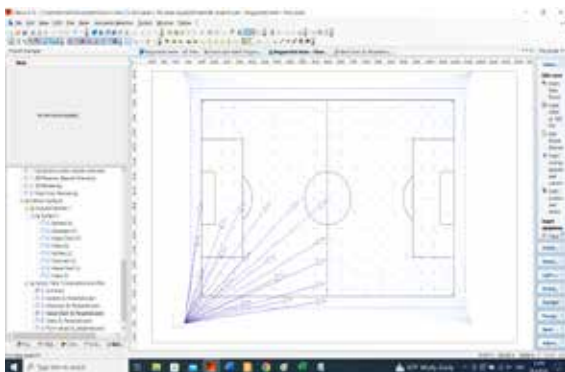


Figure 16 Floodlights aiming points

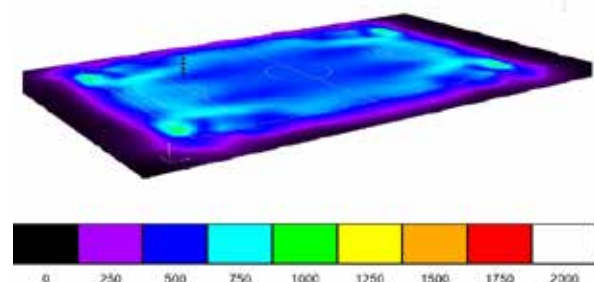


Figure 17 Results overview

It can be noted that the requirement for average illuminance of 1000 lx minimum wasn't met. It was around half the requested value, which is 500 lx, for the same floodlight nominal power. In conclusion, these floodlights wouldn't be recommended, because twice as many floodlights would have to be mounted on the poles to meet the lighting requirements. Although the price would be the same, it wouldn't be possible or safe to mount them on the poles proposed in the project.

The recommendation for Sinj city is to apply for a tender for co-financing the construction, renovation, maintenance, equipping and reconstruction of sports buildings by the Ministry of Tourism and Sports, which could sponsor the investment partly or in full. As part of the National sports programme 2019-2026, the Ministry of Tourism and Sports of the Republic of Croatia implements measures through a tender process for the construction and renovation of sports infrastructure. This initiative promotes sports values, encourages citizen participation in sports, strengthens the national sports system, and enhances Croatia's international sporting image. The programme has already co-financed the construction or renovation of nearly 200 sports facilities exceeding 12 million euros in value. These facilities encompass a wide range, including sports halls, basketball and football fields, tennis courts, athletic tracks, and more. [6] The deadline to express interest in co-financing sports infrastructure projects for 2024 closed on December 8, 2023. However, applications for co-financing in 2025 remain open. [7]

This initiative by the Ministry of Tourism and Sports aims to support the development of sports facilities and address public needs for sporting activities. This is achieved by encouraging local and regional government units to undertake the construction of new facilities, renovation and planning of existing ones, and equipment acquisition for sports buildings.

Local and regional government units were invited to submit proposals requesting co-financing for various aspects of sports infrastructure improvement, including construction, renovation, reconstruction, and equipment acquisition. This programme ultimately contributes to improved public services and a higher quality of life for residents in these regions.

5. Conclusion

With its dual design, the project met the criteria for proper lighting of large football fields, i.e. the recommended minimum average illuminance of 200 lx for recreational use, and 1000 lx for television broadcasts and public performances in front of the audience, in both cases with very high uniformity of illuminance $U_{0,0}$, over 70% and 80%, respectively. The project itself provided a concrete, energy-efficient solution, as well as a modern one.

In conclusion, the proposed lighting project for FC Junak's football field presents a valuable opportunity to improve functionality, enhance attractiveness, and contribute to Sinj's community development through its alignment with sports infrastructure goals. However, the high initial cost of 750000 euros poses a significant challenge. To overcome it, seeking co-financing through tenders offered by the Ministry of Tourism and Sports and exploring alternative equipment options that meet quality and safety standards are recommended. Beyond seeking co-financing, the project could benefit from exploring private sponsorships. Engaging with potential sponsors from diverse fields, including not only sports but also music and culture, allows the project to connect with a wider segment of the Sinj community. This approach fosters a sense of shared ownership and broadens the project's impact.

By addressing the financial obstacle, this project has the potential to significantly benefit the sporting life of Sinj and its citizens.

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TACTICAL GAME IN UNITY3D ENVIRONMENT

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Abstract. This paper describes a development of a game using Unity3D game engine and artificial intelligence algorithms. It explores the A* and minimax algorithms and implements them in a cohesive project that integrates design, animation, and sound effects. The process of creating a strategic game is described using the Unity3D game engine and the C# programming language, which is integral to the Unity3D environment. Paper delves into the genre of tactical turn-based games, a subset of strategic games where players take turns in executing moves. It demonstrates how artificial players can plan and execute their strategies, alternating turns with human opponents. Implementation of AI-controlled players, utilizing the discussed algorithms, provides a challenging experience for human players. AI decisions are based on mathematical calculations, striving for optimal solutions given the dynamic game conditions. In conclusion, the paper highlights the feasibility of developing an engaging and challenging game system within resource constraints, showcasing the practical application of artificial intelligence in strategic gaming contexts.

Key words: *Artificial Intelligence, A*, Minimax, Strategic Game, Unity3D*

1. Introduction

This paper provides a detailed overview of strategic game development within the Unity3D engine, focusing on the implementation and application of essential algorithms crucial for game mechanics. Initially, the discussion centers on the theoretical aspects and functionalities of the A* and minimax algorithms, emphasizing their importance and usefulness in strategic game design. Subsequent sections delve into the Unity engine itself, detailing its capabilities, tools, and how it supports the creation of complex game environments.

The final section is dedicated to the practical implementation of these concepts into a fully functional strategy game, demonstrating the integration of the discussed algorithms within the game's architecture. It covers the setup of game mechanics, grid system, user interface, and inventory management, explaining how core gameplay functions are structured and interact within the game environment.

Finally, the conclusion discusses potential AI improvements as well as future possibilities for expanding the game's features and enhancing the overall gameplay.

2. Theoretical Background

This section reviews the implementation of two essential algorithms, A* and minimax [1], in the context of strategy video games. These algorithms are crucial in shaping gameplay mechanics, facilitating efficient pathfinding, and enabling strategic decision-making for in-game entities. The emphasis will be on their application within Unity3D strategy game development, illustrating their roles and effectiveness in creating engaging, interesting, and challenging gaming experiences.

2.1. A* Algorithm

In Unity, there are multiple methods to move an object from point A to point B. One approach is to directly assign a new position, effectively teleporting the object, or to incrementally adjust its current position to create a gradual movement effect. Another common technique is to integrate animations, which offer smooth transitions between positions. Unlike static or abrupt shifts, animations provide fluid movement sequences.

However, the implementation of animations alone may overlook key considerations in unit movement, particularly in strategy games. Selecting a unit and specifying its destination point is a fundamental mechanic, yet it presents challenges when it comes to navigating obstacles and determining the most efficient path [2].

To address these challenges, a more comprehensive approach to unit movement is adopted. It involves pre-planning the path by detecting obstacles and calculating the shortest route to the destination. Pathfinding is implemented by representing the terrain as a grid, facilitating the use of tree-based search algorithms like breadth-first search, Dijkstra's algorithm, and A*. Each algorithm offers unique features and uses, as outlined in the Table 1 below.

Table 1 Search algorithms [3]

Algorithm	Description
Breadth First Search	Searches in all directions, also used for procedural map generation, etc.
Dijkstra	Published by Edsger W. Dijkstra. Finds the shortest path between two nodes, often used to find the shortest path from the source to all nodes in the graph.
A*	Modification of Dijkstra's algorithm, optimized for computing the fastest path to a single location. Prioritizes the path that promises the shortest route to the destination.

The A* algorithm determines the path by assessing the distance from the starting point (G cost) and the anticipated distance to the goal (H cost). The combined value of these factors yields the F cost.

During execution, the algorithm explores neighbouring nodes, selecting the one with the lowest F cost and marking it as part of the closed set. This process is repeated iteratively until the goal is reached. When no obstacles are present, the algorithm straightforwardly calculates a direct line to the goal. However, its true value lies in its ability to compute the shortest path while manoeuvring around obstacles.

When multiple nodes share the same F cost, preference is given to the one with the lowest H cost. Additionally, if any previously visited node offers a shorter route to a neighbour, the algorithm revisits that node to reassess its path. Thus, in each iteration, the algorithm prioritizes nodes with the lowest F cost, potentially uncovering more efficient paths during exploration [4].

The most time-consuming A* algorithm aspect involves locating the node with the lowest F cost, as it requires searching the entire open set. To optimize the algorithm, a heap data structure is integrated. In this approach, a binary tree functions as the heap, where each node can have up to two children. Nodes store F cost values, and when a new value is added, it must be appropriately positioned within the tree. This involves comparing the node value with its parent; if it's smaller, they swap positions until the correct placement is achieved. Removal of the node with the lowest F cost begins by deleting the first node which always contains the smallest value due to the tree's arrangement. Subsequently, the last node takes its position. The new node undergoes comparison with its children, swapping places with the one possessing a lower value, and this process continues until the tree is ordered correctly.

Incorporating weight values facilitates differential movement costs across different terrain types. For example, traversing a road incurs less cost compared to navigating through mud or similar terrain. Subsequently, determining the value assigned to each node in the grid and assigning the corresponding weight follows suit. Within the A* algorithm, this weight integrates into the F cost. Consequently, the resulting path prioritizes minimizing weight, which may not always align with the shortest route. While the project explores only a subset of possibilities, pathfinding can be further extended with various options, such as path smoothing, which rounds off sharp turns for a more natural route, and multithreading implementation, among other improvements.

2.2. Minimax Algorithm

Developing AI is pivotal in game design, tasked with solving problems within confined time and space. Game development often tackles this by predefining behaviours to simulate intelligent actions.

It revolves around tailoring AI actions based on a variety of factors, including proximity to the target, the current state of the entity, and whether the conditions to initiate the combat are met. While this approach proves efficient in action-oriented games, its effectiveness may diminish in strategic genres. The inherent challenge lies in the susceptibility to exploitative tactics, leading to compromised performance and suboptimal outcomes in strategic gameplay scenarios.

In strategy games, the implementation of an intelligent algorithm requires consideration of numerous parameters to improve decision-making processes. These parameters cover various strategic actions, including but not limited to:

- Target Selection: The algorithm evaluates factors such as the proximity and strength of nearby units, opting to prioritize attacks on the closest or weakest adversaries. This strategic choice not only maximizes offensive potential but also minimizes the risk posed by immediate threats. In turn-based strategy games, where each unit has a limited range, this tactic becomes crucial. Focusing on an opponent's unit that poses an immediate threat to friendly forces, rather than one that cannot reach them, minimizes potential damage to the team.
- Unit Elimination: Another crucial aspect that is connected to target selection involves assessing the battlefield to identify opportunities for eliminating enemy units. By strategically finishing off opponents, the algorithm aims to reduce the overall strength of the opposing force, thereby tilting the odds of victory in its favour.
- Strategic Coordination: Collaboration among allied units is essential for success on the battlefield. The algorithm may strategize to team up against a common enemy,

leveraging combined strength to overcome formidable adversaries or gain tactical advantages.

- Tactical Retreat: Recognizing unfavourable combat scenarios, the algorithm may opt for a tactical retreat from engagements where the odds are stacked against it. By prioritizing self-preservation, the algorithm ensures the longevity of its forces, ready to fight another day.
- Engagement Planning: In preparation for combat, the algorithm evaluates the positioning of enemy units and devises a plan of action. This may involve manoeuvring towards vulnerable enemy units or strengthening defensive positions to effectively repel enemy advances.

This project utilizes the minimax algorithm to guide AI decision-making processes. Minimax is a recursive algorithm that evaluates sequences of actions by alternating between max and min players. Here, max seeks to maximize outcomes, while min aims to minimize them. Graphically, minimax can be depicted as exploring a tree of possible moves, with the root node representing the current state and subsequent depths revealing potential moves [5].

Upon completion of the algorithm, the best move is selected and stored, ready for execution by the AI. However, the effectiveness of minimax depends on a critical parameter: depth. This parameter dictates the extent to which the tree of moves is explored. While deeper exploration yields more optimal results, it also demands a significant investment of time to execute the algorithm fully. Consequently, this trade-off between depth and execution time underscores the need for striking a balance to avoid prolonged AI turns that may compromise the player experience.

The evaluation depends on the game type and the players' objectives. In this game type, the evaluation resembles chess, considering factors like damage potential, health points, defence value, etc. These parameters collectively represent the state of each side, with their differences providing a numerical evaluation of the current state. This approach, while deterministic, can be susceptible to exploitation if the underlying mechanics become too predictable. To mitigate this, a random value can be incorporated into the evaluation results to introduce variability that hinders straightforward prediction of moves and injects an element of unpredictability into AI decisions. To drive units closer, the goal is to reduce the distance between them, a factor considered in the result. Evaluate method, determines the current state's worth in the context of the game. When the max player emerges victorious, the evaluation method assigns a high positive value. Conversely, if the min player wins, it assigns a high negative value.

The Minimax algorithm typically applies a pair of operations for each allowable move: one to execute the move and another to revert it afterward. This involves executing a move, invoking Minimax, and then undoing the move. The move method executes the unit move, handling scenarios such as moving to an unoccupied node or attacking an enemy unit, deducting hit points based on the attack value. Finally, the unit is placed at the end of the queue, and the next unit in line proceeds to play.

The basic implementation examines all possible moves, thus generating many nodes. This is primarily determined by factors such as the unit's range or the number of steps it can take. A modified version of this algorithm is known as alpha-beta pruning [6]. While eliminating this improvement won't solve exponential growth, total number of explored nodes can be significantly reduced by pruning them. Pruning allows for computing the best move without having to explore the entire tree. This process relies on values called alpha and beta. Alpha-beta pruning can be applied at any depth, and in some cases, entire subtrees can be cut off, not just individual leaves. Alpha represents the current best result or the highest value, initially set as

the small number or negative infinity that will never be the result of evaluation. Conversely, beta represents the current best result or the lowest value, initially set as positive infinity. A properly implemented alpha-beta pruning approach will yield the best move like the basic implementation but will avoid exploring nodes that don't influence the decision. The main condition for pruning is beta being less than or equal to alpha. The Max player updates alpha values, while the Min player updates beta values. Throughout recursion, node values propagate to the parent, and alpha and beta values propagate to the children. The effectiveness of alpha-beta pruning relies heavily on the order in which nodes are explored. In the worst-case scenario, none of the leaf nodes are pruned, resulting in a speed equivalent to basic minimax. Conversely, in the best-case scenario, the most promising moves is explored early in the tree search causing early beta cut, i.e. pruning remaining moves in some node.

Achieving an ideal node ordering involves implementing a method that accurately evaluates moves, prioritizing exploration of the most promising moves at lower depths. Sorting moves to prioritize attacks, followed by threats, forward moves, and retreats, can optimize the search process. Quality move evaluation is essential to explore greater depths effectively and extract the most from alpha-beta pruning.

One challenge in minimax implementation is the horizon effect [7]. This occurs when all moves are explored to maximum depth, but threats and opportunities beyond that depth remain undetected. It can lead to delayed or misguided moves until the horizon effect is resolved. This may result in unexpected AI behaviours, such as fleeing when it could attack and improve its position. The solution lies in implementing quiescence search, which evaluates peaceful moves. After reaching maximum depth, if the position is unstable, moves are searched until stability allows evaluation.

3. Unity3D Environment

Unity [8] is a versatile cross-platform tool that enables developers to build and deploy their final product across different operating systems. It equips game developers with all the necessary tools for faster and more efficient game development. Developers can create a wide range of games, including:

- Action-adventure games,
- Platformers,
- RPGs (Role-Playing Games),
- FPS (First-Person Shooters),
- Strategy Games,
- Simulation Games

It also offers support for a wide range of non-gaming related project types, such as:

- Various game genres such as action-adventure, platformers, RPGs, and simulations.
- Interactive experiences like virtual and augmented reality applications, training simulations, and architectural visualizations.
- Character animations, visual effects, and scenes for animated content and short films.
- Simulations and training modules, covering areas such as military training, medical simulations, and safety training.
- Interactive art installations and exhibits, fostering immersive experiences and interactive sculptures.

As a game engine, Unity facilitates the creation of both 2D and 3D games, allowing for seamless import of various materials such as models, sounds, special effects, animations, and more. Additionally, it provides ready-made tools for processing and utilizing these assets.

The Unity development environment offers tools for scene design, animation integration, sound integration, and graphical user interface creation. Unity provides users with everything necessary for game development, including graphical representation of the game, advanced functionalities related to lighting integration, terrain creation, user control implementation, camera manipulation, dynamic object instantiation, physics, and more. All these features allow game designers to spend less time implementing essential components and more time realizing the ideas behind the game they want to create. Unity supports programming in C# and comes with predefined standard scripts that enable users to quickly start working and create their first games with minimal coding. Ready-made projects available on the Unity website are immensely helpful for users to familiarize themselves with the workflow and key aspects of game development.

The Unity Editor offers a customizable workspace, allowing users to arrange and configure primary working windows to their preferences which includes:

- Project Window displays the complete library of project assets in a hierarchical list for organized file management.
- Scene View enables object manipulation, rotation, and navigation within the scene. It provides both 3D and 2D perspectives, orthogonal, front, and topographic.
- Game Window displays the final product for testing implemented functionalities.
- Hierarchy Window presents a hierarchical textual representation of all objects in the scene, showing how they are interrelated. It lists all objects within the current scene, distinguishing between normal objects and prefabs.
- Inspector Window allows for the display and modification of properties of the currently selected object, including position, size, and addition of various components such as physics properties, graphical representation, materials, and scripts. It provides detailed information about the selected object, including all components attached to it.

In Unity, developers have access to robust physics systems [8] that allow them to dictate object behaviours, simulate forces such as gravity and friction, and ensure realistic collision detection and responses.

The Rigidbody component is essential for applying physics to game objects. Once attached, an object automatically responds to gravity. Adding colliders to these objects enables collision detection and response, facilitating interactions within the game environment. These colliders are categorized into static colliders for immovable objects like floors and walls, and dynamic colliders for movable objects.

For more in-game objects, primitive colliders like cubes, spheres, and capsules are typically sufficient for general purposes. However, more complex Mesh colliders, which are tailored to the shape of the object, should be employed carefully to optimize performance.

Beyond facilitating physics interactions, colliders serve an additional function in triggering in-game events. With the Trigger property enabled on a collider, various activities can be activated, such as displaying text, triggering short films, facilitating scene transitions, and more, enriching the gameplay and interactive elements of the game.

Unity's animation system is a sophisticated tool enabling the creation, editing, state management, transition between animations, and the linkage of multiple states into unified behaviours. Animations can be controlled through events or variables activated via scripts.

They are categorized into generic and humanoid animations. Unity identifies humanoid models through avatars, allowing for the reuse of existing logic due to bone structure similarities. When creating new animations, attention is paid to key elements such as the model, timing of change occurrence, change type (e.g., position or rotation), change duration, and final position. Animator controllers manage states, transitions, and the blending of different animations.

Unity's navigation system [8] enables the creation of traversable areas within scenes based on their geometry. This system enables the addition of characters that can navigate within the scene according to specific rules, including obstacle avoidance, stopping at edges, jumping, and more.

The navigation system consists of the following components:

- NavMesh: A data structure describing areas where navigation is permitted and facilitating pathfinding from one area to another. This data is automatically generated based on the level's geometry.
- NavMesh Agent: A component aiding in the creation of characters that can avoid each other while moving toward a goal and dodge any other obstacles.
- Off-Mesh Link: A component allowing the use of shortcuts during navigation, such as jumping over fences or opening doors, which may not be represented as traversable surfaces.
- NavMesh Obstacle: A component used to describe obstacles that characters should avoid while navigating through the world. It allows characters to move around the obstacle or find an alternative path if it's a static object.

User interface (UI) in game development is essential for providing players with intuitive menus, informative displays, and interactive elements during gameplay. The primary component of UI design in Unity is the Canvas. It serves as the container for all UI elements within a scene, acting as the parent component for other UI elements in the hierarchy. The Canvas is typically set up as a 2D display within the scene, represented as a rectangle. There are three ways to load a Canvas:

- Overlay adjusts the Canvas size based on resolution changes.
- Camera loads the Canvas relative to a specific camera's settings and distance.
- World Space treats the Canvas like any other object in the scene, allowing manual resizing and loading based on its position relative to other objects.

Element positioning is defined using Anchors, which determine where an element is anchored on the screen, ensuring it remains in the expected position regardless of screen size or resolution changes. These elements can be accessed and manipulated both through the Unity editor and via scripts.

4. Practical Implementation

This section delves into the game, covering fundamental functionalities implemented in the project. It provides an explanation of how these functionalities interact to create a cohesive gameplay experience, highlighting the game's mechanics and user interface. The emphasis has been on implementing clean scripts with minimal unnecessary dependencies, prioritizing the reusability of functionalities wherever feasible. The implementation of the algorithms and game features is available in a Git repository [9].

The grid management system facilitates movement within the game environment, orchestrates levels constructed atop Unity terrains with an underlying grid system. This grid,

marked by its starting and ending points and filled with individual nodes, controls where players can move. Setting up the grid requires placing markers within the scene to outline its boundaries. Creating nodes within this grid involves several steps: verifying the coordinates to ensure they fall within the grid, instantiating node objects at these coordinates, assessing each node's walkability for any obstructions, and finally, establishing connections to neighbouring nodes to facilitate movement across the grid.

All player interactions, including unit movement and other actions, are coordinated through an abstract class called the Interaction Handler. Each specific interaction extends this base class, customizing methods to manage the initiation and conclusion of interactions, along with handling details before and after the interaction occurs. The Interaction Trigger component, associated with interactable objects, holds crucial details such as the type of interaction, related items, and their quantities. This setup ensures that interactions are executed smoothly and effectively within the game environment.

The graphical interface manager controls the game's user interface, overseeing the main menu functions and creating UI objects that display available heroes or units. It serves as a central hub for essential player information, such as available steps, details of interactions, the current hero, and the sequence of unit turns. This setup ensures that players can easily monitor and respond to game events.

Most graphical elements are instantiated from templates, allowing for flexible management regardless of the number of heroes. It's essential to consider screen size variations, and the Canvas feature scales accordingly, maintaining proper positioning regardless of resolution.

The Inventory system incorporates all the expected functionalities, such as item rearrangement, grouping, splitting, adding new items, and utilizing them. These features are enabled by reading the cursor position and user input. When the user hovers over an inventory element, specific events are triggered. These events allow for reading the cursor position, checking if it's above an inventory element, and determining which mouse button the user pressed.

The game operates in two distinct states: exploration and combat, each managed by dedicated scripts that handle state-specific functionalities. These scripts are responsible for overseeing player interactions, controlling the camera, detecting user inputs, and managing the available actions. Player control is primarily managed through mouse inputs, which include tracking the cursor's location, detecting clicks, and manipulating the camera view. The camera control script includes all necessary functionalities for strategic gameplay, such as zooming, rotation, and navigating the terrain. The game employs Unity's Cinemachine [8] components for camera functionality, offering pre-built functionalities such as smooth transitions between camera views, object tracking, and focus adjustments.

The combat management system orchestrates battle progression in three phases. Initially, units, including heroes and those related to specific interactions, are set up. The tactical phase follows, granting players 30 seconds to strategically relocate units within a designated area. This phase leverages camera methods to manage unit positions in 3D space. The final phase involves activating an array of units sorted by their initiative and enabling the necessary graphical interface elements for battle visualization.

Interactions with enemy units function similarly to interactions with objects within the game world. When a player detects an enemy unit within range and clicks on it, the game initiates combat, activating the corresponding combat sequence. The system manages the flow of combat by assessing damage inflicted upon units and monitoring their remaining health. Critical combat functions include evaluating damage received by units and checking for unit fatalities. If a unit's health falls below zero, it is removed from play. Combat continues until one

side depletes all its units, indicated by the total remaining hit points.

Efficient navigation in the game is facilitated by the A* algorithm, which calculates optimal paths for interactions. To visually represent these paths and improve gameplay clarity, LineRenderers [8] are used to illustrate the routes that players and objects can follow. In the exploration phase, the path is color-coded: the section within the hero's movement range appears in green, while the remainder is shown in red.

During combat scenarios, the game introduces a visual representation of available nodes, marked to show the steps each unit can reach. This feature not only displays possible moves for the player but also highlights the movement capabilities of enemy units, aiding in strategic planning. Additionally, diagonal movement is restricted in favour of orthogonal movements, which allow for a greater number of steps due to their layout.

Node accessibility depends on the height of the node relative to what the unit can reach. The algorithm also detects obstacles by scanning for colliders within a specified radius. Nodes that contain colliders surpassing a certain height are automatically excluded from the pathfinding process, ensuring the routes generated are viable for navigation.

The components and features discussed are visually presented in Figure 1.



Figure 1 In-game screenshots depicting combat, exploration, and inventory management.

5. Conclusion

In conclusion, this project has introduced and implemented the A* and minimax algorithms, showcasing their practical application in a strategic game developed using the Unity3D engine. Through thoughtful consideration of the necessity and prerequisites for their application, the implementation of these algorithms has progressed from basic to optimized, ensuring seamless integration into the game.

In most scenarios, algorithms execution time is approximately ~3 seconds, which is quick enough to avoid negatively impacting the player experience. Nevertheless, as more players participate in the game, execution time increases due to a higher number of available moves, minimax depth, size and complexity of the terrain and various other factors that amplify computation time. This scaling issue highlights the importance of optimizing the algorithm to handle increased loads efficiently, ensuring that the game remains responsive and enjoyable for all players. The use of minimax has facilitated the creation of intelligent AI adversaries, enhanced gameplay complexity and providing players with challenging opponents. Utilization of alpha-beta pruning reduces node count by ~50% in most cases, and up to 90% if the search

tree has significant depth. Additionally, the A* algorithm has been instrumental in enabling efficient pathfinding for heroes and units within the game world, contributing to a smooth and immersive gaming experience. The incorporation of heap optimization within the A* algorithm significantly enhances its efficiency by quickly selecting the most promising nodes for expansion, which is crucial for maintaining fast and effective pathfinding as the game scales.

Throughout the project, adherence to best practices in Unity game development has been maintained, resulting in a polished and optimized final product. The game encompasses various expected gameplay mechanics, intuitive controls, resource management systems, and constraints, providing players with a comprehensive and engaging experience. Furthermore, the addition of graphical interfaces, visual effects, and sound effects has enriched the overall gaming experience, enhancing immersion and enjoyment for players.

There are many opportunities for further expansion and enhancement of the project. Future iterations could explore improvements to AI behaviour, such as advanced world exploration and decision-making capabilities for enemy heroes. Additional features, such as dynamic objectives like fortress construction, could introduce further layers of complexity to AI decision-making. However, it's important to note that certain Unity optimizations, such as the utilization of optimized models or algorithm computation in separate threads were not incorporated in this iteration but could be considered for future development efforts. Overall, this project serves as a solid foundation for the creation of sophisticated gaming experiences, with room for ongoing refinement and innovation.

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EXPLORING CHALLENGES AND DISCREPANCIES IN 3D SCANNING: A COMPARATIVE ANALYSIS OF DEVICE-DEPENDENT PRECISION ALIGNMENT AND MODEL FIDELITY

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Abstract: This paper explores the challenges and results associated with the 3D scanning of models using various devices, focusing on the precision alignment of scanned models through overlapping techniques. Emphasis is placed on the discrepancies between models scanned with Artec devices, cameras, and iPhones, highlighting the impact of device selection on model accuracy and fidelity. The process involves aligning models based on facial features (nose, eyes, chin) and refining the scans through manual adjustments and Boolean operations. The paper identifies key issues encountered during the scanning process, such as geometric inconsistencies, mesh deformation, and the variability of results with manual editing. Results demonstrate significant differences in polygon counts and detail levels across devices, revealing the limitations of current 3D scanning technology in achieving high-fidelity replicas. The findings contribute to a better understanding of the intricacies involved in 3D model scanning and the implications of using different devices and techniques for digital preservation and analysis.

Key words: 3D Scanning, Fidelity, 3D Alignment, 3D Discrepancies

1. Introduction

The field of 3D scanning has evolved into a cornerstone technology that bridges the gap between the physical and digital worlds, providing unrivaled precision in the digital replication of real-world objects. The benevolent utilization of scanner outputs finds profound implementation within the realm of medicine, facilitating the crafting of prostheses and dental implants, as well as informing the intricate design of cranial remodelling and various other orthotic interventions [1]. A plethora of three-dimensional (3D) facial scanners have surfaced in the market; nevertheless, publications appraising their precision remain scarce. This paper examines the intricacies of 3D scanning, specifically honing in on the challenges and discrepancies inherent in precision alignment and model fidelity. By analysing the stages involved in model processing, addressing the challenges of these stages, and evaluating the outcomes across various scanning devices, this research aims to explore the understanding of 3D scanning technology further.

2. Overview of the Literature

In the referenced study [2], the accuracy of two such scanners in facial scanning was examined carefully. A test subject was affixed to the right cheek and forehead of 41 participants, who were

subsequently scanned using Artec EVA and FaceScan3D devices. The gathered data underwent alignment with a 3D model of the test subject to compare mean error, original dimensions, and angles against measured values. Notably, scanning with Artec EVA yielded superior accuracy in generating 3D models compared to FaceScan3D. Furthermore, the precision achieved by both scanners was found to be commensurate with that reported for other scanners in the existing literature.

The feasibility of employing medical imaging techniques such as X-ray or computed tomography (CT) for scanning the human body was explored in the research [3]. While such methods offer potential benefits for orthotic manufacturing, they also expose patients to radiation. To mitigate this significant drawback, various non-ionizing 3D scanning technologies have emerged. This article outlines the utilisation of diverse scanner types capable of digitising the human body to create customised orthoses. Research indicates that photogrammetry stands out as the most widely used and suitable 3D scanning method for capturing human body dimensions in three dimensions.

In the arena of forensic analysis, optical scanning methods have been compared to gauge the depth of projectile indentations in ballistics tests [4]. It compares two optical scanning methods, analysing the same object. The evaluation hinges on reference planes identified via Random Sample Consensus methodology in each scan. Results reveal that stereo image-based 3D reconstruction provides closer estimates of reality compared to structured light scanning, primarily because of static image acquisition.

In another study [5], authors discuss the growing interest in three-dimensional body scanners across various fields. They highlight the necessity of comparing scanner outputs to a reference system, requiring alignment due to differing coordinate systems among scanning devices. The study simulates misalignment to assess its impact on measuring lower body circumferences and identifying translational and tilt errors. Results reveal strong correlations between translational error and circumference changes, as well as between tilt error and alterations in body outline. Through systematic analysis, recommendations are proposed, resulting in a significant reduction in error rates in subsequent human subject scans.

Expanding beyond the medical and forensic domains, the significance of three-dimensional scanning and 3D printing in cultural heritage preservation has been pointed out in the research [6]. Three-dimensional scanning captures detailed digital models of heritage sites and artefacts for research, restoration, and virtual display, while 3D printing enables the creation of physical replicas for education and exhibition. These technologies offer non-invasive documentation and preservation methods, along with opportunities for educational and exhibition purposes. Despite requiring specialised equipment and expertise, their value in cultural heritage preservation is evident and their usage is anticipated to expand further in the future.

In the study ensuring geometric compliance in offsite manufacturing (OSM) [7], the article proposes the usage of geometric digital twin (gDT) generated from 3D scanning to detect and address potential issues early on. It introduces a framework comparing three gDT approaches, each with its unique strengths and limitations. The vast range of applications, such as in the fields of manufacturing, forensics, medicine, and culture, shows how effective 3D scanning is in many different fields.

Advancements in capturing highly realistic 3D facial performances have been achieved through the integration of motion capture and advanced 3D scanning technologies [8]. Initially, 3D facial performances of an actor were recorded using a marker-based motion capture system, followed by facial analysis to determine the necessary minimal set of face scans for accurate reconstruction. A two-step registration process was then employed to establish consistent

surface correspondences across all face scans. Finally, high-fidelity 3D facial performances were reconstructed by blending motion capture data with the minimal set of face scans. Evaluation of real and synthetic data demonstrated that the system achieved facial performances matching the spatial resolution of static face scans while maintaining the acquisition speed of motion capture systems [8].

From the diverse array of applications encompassing medical prosthetics, forensic analysis, cultural heritage preservation, and offsite manufacturing, it becomes evident that 3D scanning serves as a versatile tool across various domains.

3. Preliminary Considerations for Model Alignment

In the quest to enhance the precision and application of 3D scanning technologies, a structured investigation into the technical and procedural methods is presented. It emphasises the critical importance of model alignment as a foundational step in achieving high-fidelity digital replicas, as demonstrated in the juxtaposition of scanned models for alignment purposes, as shown in Figure 1. Furthermore, the subsequent analysis of alignment accuracy and the detailed exploration of issues encountered during the scanning process underscores the complex nature of creating accurate digital representations. The challenges associated with model adjustment, including dealing with polygonal mesh deformations, and ensuring the precision of cut lines, are depicted in Figure 2, highlighting the complex work required to refine and perfect digital models. Through this detailed examination, the paper contributes valuable insights to the ongoing discourse on enhancing 3D scanning techniques, aiming to pave the way for future advancements.



Figure 1 Comparison of original camera photo with an aligned 3D scanned model to illustrate matching accuracy



Figure 2: Overlay of Artec 3D model and digital camera image highlighting precision in model matching

4. The Process of Aligning Scanned Models

The alignment of 3D scanned models is a critical yet intricate step in the 3D scanning process, serving as the foundation for accurate model reconstruction and analysis. This chapter explores the detailed procedure of aligning scanned models, highlighting the technical expertise and precision required to achieve optimal results. The discussion is structured around the

sequential steps involved in model alignment, the challenges encountered, and the strategies employed to mitigate these issues.

The initial phase of model alignment involves a precise overlay of scanned models to ensure their accurate overlap. This step is important for the subsequent processing and analysis, as inaccuracies at this stage can significantly affect the fidelity of the final model. The primary reference for alignment is typically derived from high-precision scans, such as those from Artec scanners, which offer detailed surface geometry and texture information. The alignment process, as illustrated in Figure 3, requires the careful manipulation of the models to align key features such as the edges of the nose, eyes, and chin. This precision alignment is crucial for the successful integration of multiple scans into a realistic model.

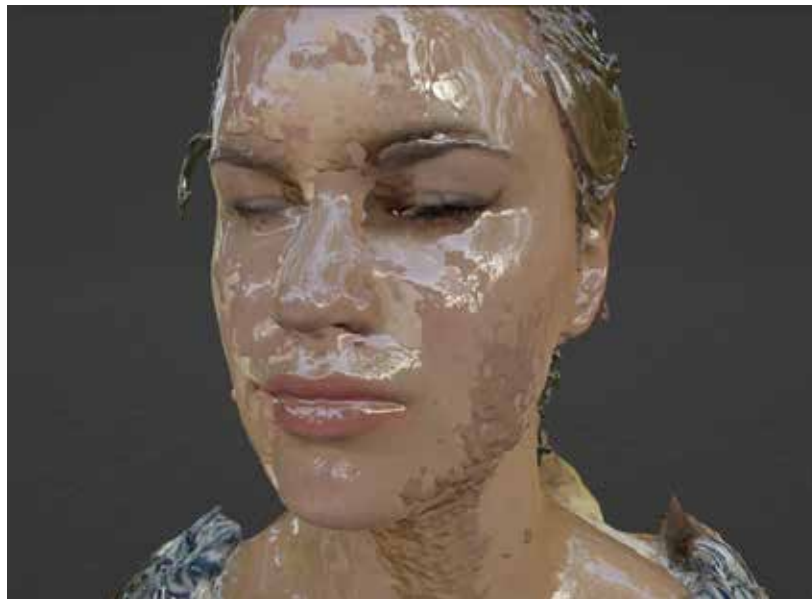


Figure 3 Detailed view of model alignment showcasing precise feature matching (nose, eyes, chin)

Following the initial alignment, further refinement is achieved through the application of advanced software tools (e.g. *Meshroom* or *Blender*) that enable precise manipulation of the mesh. This implies careful adjustment of vertices and polygons to ensure seamless integration of different model sections. The complexity of this task cannot be understated, as it requires a deep understanding of mesh topology and the spatial relationships within the model. Figure 4 and Figure 5 provide a visual representation of this process, showcasing the meticulous detail involved in model refinement.

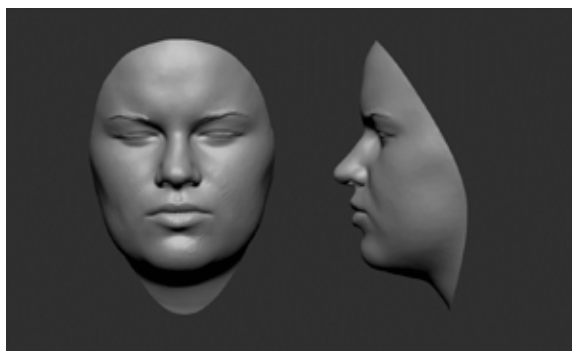


Figure 4: Section of an ARTEC model demonstrating detailed cut lines for model refinement

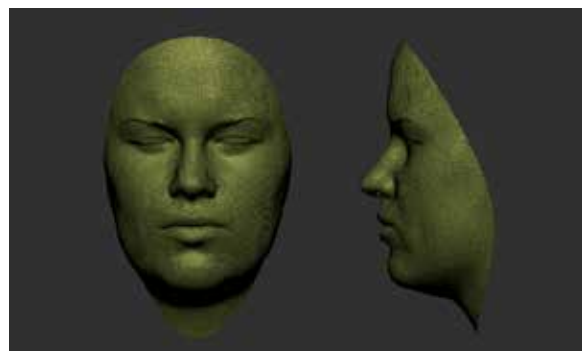


Figure 5: Wireframe view of Artec model, emphasising mesh complexity and alignment accuracy

The difficulties that arise during the alignment process are frequently caused by differences in model resolution, disparities in scan quality, and the intrinsic constraints of scanning technology. These issues can manifest as misalignments, gaps, or overlaps in the combined model, necessitating iterative adjustments and corrections. To address these challenges, practitioners use a variety of techniques, from manual adjustments to sophisticated algorithms, designed to automate and refine the alignment process. The effectiveness of these solutions is demonstrated in Figure 6 and Figure 7, where advanced techniques are applied to resolve alignment issues and enhance model integrity.



Figure 6 Model preparation phase highlighting areas designated for precise cutting

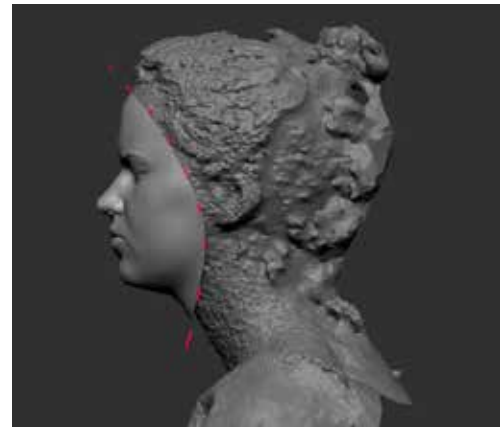


Figure 7 Visual representation of the cutting line application on a model for accuracy in segmentation

In conclusion, the alignment of 3D scanned models is a complex yet crucial step in the digital replication process. It requires not only technical skill and precision but also a comprehensive understanding of the properties and limitations of 3D scanning technologies. Through the careful application of alignment strategies and the resolution of challenges, it is possible to achieve high levels of accuracy and fidelity in digital models, paving the way for their application across a wide range of disciplines.

5. Challenges in 3D Scanning

3D scanning offers a bridge between the tangible and the digital, yet many challenges can arise from even a simple model. This chapter discusses the principal obstacles in 3D scanning, emphasising the difficulties that arise from hardware limitations, software inaccuracies, and environmental factors, and their collective impact on scan fidelity and accuracy.

Variations in device capabilities pose a significant challenge. Figure 8 depicts the “Pentagon” problem, which shows the geometric distortions common in models scanned with less advanced devices, such as smartphones. The “Pentagon problem” describes a scenario where a grid of squares is intersected by a line that is not parallel to the grid, resulting in at least one square being divided into two shapes: an irregular pentagon and a triangle. These resulting pentagons represent distortions and cannot be processed as efficiently by software as triangles and quadrilaterals can. Unlike high-end 3D scanners that capture complex details and textures, smartphones and even some cameras can introduce artefacts and inaccuracies into the scanned models which are shown as pentagons on the model lattice. This discrepancy underscores the need for careful device selection and the understanding of each device’s limitations to ensure the highest quality scans.

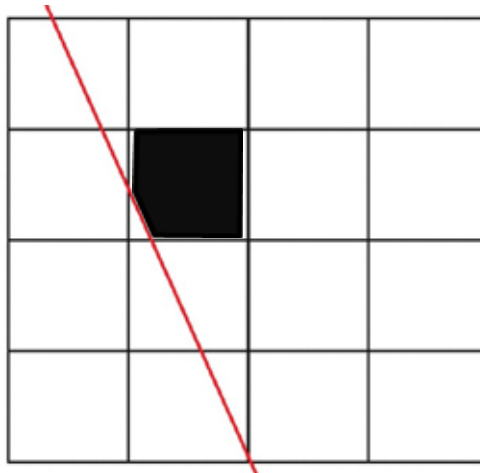


Figure 8 Illustration of the “Pentagon” problem encountered during model subtraction and refinement. The red line represents the cutting line, while the orange points represent the cutting points of the quadrilateral within a model. Points enclose irregular pentagons when connected.

Software challenges add another layer of complexity to 3D scanning. The process of aligning and merging scanned data into a cohesive model is critical, yet often compromised by software limitations. Extensive manual corrections are necessary due to issues such as non-manifold geometries and feature misalignments, as shown in Figure 9. This phase of refining the model demands a high degree of expertise and time investment due to software constraints but is pivotal for achieving accurate digital replicas.

Furthermore, environmental factors play a crucial role in the scanning process. Optimal lighting conditions are essential for capturing accurate colour and texture details, yet achieving such conditions can be challenging, as seen in Figure 10, where iPhone scans demonstrate noticeable distortions due to poor lighting. Additionally, the physical setup, including the object’s orientation and the scanner’s position, influences the scan’s quality, introducing the potential for shadows and reflections that obscure critical details. It is important to keep in mind that environmental factors can have a significant impact on the accuracy of scanning results. To ensure the best possible outcome, it is crucial to plan and set up the scanning process in a way that mitigates any potential negative effects.



Figure 9 Example of vertex stretching due to the pentagon issue in 3D model editing

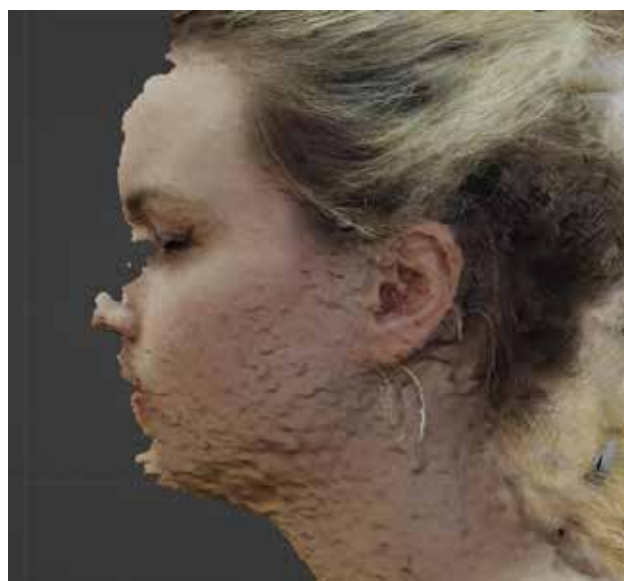


Figure 10 Results of 3D scanning with an iPhone, demonstrating deformation and loss of detail

6. Evaluation of Scanning Results

The precision and reliability of various scanning devices, including Artec scanners, DSLR cameras, and iPhones, can be assessed through outcomes from 3D scanning processes. This chapter focuses on a detailed analysis of the models generated by these devices, with a particular emphasis on polygon counts and model fidelity, which are crucial metrics for evaluating the accuracy and detail of the scans.

Table 1 shows a comparison of polygon counts among different devices. The table compares the detail capture capabilities of high-end scanners like Artec with commonly accessible devices like DSLR cameras and smartphones, highlighting the significant difference between them. For instance, the Artec scanner, renowned for its high precision, produces models with significantly higher polygon counts, indicating a depth of detail that less advanced devices struggle to achieve. This contrast is starkly depicted in Figure 11, where a model’s surface texture and resolution are visibly superior when scanned with the Artec device compared to those produced by other devices.

Table 1 Comparison of model subtraction results, showcasing differences in detail and polygon count

Device	Polygon Count	Detail Level (High/Medium/Low)	Notes
Artec	25,963	High	Best for intricate details and textures, optimal for professional use.
DSLR Camera	106,804	Medium	Good for general purposes, but compromises on fine details.
iPhone	139,923	Low	Accessible but limited by hardware capabilities, best for broad shapes without fine details.
Comparison	Subtraction Results	Detail Preservation	Adjustment Needed
Kamera - Artec	75,277	Medium-High	Manual adjustments are required to match Artec detail level.
iPhone - Artec	79,903	Low-Medium	Significant manual detailing is needed to approximate Artec quality.

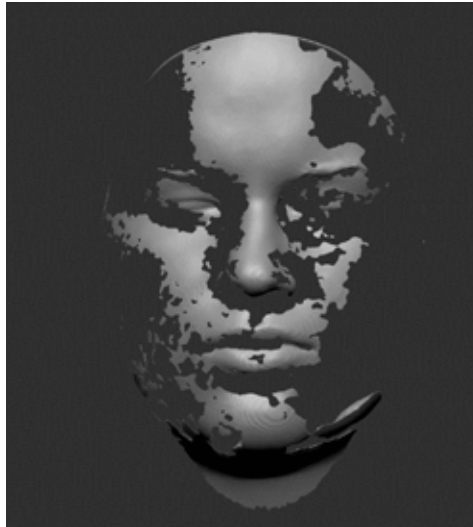


Figure 11 Visualisation of a model without smoothing to highlight the impact on surface texture and detail resolution

Further examination of the table reveals the inherent challenges associated with achieving high fidelity in digital replicas, particularly when utilising lower-end scanning devices. The process of manually adjusting polygon counts to enhance detail in less detailed scans is a meticulous and skill-intensive technique. This endeavour, while beneficial, is fraught with the potential for inaccuracies, as manual interventions can introduce human error into the digital models. The implications of this process are visually represented in Figures 10 and 11, where the difference in quality between manually enhanced models and those directly scanned with high-end equipment is evident.

In synthesising the findings from the table and associated figures, this chapter underscores the critical importance of device selection in the 3D scanning process. It brings to light the trade-offs between accessibility and accuracy, and the extent to which manual post-processing can mitigate these disparities. The insights learned from this evaluation not only shed light on the limitations and potentials of current 3D scanning technology but also serve as a guide for optimising scanning strategies to achieve the highest possible fidelity in digital models. Through a nuanced understanding of these dynamics, the chapter contributes valuable knowledge towards advancing the field of 3D scanning and its applications across various disciplines.

7. Conclusion

The exploration of 3D scanning technologies, through the lens of device-dependent precision alignment and model fidelity, unveils a landscape marked by advancements and challenges. The paper provides an in-depth analysis of the alignment and adjustment processes of 3D scanned models, highlighting their paramount importance in advancing the accuracy and utility of 3D scanning methodologies in both academic research and practical applications.

A key finding from this study is that a model's surface texture and resolution are visibly superior when scanned with the Artec device compared to those produced by other devices. This is further elaborated in the associated tables and figures, which illustrate the inherent challenges in achieving high fidelity with lower-end scanning devices. The manual adjustment of polygon counts to enhance detail in less detailed scans is a meticulous and skill-intensive technique. Although beneficial, this process is fraught with potential inaccuracies due to the introduction of human error into the digital models. The synthesis of findings underscores the critical importance of device selection in the 3D scanning process, revealing the trade-

offs between accessibility and accuracy. It also highlights the extent to which manual post-processing can mitigate these disparities. The implications of this study are significant, as they illuminate the current limitations and potentials of 3D scanning technology. Furthermore, the insights garnered serve as a guide for optimizing scanning strategies to achieve the highest possible fidelity in digital models.

As the field progresses, the continuous refinement of 3D scanning technologies and techniques remains essential. The insights from this comparative analysis not only highlight existing limitations but also chart a course toward overcoming these obstacles, fostering innovation, and enhancing the utility of 3D scanning across various disciplines.

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OPTIMIZING GAME READY ASSET CREATION PIPELINE: FROM CONCEPT TO IMPLEMENTATION IN UNREAL ENGINE 5

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Abstract. This paper presents an optimized pipeline for creating game-ready assets, focusing on the main character, and its implementation in *Unreal Engine 5*. The pipeline encompasses key stages, including concept visualization, sculpting, retopology, UV mapping, baking maps, and texturing. The initial stage involves envisioning the character's appearance using references generated with tools like *PureRef*. The sculpting process, primarily in *zBrush*, begins with a low-resolution silhouette, progressively refining it to achieve a detailed and realistic model. Additional assets such as clothing and weapons are created using efficient tools like *Marvelous Designer* and *zBrush*. Optimisation is achieved through retopology, reducing the number of polygons for efficient memory usage. UV mapping transforms the 3D network into 2D space, facilitating the application of textures for realistic rendering. Baking maps, performed with tools like *Marmoset Toolbag* and *Substance Painter*, ensure a high-quality appearance. The streamlined pipeline ensures a balance between visual fidelity and computational efficiency. The final step involves exporting assets to *Unreal Engine 5*, where they are integrated for use in games, movies, or animated films. The benefits of this approach include resource-efficient memory usage and a seamless workflow, contributing to the creation of visually appealing and optimised interactive or cinematic experiences.

Keywords: *Game Asset Pipeline, Unreal Engine 5, Character Modelling, Optimization, Visual Fidelity*

1. Introduction: a comprehensive overview of the evolution and current state of 3D modelling technology

The digitization of visual content has revolutionized industries from gaming to film, creating a high demand for high-quality 3D models. These models are important not just for their aesthetic value but for their functionality in interactive media such as video games and virtual reality simulations.

In 1997 scientists discussed the burgeoning impact of 3D accelerator chips on mainstream computing, particularly for the *World Wide Web* [1]. Industry predictions at the time foresaw a transition of the *Web* from a static platform to a dynamic, interactive 3D environment, facilitated by the integration of 3D viewing technology into web browsers. Edward R. McCracken of *Silicon Graphics* highlighted a rising demand in commercial and consumer sectors, initiated by the Internet's popularity, leading to acquisitions and new developments like the "Second Web." Despite this enthusiasm, a *Forrester Research* study from November 1996 tempered expectations, noting that the online 3D technology was not yet ready for

mainstream application, citing a weak market and unclear value. The technology was deemed most effective in practical applications such as interactive manuals or complex data models [1]. The paper also pointed out potential growth areas for online 3D technology, like e-commerce, gaming, and education, while acknowledging the challenges of improving and standardising *Virtual Reality Modelling Language* (VRML), the file format standard for online 3D content of that time. Reflecting on the predictions from the past [1], from today's perspective shows a mix of accurate predictions and over-optimism regarding the speed of technology adoption. While 3D technology has indeed become critical in gaming, simulation, and some educational applications, its integration into everyday web browsing has not reached the levels anticipated in 1997. The discussion around VRML also highlights early attempts to standardize 3D content on the web, a concept that has evolved but remains somewhat niche compared to the broader web technologies in use today. While VRML was foundational in the development of 3D web technologies, it has been succeeded by more capable and flexible technologies that are better integrated with the modern web ecosystem. VRML was indeed a significant development in the 1990s for creating and viewing 3D graphics on the internet. It allowed users to create detailed 3D environments that could be navigated virtually. However, as technology evolved, newer formats and technologies surpassed VRML in terms of functionality and compatibility. *Virtual Reality Modelling Language* is no longer the standard file format for online 3D content. One of the more notable successors of VRML is X3D, which extends VRML with more robust features, greater extensibility, and integration with other web standards. X3D supports event-driven and interactive 3D graphics. It allows for user interaction with 3D objects and environments, making it suitable for applications like virtual reality (VR), augmented reality (AR), and online 3D gaming. It also allows the use of scripts and programmable shaders, enabling developers to create complex animations, behaviours, and realistic materials. X3D scenes can integrate multimedia components, including text, images, sounds, and videos, creating rich, immersive environments. Furthermore, modern web applications often utilize *WebGL*, a *JavaScript* API that renders interactive 3D graphics directly in the browser without the need for plugins. *WebGL* is supported by a variety of frameworks like *Three.js*, *Babylon.js*, and *A-Frame*. These tools make it accessible to developers without deep knowledge of 3D graphics programming to develop and deploy 3D applications on the web [2].

The significant role of computer graphics and 3D modelling technology in advancing 3D game animation is explored in [3]. It discusses the fusion of art and technology in creating immersive 3D models, and their widespread use in the gaming industry, and outlines the evolution and application of these technologies in game development. Additionally, it addresses current challenges in the field and anticipates future trends in 3D modelling technology. In [4] a study that develops a VR-based approach to structurally advance the game industry is outlined. It utilizes interactive 3D models and professional game engines to enhance the expansion processes of functional games. The expansion is driven by the ARCS motivational model and focuses on technology innovation and industrial integration to improve realistic experiences in games. The findings from a simulation analysis indicate that VR technology significantly enhances the quality and performance metrics of functional games, suggesting that VR is effective in promoting sustainable growth and transformation within the game industry.

Utilizing the *Unreal Development Kit*, two variations of a previously constructed 3D scene were developed in [5]: one incorporating unoptimized meshes, and the other featuring optimized meshes. Measurements were taken regarding draw calls, frame rates, milliseconds per frame, visible static mesh elements, and memory utilization. The analysis indicates that optimization notably decreases draw calls and memory consumption, thereby enhancing game fluidity while maintaining substantial aesthetic integrity.

As technology advanced, particularly with the integration of engines like *Unreal Engine 5* (UE5), the creation of ‘game-ready’ 3D objects—models optimized for real-time rendering without losing their visual appeal—becomes increasingly significant [6]. UE5 is a state-of-the-art game engine developed by *Epic Games*. It is used primarily for developing high-fidelity video games, virtual reality experiences, and simulations. UE5 is renowned for its cutting-edge graphics, real-time rendering capabilities, and a comprehensive toolset that allows developers to create complex, interactive 3D environments. *Unreal Engine* is a complete suite that provides a wide range of development tools including scripting, physics engine, animation, and more. Both X3D and *WebGL* are directly used for web applications. *Unreal Engine 5*, while primarily a tool for standalone applications, can also be used for creating web-based applications through technologies like *WebAssembly* and HTML5. Developers can compile *Unreal Engine* projects to run in web browsers using *WebGL* as the rendering backend. All three technologies deal with 3D content but at different levels of complexity and interactivity. X3D and *WebGL* are more suited for web applications due to their integration into web standards, whereas UE5 is used for creating high-end, immersive environments. UE5 and *WebGL* both support real-time rendering and interactivity, but UE5 offers more advanced features and higher fidelity graphics at the cost of requiring more powerful hardware and complex development. *WebGL* provides a way to deliver interactive graphics over the web efficiently but with some limitations compared to standalone software. Tools and platforms like *Unreal Engine* often include or work with export tools that can convert scenes or models into formats like X3D or utilize *WebGL* for rendering, thus bridging the gap between high-end game development and web-based presentation. *Unreal Engine 5*, X3D, and *WebGL* all contribute to the field of 3D graphics from different angles, with overlaps, particularly in areas like web deployment and real-time interactivity. They cater to different needs and offer varying degrees of complexity and integration with web technologies.

This study aims to evaluate the influence of 3D game model optimization on overall game performance. It shows the comprehensive guidelines for 3D modelling, highlighting the tools and methodologies that transform initial concepts into fully realized, interactive 3D assets.

Exploring this pipeline reveals the nuances of 3D model creation, from the initial design and sculpting stages through to final texturing and integration into gaming environments. Utilizing a range of industry-standard tools, such as *ZBrush* [7], *Blender* [8], and *Substance Painter*, this process not only requires technical skill but also artistic vision. The paper aims to examine each step of this detailed process, offering insights into the strategies employed by professionals to produce models that are not only visually convincing but are also optimized for performance within game engines. Through this examination, a framework is provided for understanding the current state of 3D modelling techniques and their application in the creation of dynamic, game-ready models.

2. Model optimization in the context of 3D graphics

Model optimization in the context of 3D graphics and game development involves refining the 3D models to ensure they are efficient and effective within a given application, particularly video games or simulations. The optimization process aims to enhance the visual quality of the models while minimizing the computational resources required to render them in real time. Model optimization consists of *Polygon Reduction*, *Texture Optimization*, *Level of Detail (LOD) Implementation*, *Mesh Baking* and *Shader Optimization*. *Polygon Reduction* involves decreasing the polygon count in a model while maintaining its visual quality. A lower polygon count reduces computational load, which is crucial for maintaining high frame rates, particularly in complex scenes. To enhance the visual quality of graphics while also using

memory economically, it is necessary to optimize textures. This process involves adjusting the size and quantity of texture maps to strike a balance between the two aforementioned factors. One such technique for optimization is texture atlasing, which involves combining multiple smaller textures into a single, larger texture, thereby reducing draw calls. Creating multiple versions of a model with varying levels of detail reduces the rendering load for distant and less noticeable objects (LOD). **Mesh Baking combines rendering effects into texture or vertex data for efficient single-pass rendering. For example, pre-calculated ambient occlusion can be stored in textures.** Efficiently developed and refined shaders have a direct impact on rendering performance and visual output, making it crucial to optimize them for improved rendering speed and reduced GPU load. In summary, model optimization is a critical aspect of 3D content creation and game development that impacts both the technical performance and the overall user experience. By making models lighter and more efficient, developers can deliver rich, immersive environments that are accessible on a variety of platforms and devices.

3. Tools and technologies

The foundation of any 3D modelling technique is the selection of appropriate tools and technologies, each chosen for its strengths in handling various aspects of model creation. Industry-standard software such as *ZBrush*, *Blender*, *Maya* [9], and *Substance Painter* are integral to the process, enabling artists to create detailed, high-quality models from scratch. *ZBrush* is renowned for its powerful sculpting capabilities, allowing artists to manipulate mesh with an intuitive brush-based interface that mimics real-world sculpting techniques. This software is pivotal for defining the fine details of a model's surface, which are essential for the next stages of modelling.

Blender and *Maya* offer robust suites of tools for modelling, animating, and rendering, supporting a broad workflow from initial model creation to final animations. *Blender*, being an open source, has a particularly flexible toolset that can be tailored to specific project needs through custom plugins and modifications. Its comprehensive feature set includes 3D modelling, texturing, and particle simulation, which are vital for creating complex animations and realistic environments. *Maya*, on the other hand, is often preferred for its advanced animation tools and superior handling of complex simulation tasks, such as cloth dynamics and hair modelling.

Substance Painter stands out in the texturing phase, offering a user-friendly interface to paint textures directly onto 3D models. It integrates seamlessly with other tools, providing a streamlined workflow that allows textures to react realistically to various lighting conditions. This interoperability is crucial for ensuring that the visual quality of the model remains consistent across different platforms and software. The combination of these tools provides a comprehensive suite that enables artists to transform basic 3D shapes into detailed, textured, and animated models ready for use in dynamic and interactive media environments.

4. Modelling Process

The modelling process is a critical step in the creation of a 3D asset, involving the transformation of an initial concept into a detailed digital object. This process begins with conceptualization, where artists draw inspiration from various sources to create initial sketches and blueprints. Using tools like *PureRef*, artists compile visual references to guide the sculpting and modelling phases. Usually, those references are presented as collages shown in Figure 1. The goal here is to establish a clear visual and functional direction for the model, which informs all future design decisions.

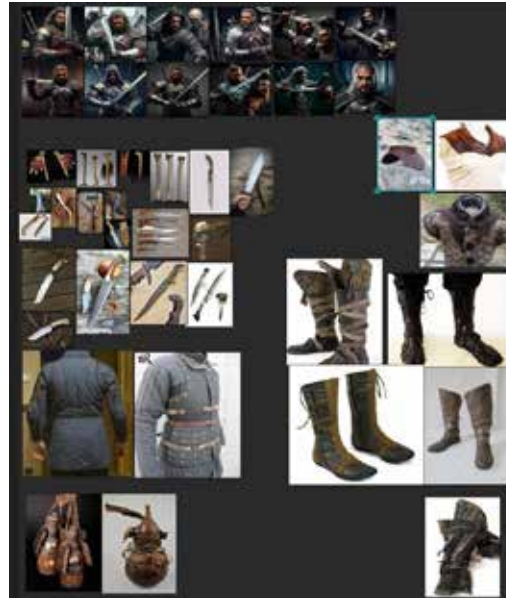


Figure 1 Reference collage.

Once the concept is established, the artist moves into the sculpting phase, primarily using *ZBrush*. Here, the model begins to take shape as the artist adds volume and details to the initial mesh. *ZBrush*'s dynamic tessellation allows for the manipulation of millions of polygons without a significant performance hit, making it ideal for creating complex organic shapes like human figures or intricate terrain features. The artist incrementally refines the model, adding details such as wrinkles, scars, and other textures that give the model character and realism. Progress in adding details on humanoid shapes can be seen in Figure 2.

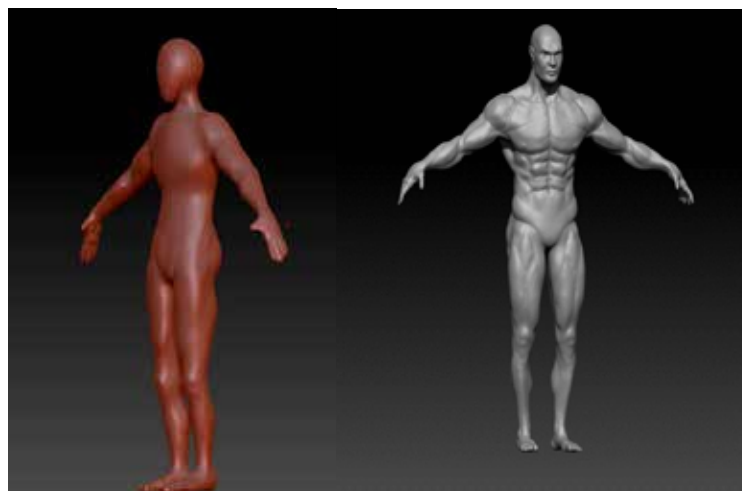


Figure 2 First step of the modelling process - the creation of a humanoid shape (left); Creation of anatomical details such as muscle mass or skin deformities (right).

Following the sculpting phase, the model must be optimized for use in a game engine, which involves a process called retopology. This step is crucial for ensuring the model is not overly complex for real-time rendering. Using *Blender*, the high-polygon model from *ZBrush* is converted into a more manageable form with fewer polygons, while preserving the detailed features essential for high-quality visuals. The retopologized model is then UV unwrapped in *Maya*, which involves flattening the model's surface into a 2D space for texturing. This stage sets the groundwork for the next critical phase: texturing, where the model truly comes to life with colours and surface details.



Figure 3 Retopology process.

5. Texturing and Materials

Texturing is where the visual realism of a 3D model is enhanced, imbuing it with colours, patterns, and other surface details that define its appearance under various lighting conditions. This phase begins with the creation of UV maps, which are essential for accurately applying textures to the 3D model. UV mapping involves projecting a 2D image onto a 3D model's surface, ensuring that textures align correctly with the model's geometry. The process of UV unwrapping prepares the model for texturing by laying out the model's surfaces in a 2D space, which allows for more precise control over how textures are applied.

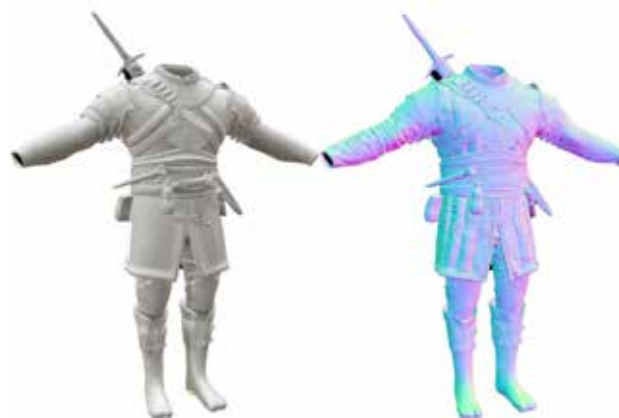


Figure 4 3D Low-poly object without map (left) and with normal map (right).

Substance Painter is the primary tool used in this phase due to its powerful painting features and ability to handle complex texturing workflows. It enables artists to layer materials and textures directly onto the 3D model, simulating realistic wear and tear, dirt accumulation, and other environmental effects. The program uses physically based rendering (PBR) materials, which ensure that the textures behave realistically under different lighting conditions. This is crucial for maintaining visual consistency across various game environments.

The final part of the texturing process involves baking high-resolution details onto lower-resolution models. This technique, known as baking, transfers details from the high-poly model to the low-poly version using normal maps, ambient occlusion, and other specialized maps.

These maps enhance the low-poly model with details that mimic the high-resolution version without the computational overhead. The well-prepared texture maps are crucial for the next steps where the model is brought into the game engine, ensuring it looks realistic and performs well in real-time scenarios.



Figure 5 Base wireframe model with shown polygons (left); Full model render with textures (right).

6. Character Details

Adding character details is a nuanced and crucial phase in 3D modelling, particularly for creating characters that need to interact dynamically within a game environment. This process includes the creation of hair, clothing, and other specific attributes that contribute to the realism and personality of the character. Using tools like *Xgen* within *Maya* for hair and *Marvelous Designer* for clothing, artists can achieve an impressive level of detail and realism that significantly enhances the overall visual fidelity of the model.

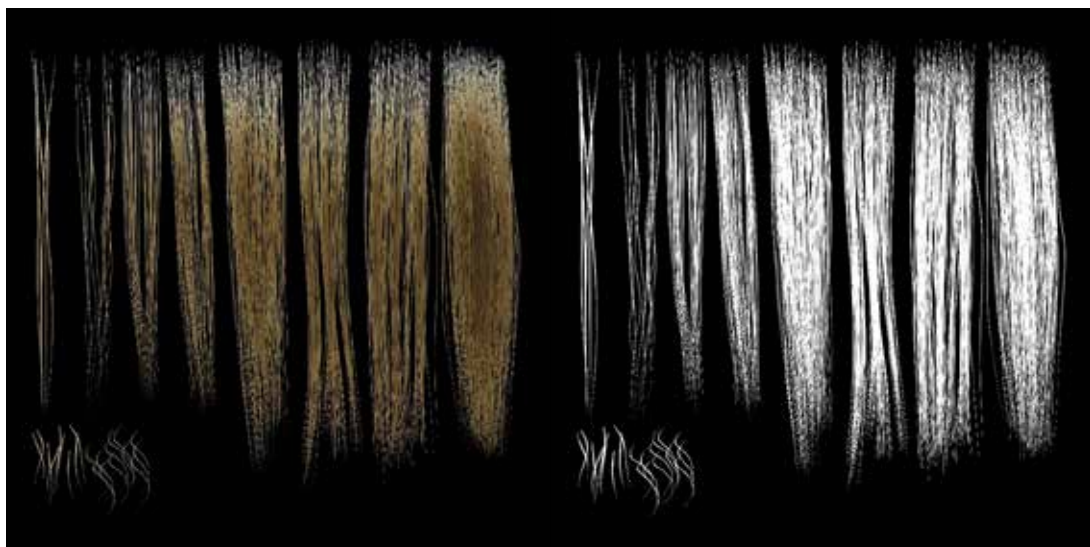


Figure 6 Haircards modelling - Model with baked textures (left) and same model with distortion removal (right)

Marvelous Designer specializes in the creation of realistic digital clothing. It simulates cloth physics, allowing artists to design garments that behave like real fabric when the character moves. This software is invaluable for creating clothing that adapts naturally to the movements of the character, adding an extra layer of realism to animations. The artist designs the clothing by creating patterns and simulating the sewing process, which *Marvelous Designer* then translates

into a 3D model that can drape naturally over the character model.

Hair and fur creation are meticulously handled in *Maya* using the *XGen* plugin, which allows for the precise placement and styling of hair, fur, and feathers. This tool creates highly realistic hair strands that can be styled and controlled to match the character's design, from flowing locks to stiff bristles. *XGen* uses guide curves to direct the growth and behaviour of the hair, providing artists with the control needed to style complex hairstyles or fur patterns. This detailed approach ensures that even the smallest details contribute to the accuracy and immersion of the characters, making them a believable part of their virtual worlds. These detailed elements are crucial not only for the aesthetics of the character but also for their performance in dynamic scenes within the game, where realism in movement and appearance can significantly enhance the player's experience.



Figure 7 *XGen* plugin hair creation using vectors.

7. Environment Creation

The creation of a digital environment is as critical as character modelling, providing the context and atmosphere in which the story unfolds, and interactions occur. This process begins with the 'blockout' stage, where the basic layout of the environment is established using simple geometric shapes. This phase is crucial for determining the spatial relationships and functional aspects of the environment, such as pathways for player movement, locations for key interactions, and the overall scale of different areas. *Unreal Engine 5* eases this with its robust suite of modelling tools and pre-built assets that can be used to quickly make changes to design concepts.

Following the 'blockout', artists move to the detailing phase, where the environment is enriched with textures, lighting, and interactive elements that bring the scene to life. This step often involves a combination of hand-crafted assets and procedural generation techniques. *Unreal Engine 5's* advanced lighting and rendering capabilities allow for realistic lighting effects that are crucial for setting the mood and enhancing the realism of the environment. Artists integrate textures and materials that reflect the natural wear and tear of real-world environments, adding depth and authenticity to the scene.



Figure 8 House environment creation with modular parts.

Lastly, the optimization phase ensures that the environment performs well within the game's technical constraints. This includes the reduction of polygon counts, efficient use of textures, and the strategic placement of high-detail models where they contribute most to the player's experience. Optimization is vital in maintaining high frame rates and ensuring that the game runs smoothly across various hardware specifications. *Unreal Engine 5* supports these efforts with tools that automate much of the optimization process, allowing artists to focus on creative outputs without sacrificing performance. This comprehensive approach to environment creation ensures that the game not only looks visually appealing but also provides a stable and engaging experience for players.

8. Conclusion

The comprehensive exploration of 3D modelling for game-ready assets highlights the complex relationship of creativity, technology, and strategy in digital content creation. Each phase of the modelling process, from initial concept through texturing, detailing, and environmental integration, contributes significantly to the final quality and performance of the model within a game. The use of advanced tools like *ZBrush*, *Maya*, *Substance Painter*, and *Unreal Engine 5* enables artists to achieve an unprecedented level of detail and realism, which is essential in today's competitive gaming market. These tools not only enable the creation of visually stunning models but also ensure that they are optimized for real-time performance, which is crucial for maintaining immersive gameplay experiences.

Looking to the future, the field of 3D modelling is poised for further innovations, particularly with advancements in AI and machine learning, which promise to revolutionize how textures and models are created and implemented. As technology evolves, so too will the capabilities and efficiencies of 3D modelling tools, allowing for even greater creativity and productivity in the gaming industry. By continuing to leverage and adapt to these technological advancements, artists and developers will be able to push the boundaries of what is possible in digital storytelling and interactive media, enhancing both the creativity and the accessibility of game development.

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CASE STUDY FOR AN ADVANCED EDUCATIONAL SYSTEM BASED ON AI IN CROATIA

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Abstract. In this paper, a comprehensive overview of an advanced educational system is presented alongside a case study focusing on the integration of artificial intelligence (AI) in the educational lifecycle of students in Croatia. The already implemented system digitizes the entire student education process, from enrolment into elementary schools to college graduation. The core of this system is the utilization of several interconnected information systems. It begins with the national information system, e-Građani, used for enrolling children in elementary schools. Post-enrolment, the child's data is fed into the central system of the Ministry of Science and Education, known as e-Matica. This system houses comprehensive data on students, including their grades, and is linked with e-Dnevnik, an application used by teachers for managing class records. e-Matica plays a pivotal role in the educational journey. When students transition from elementary to high school, and later to college, e-Matica's data aids in the online enrolment process. For high schools, the e-Upisi system is used, while colleges have their distinct enrolment system. Both systems get the data from e-Matica to facilitate the enrolment process based on student performance and available spots. Moreover, the system extends into college education, where student performance data is recorded in a national information system for higher education. Although currently this data is not integrated with the central student data, potential future integration is highlighted.

The incorporation of AI technology into this system is a significant aspect. AI can analyse the strengths and weaknesses of the educational system and make predictions for each student's best educational path. It can enable personalised guidance, helping students choose appropriate high schools or colleges and providing real-time support in subjects where they may struggle. This system could conduct predictive analyses, determining the quality of schools and identifying trends in student success. By realising the immense potential of such an evolving system students can be guided more effectively, improve educational outcomes, thus reshaping Croatia's entire education system. The comprehensive nature of the proposed system, encompassing all levels of education and utilizing advanced technology, makes it an innovative model in educational systems.

In summary, the paper suggests a way to transform the educational system in Croatia, harnessing AI and digital technologies to streamline processes, personalize education, and enhance the overall educational quality and efficiency.

Key words: *artificial intelligence (AI), educational system, personalised education, education transformation*

1. Introduction

Several information systems within the primary and secondary education system have already been developed in Croatia. These systems fully digitize all processes in students' education. As these information systems have the ability to exchange information, they enable all students to complete their education from the enrolment in elementary schools to their college graduation through the Internet. At the same time, these information systems can unite this data into a singular system that may become able to use AI technologies to provide accurate analyses and predictions for the entire education system, as well as for individual students.

The path starts when children are enrolled in elementary schools, though even some kindergartens use the same system in their enrolment process. Parents use the national online information system, e-Građani (e-Citizens) [1], to enrol their child in elementary school [2].

When a child is enrolled in the first grade of elementary school, their data is submitted to the central system of the Ministry of Science and Education, known as e-Matica [3]. e-Matica contains all data about all students, including their grades, through the entirety of their education, as well as data about schools and school staff. It's a system that is used, not only in elementary, but in high schools as well. The application is designed as a digital form of the School Register, which has to be filled out by teachers in schools through the application called ednevnik [4]. At the end of the school year, teachers can print out a transcript of the education data available for each student.

By using the application e-dnevnik, all data, both about the activities and the grades of all students in elementary and high schools in the Republic of Croatia are united in a single information system. At the same time, this application shares its data with e-Matica.

After finishing elementary school, by using all the data from e-Matica, students enrol in high school. The enrolment process is done online, using the national information system created for enrolling in high schools, called e-upisi [5]. As input this system uses data from eMatica on one side, and data about high schools and available spots on the other side. In this system, students are automatically enrolled in high schools based on their performance in elementary school and the order in which they listed their preferred high schools if they meet the stated criteria. In high schools, teachers also use e-dnevnik to input all data about students into eMatica.

After graduating from high school, students enrol in college, using the national information system for college enrolment [6]. The enrolment data is used in the same way as it was during high school enrolment. The data about available spots comes from the colleges themselves. Throughout college education, all data about students' performance is also recorded electronically in the national information system for higher education, which all colleges are required to use by law [7]. The data about students' performance and grades isn't shared with the central student data, and there is no calculation of mutual correlation, but it is a possibility which could soon happen.

By using all the collected data and AI technology, it is possible to analyse the strengths and weaknesses in the system. Moreover, this system could make suggestions for each individual student regarding their best choice of high school or college. A complete analysis of the quality of elementary, high schools, and colleges could be made. It could help in finding the data about which elementary schools' pupils graduate at the best colleges, among many other predictive analyses.

With all the available data, an AI system can begin guiding pupils and students in the right direction early in their education with a greater precision and clarity than some currently available tests that can tell pupils which high school they should enrol in. Also, since all students' grades are tracked, AI can provide real-time support and guidance to students in subjects where

they may be struggling, or, with the help of the system, conduct additional online lectures and virtual schools.

The existing system is constantly evolving, and it could become incredibly useful. With the addition of AI to these systems, its future usefulness could improve pupils' and students' daily education, guiding them in the right direction during lifelong education and it could remodel the entire Croatian education system.

2. Advanced Educational System (AeS)

The proposed Advanced Educational System (AeS) project represents a significant step forward when it comes to incorporation of artificial intelligence in education. Based on an all-encompassing database that includes information on students' academic achievements, skills, interests, and social context from elementary school to university, which was built and implemented within the mentioned systems, this new system could personalize and optimize the educational process.

By utilizing advanced artificial intelligence (AI) and machine learning (ML) technologies, AeS could not only improve the experience of each individual student but also to provide important insight on how to shape educational policies which would be useful in the changing and evolving needs of the labour market and society. This project connects technological innovation and the goals of education. Its goal is to create a system that not only tracks but actively shapes the education of each student.

Furthermore, this system can use the available data on the educational system to provide information which could help in tailoring education to the specific needs of the labour market. The following are three possibilities for the development of the advanced educational system:

1. **Personalized learning and individual guidance:** AI can process large amounts of data to provide insights into abilities preferences of each student. Based on this, AI can suggest more personalized educational paths, identify subjects and skills where students need additional help or the ones they find challenging, and suggest the most suitable high schools or universities for them. This approach allows students to maximize their potential and provides support at important moments in their education.
2. **Strategic planning and development of the education system by using AI at the system level:** With this kind of implementation of AI it would be possible to analyse changing trends in education, the success of different schools and programs, and predict future labour market needs. This can assist the state and educational institutions in making appropriate decisions on how to allocate their resources, reform the educational system, and align educational programs with the real needs of the economy.
3. **Adapting the system to the labour market;** Using AI when analysing data within the educational system can help in adapting education to the specific needs of the labour market. Based on the available data and various assessments, the system can make recommendations and identify current and future skills of students, especially those needed in the labour market, analyse how useful the current curriculum is, predict workforce shortages, offer career counselling, and more.

The application of AI in the aforementioned system can improve individual educational outcomes and enable more efficient and proactive management of educational resources at the national level. Ultimately, this can create an educational system that is flexible, adaptable, and future-oriented, with a clear focus on supporting students and preparing them for the challenges brought by the changing technological and globalized world.

3. Translation into ML problem

The translation of data from various databases into a format suitable for machine learning (ML) and artificial intelligence (AI) in the context of the AeS project, involves addressing several challenges. These challenges include standardizing data formats and structures, interpreting data and understanding its semantics, ensuring system scalability and performance, data quality and purity, and connecting various data sources. Overcoming these challenges requires expertise in data processing, machine learning, NLP, ethics, and legislation.

When translating data from different databases into a format suitable for ML and AI the following steps should be taken. Data formats have to be standardized. This can be performed by developing a protocol for standardizing data formats from different sources and might include transforming various formats into a unified format like CSV, JSON, or XML. In order to keep the system and data clean automated systems should be put in use to remove or correct errors, address missing values, and identify and correct anomalies. To interpret data in a way that reflects real-world concepts, particularly in the field of education, semantic analysis and natural language processing (NLP) techniques are required. To merge data from different sources data integration tools have to be utilized. Finally, due to the use of a large amount of personal student data, it is essential to adopt strict protocols for data privacy and security in compliance with local laws and regulations, such as the GDPR. This also includes the anonymization or pseudonymization of sensitive data.

By adopting these steps, the project would effectively address key challenges associated with processing and integrating data from various sources, ensuring that the data is suitable for use in AI and ML applications within an educational context.

4. Data Understanding / Attributes

Understanding and defining data attributes are key steps in data processing, especially when a system is being prepared for an implementation of AI and ML. The main issue of understanding data primarily involves conducting a detailed analysis of the available data, identifying significant data patterns, as well as eliminating potential anomalies. It is important to understand the data context and the context from which the data originates, as well as ensuring the quality of the data used.

The second part defines the attributes, approached from different aspects. When defining attributes, it is necessary to identify the important attributes, i.e., the significant data (for example, in the AeS project, it could be student grades). It is also possible to create and define some new attributes from existing ones. Following that, the selection is the next important step. It entails choosing relevant attributes that should be included in the model, as well as the assessment of the importance of all attributes.

Understanding data and defining attributes is essential for the success of AI/ML projects because they ensure that models have access to relevant, accurate, and quality information which could generate accurate predictions and insights.

For the needs of the AeS project, preliminary work on the data is necessary to define the attributes that will later be used in the system. To understand the data, it is necessary to first perform certain steps. In-depth analysis of data sets is necessary to collect and analyse all available data from the existing systems that deal with education, which include grades, attendance, teacher feedback, student interactions, test results, etc. It is helpful to present data using data visualization tools to identify patterns, trends, and anomalies. This can include maps, diagrams, and others. It is also possible to perform a qualitative analysis of data through

interviews with teachers, students, and parents to better understand the context and deeper layers of data that are not visible only through quantitative analysis. A quality assessment and data cleaning should also be performed, which is done by identifying and correcting errors in the data, such as missing or inconsistent values.

For defining attributes in data, which was previously assessed, it is necessary to carry out processes that include selecting attributes using information from the data understanding phase, creating new attributes to improve the predictive power of the model and continuously testing and adjusting attributes through modelling iterations to ensure that the model correctly interprets and uses the data. When selecting attributes, it is necessary to select those important for achieving the goals of the project (e.g. grades). Creating new attributes may include combining multiple attributes or deriving new features from existing data.

In this project, the goal is to establish an understanding of the data through a combination of quantitative and qualitative methods and to define attributes that will enable effective modelling and accurate predictions or recommendations. This approach ensures that AI/ML models are not only technologically advanced but also pedagogically relevant and adaptable to the specific needs of students and the educational system.

5. Ontologies, Thesauri, Knowledge Graphs

Integrating ontologies, thesauri, knowledge graphs into AI and ML projects in the education sector can significantly improve the system.

To define terms in the context of this project, ontologies would be used to structure and categorize educational content and inquiries. It would enable the system to accurately understand and link different educational concepts. On the other hand, thesauri would help to expand and refine responses to student inquiries, allowing the system to understand and respond different terms and expressions. Knowledge graphs could be used to visually map and connect different educational concepts. They would enable the system to provide contextually relevant recommendations and guide students through their educational journey.

The AeS project could define new policy to manage the educational system based on the obtained data. It includes an analysis of educational data throughout an individual's educational journey. Three components, ontologies, thesauri and knowledge graphs, play an important role.

Ontologies would be the foundation for structuring various data in the educational system. They could define concepts and relationships, such as those between subjects, grades, student activities, and skills, and could be used to present the relationships between different academic disciplines or skills and the job market.

Thesauri would be useful for data normalization, as they would enable consistent labelling and searching through various data sources. They could link related terms and concepts and analyse trends and patterns. In the educational context, this could help improve the curriculum or recognize equivalent skills despite the different educational pathways or certifications students have.

Knowledge Graphs (KG) could be used to visualize and analyse connections between data and explain more complex questions. KG could link information about educational pathways, careers, and the job market to provide predictive analytics and personalized recommendations for students. For example, KG could recognize which universities lead to successful careers based both on historical data and current market trends.

By combining these tools, AI and ML technologies can produce advanced analytics and insights that could improve individual education and development, as well as inform educational

policies at a macro level. They could also provide personalized and relevant recommendations to their users which can help them make decisions.

6. Modelling Choice

ML models are algorithms used in machine learning to process data and make predictions or decisions. They are based on mathematical models that learn from data. The goal of machine learning is to develop models which can recognize patterns and make decisions with minimal human intervention. Potential models and their combinations that could be used in an advanced educational system are:

- **Supervised learning models** would be used to predict grades, career success, or educational outcomes. These models require clearly labelled datasets for training.
- **Unsupervised learning models** would be used to identify hidden patterns in data.
- **Time series analysis** could be used to analyse changing trends, such as changes in employment or the popularity of certain subjects.
- **Natural language processing (NLP)** could be used to analyse essays, various feedback, or documentation. NLP techniques such as sentiment analysis, thematic modelling, or transformers can provide better insights.
- **Recommender systems** could be used to develop personalized recommendations for educational paths or career counselling.
- **Deep learning** could be used to handle large and complex datasets with many variables.

It is important to note that the choice of models should be based on a careful analysis of the available data, desired outcomes, and ethical guidelines. Before choosing models an exploratory data analysis should be conducted to better understand the used data.

7. Evaluation and Satisfaction Criteria

The success and satisfaction with an AeS, which utilizes AI and ML technologies to analyse of educational systems and the labour market, will depend on many factors. The system will be assessed on its technical capabilities, how it improves education and contributes to the job market. This includes providing equal learning opportunities to all pupils and students, increasing employment, and ensuring that education follows the market demands.

Evaluating the system's effectiveness and measuring user satisfaction requires a multi-dimensional approach. From the perspective of project success evaluation, the following factors should be observed: accuracy of predictions, monitoring changes and reducing dropout rates before and after system implementation, analysing graduate employment rates as an indicator of the alignment of education with the job market, analysing opinions of teachers, students, and employers, implementing innovations in the curriculum and measuring how effective new approaches and subjects introduced based on AI analysis are, and finally, personalising learning and evaluating the effectiveness of individualized educational plans.

From the perspective of user satisfaction, which a necessary factor for any system's usage, it is important to continuously monitor and improve the system's functionality, based on the feedback received from users. This can be ensured by regularly conducting surveys among users (students, teachers, school administrators), analysing responses to identify areas which could be improved, organizing focus groups with stakeholders to better understand their impressions and experiences, having individual interviews to get more detailed insights, analysing system

usage data (e.g., frequency of use, session duration) and collaborating with employers to assess the quality of education and graduates' preparedness.

Ultimately, the project's success and user satisfaction will be measured by its ability to provide relevant, accurate, and useful insights which could improve educational processes and outcomes for students.

8. Conclusion

AeS is a project which implements AI and ML technologies in the education system. It represents a significant step towards personalized, flexible, and market-adapted education. Through an analysis of student data, their academic achievements and behaviour, this system enable a better understanding of individual student needs and predict future trends in education and the labour market.

With the ability to identify the most effective teaching methods and to adapt the curriculum, AeS improves the learning experience and helps to change the education system. Through ongoing evaluation and adjustment, this project has the potential to improve academic outcomes and give students the opportunities to develop skills crucial for success in a rapidly changing world.

Ultimately, AeS represents an important step towards creating an education system that is truly future-oriented and adaptable to the needs and goals of every individual.

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A STEP TOWARDS SUSTAINABLE CITIES: SIMULATION OF A SMART GRID

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Abstract. Contemporary urban societies face serious challenges when it comes to air, water, and soil pollution, as well as issues related to waste management and excessive resource consumption. Maintaining healthy ecosystems, reducing environmental pollution, creating green spaces, promoting biodiversity, and advocating for sustainable resource usage are just some of the many benefits of ecological planning. Furthermore, key steps in the development of sustainable cities include the implementation of innovative waste management systems, encouragement of smart transportation solutions, integration of renewable energy sources, and the introduction of energy-efficient infrastructure solutions. The purpose of this paper is to emphasise, through the analysis of existing sustainability solutions such as smart grids, the importance of integrating engineering solutions with environmental awareness as a response to increasing urbanisation.

Key words: *sustainable cities, engineering solutions, environmental awareness, urban planning*

1. Introduction

Urbanisation is an inevitable process which transforms cities and impacts local communities and the environment. Sustainable urban development is key to successfully building cities demanded by increased population while simultaneously protecting the environment and improving life quality. This approach balances economic, environmental, and social dimensions, while striving to reduce pollution, preserve natural resources, encourage sustainable transport, create green spaces, and promote social justice.[1] It is crucial to educate citizens about the importance of sustainability. In the long-term, sustainable urban development brings economic benefits, quality of life improvement, reduces negative ecological impact, encourages investments, increases employment, and reduces energy consumption, waste and pollution. Engineering solutions, like sustainable infrastructure, smart transport systems, and energy efficient technologies are crucial to achieve the balance between the population growth and preservation of environment.

Traditionally, some power sources are operated by burning fossil fuels which are a prominent source of greenhouse gasses, and they pollute air, soil, and water - a shift towards renewable energy sources is needed.[2] Hydropower stations are considered as sustainable but big dams can largely affect environment. Nuclear power stations are large sources of stable energy production and low emissions of greenhouse gases, but they produce radioactive waste and risk of accidents. However, they have the potential to be more environmentally friendly than fossil fuels.

Conventional power stations produce a large amount of power in a single location, and then distribute it via a network of cables. In particular, there is a centralised distribution model

– there is a clear producer who outputs the power from a single location to all consumers. Furthermore, these sources provide energy continuously and are not dependent on daily or seasonal effects. On the other hand, sustainable power sources like solar and wind power plants are often incompatible with this model due to their scattered nature and variable availability. Each individual supplier is smaller and produces less power, and there are generally a lot of them. Consider wind turbines and solar panels – they can easily be scattered around, rather than all being located in one monolithic cluster, and the amount of wind and sun power available fluctuates significantly.[3], [4] This means we can no longer view the power distribution problem as having a single supplier with uninterrupted power generation – instead we must turn to a smart grid. A smart grid gives us the important property of having a decentralised and adaptable system, where consumers and producers can communicate with one another to decide how best to distribute power.

2. Smart grid simulation

In this section, we compare traditional energy grids with smart grids. We then present a simulation of a smart grid system. The code can be found at <https://github.com/ciet2024smartgrid/smart-grid-simulation>.

2.1. Comparison between smart grid and traditional grid

Traditional electrical grids were developed when the electrical demand was small. Over time, the infrastructure grew without regard for scalability and sustainability, as civilisation's dependence on electricity increased. These conventional grids rely on centralised power generation which is often located far away, leading to significant electricity transmission losses. As more consumers connect to the network, more burden is put on the existing power lines - a big number of consumers can depend on the same power lines. This old infrastructure is opening a susceptibility to blackouts - if these burdened transmissions are pushed beyond their capacity, a cascading outage is initiated, resulting in severe life disruption in the affected area, damage to electronic devices, and data loss. Furthermore, traditional power grids are based primarily on fossil fuels, and they are not compatible with modern renewable energy technologies.

A smart grid is an enhancement of the 20th century electrical grid. Smart grids introduce bidirectional flow of information and electricity and integrate sensing technologies, allowing for a self-monitoring, self-healing, and adaptive energy distribution system.[5], [6] In contrast to classical grids, power generation is decentralised over many energy providers spread out across the network, and the integration of renewable energy is facilitated, which puts smart grids on the front of fighting climate change. The line between consumers and suppliers is blurred - for example, a house can generate its own power by installing solar panels.

In this paper, we present a simulation of a smart grid in its simplest form, in order to give us insight into how energy distribution works, and to help us understand how a real smart grid should be built. This simulation can further be upgraded to allow more complex electricity management and to simulate the grid on a realistic scale of a city.

2.2. Ford-Fulkerson algorithm

To describe a smart grid, we use graphs where the nodes are power generators and consumers, and the edges are transmission lines connecting them. All power suppliers are sources, and all

consumers are sinks. Each edge has a specified capacity, i.e. the maximum allowed flow, which is imposed and therefore prevents line failures in smart grids, and at each moment we specify the current flow through the edge. Each source has an associated quantity of power it produces, similarly each sink specifies how much power it needs to operate. We use undirected graphs, which naturally implement the two-way directionality of smart grids. The simulation makes use of Ford-Fulkerson algorithm. A rigorous algorithm can be found in Ref. [7]; here we will limit ourselves only to a demonstration of the algorithm. This algorithm takes a greedy approach to finding the maximum flow in a flow network. The procedure is as follows:

1. Initialise flow to zero in all edges.
2. While there is an *augmenting path*, increase the flow along this path by the maximum allowed flow (which is equal to the minimum capacity along the path). Update the residual graph.

An augmenting path is a path between the source and the sink that has an available capacity, i.e. there is no edge that has been saturated and we can send additional flow. *Residual graphs* are calculated at every iteration in order to find an augmenting path at the next step. They are defined as the graphs we get by updating the capacities of the edges to *residual capacities* after some amount of flow was let through. The residual capacity of each edge is found by subtracting the amount of new flow from the previous edge capacity. To make this clearer, let us look at an example of a general graph in Figure 1 a). We have a source and a sink node, while nodes A to D are generic nodes. Each edge has its capacity and the flow through it denoted by “flow/capacity”. As the first step, all edges have been initialised to zero flow. Next, we find an augmenting path Source-A-B-Sink, as seen in Figure 1 b). We note that the minimum edge capacity is 2 (edge B-Sink), therefore the maximum flow via this path is 2. Figure 1 c) shows the graph after letting through the flow of 2. Now we need to find the residual graph by calculating the residual capacities. For the edge Sink-A we find the residual capacity to be 6 (initial capacity of 8 minus the flow of 2), and for the edges A-B and B-Sink we find 7 and 2 respectively (denoted in light blue next to the initial edges capacity in Figure 1 d)). Next, we again search for an augmenting path and we find the path Source-C-D-Sink (Figure 1 d)). The constraining capacity is 3 (the edge Source-C), therefore we let through the flow of 3 (Figure 1 e)). Figure 1 f) shows the new residual graph (residual capacities in light blue) and a new augmenting path Source-A-B-C-D-Sink. The constraining capacity now is the residual capacity of 1 belonging to the edge C-B, so we let through the flow of 1 (Figure 1 g)). Finally, Figure 1 h) shows the new residual graph and we notice that we can no longer find an augmenting path, and the total flow to the sink is 6 (2 due to the B-Sink, and 4 due to the D-Sink).

In this example we didn’t define how we find the augmenting paths. The Ford-Fulkerson method does not dictate how to find these paths, so we use a simple breadth-first search.

There are four invariants observed at each stage of the Ford-Fulkerson method:

1. Capacity constraints: the flow along each edge is less than or equal to the capacity
2. Symmetry: the flow from a node A to a node B is the negative of the flow from B to A. This represents the idea that flow is directional – from one perspective, a positive flow is going from A to B; from another perspective, a negative flow is going from B to A
3. Flow conservation: for each node, besides the source and sink nodes, the total incoming flow is equal to the total outgoing flow. This intuitively means flow is neither created nor destroyed at nodes (besides the source and sink)
4. Total network flow: the total flow out of the source node is equal to the total flow into the sink node

The algorithm also deals only with a single source and a single target, however in the case of a smart grid, we must express many sources and targets. We solve this by augmenting the energy grid graph with a “super”-source and “super”-target node. For every energy supplier in the network, there is an edge from the super-source to the supplier. The capacity of this edge is defined as the maximum power output of the source - this way, the Ford-Fulkerson algorithm ensures the total power output by each supplier is bounded by its maximum output – invariant 3 states the outgoing power of the source is equal to the incoming, and the incoming is bounded by the maximum¹. Similarly, there is an edge from each consumer to the super-sink where the capacity is defined as the requested power by that consumer. This way, consumers never take more power than they need.

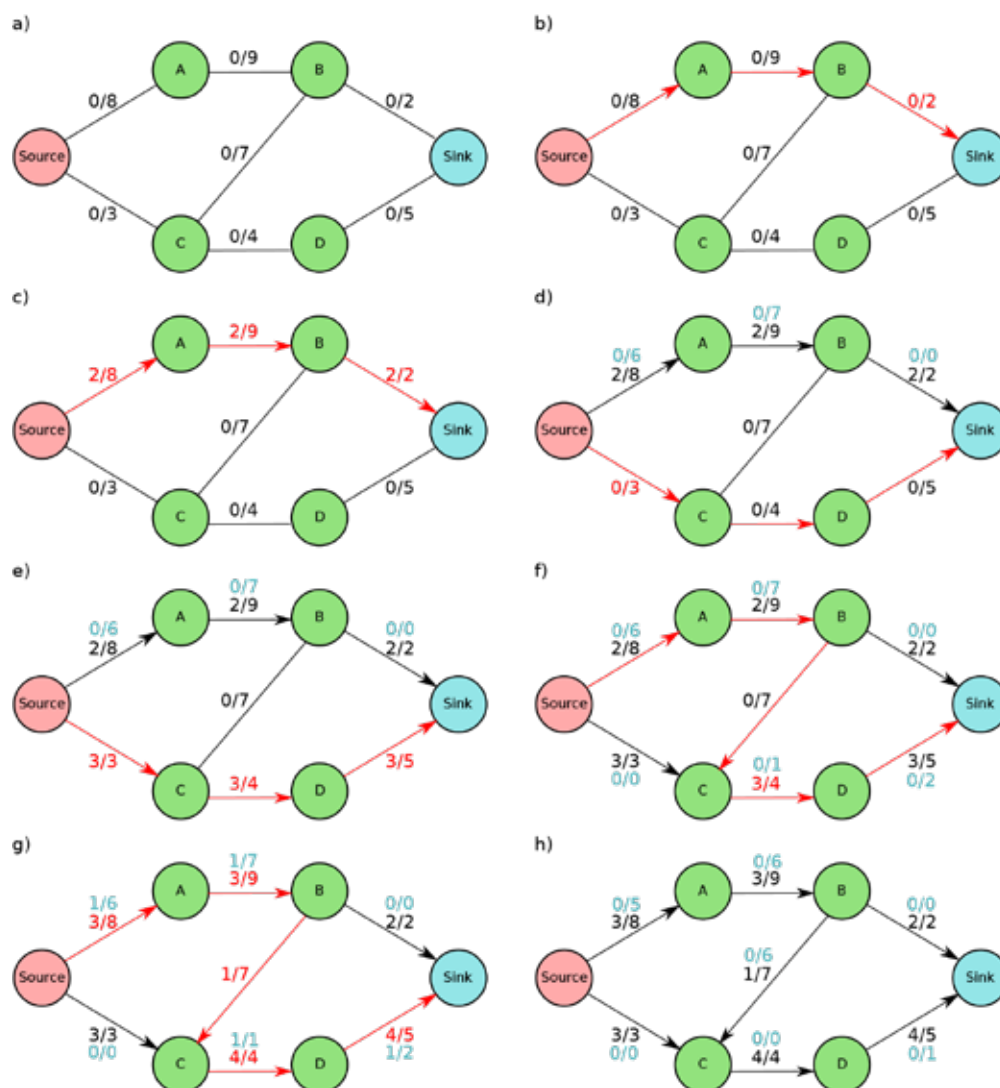


Figure 1: Step by step demonstration of Ford-Fulkerson algorithm.

2.3. The simulation

The first step of the simulation is specifying the grid we'd like to simulate. We create a text file example grid.txt in which we write the following:

- The reader may notice a caveat here, being that a source may in fact receive flow from another source, in which case its total outgoing power can be greater than its maximum production. We note that this is alright – the node itself is not producing too much power; it is instead just forwarding power from another supplier.

```
nodes
0 House -5
1 Office -80
2 Office -80
3 Train -350
4 SolarPanels 7
5 NuclearPowerStation 10000
links
4 0 100
5 1 400
5 2 400
1 3 100
```

Running the program with this input yields the following:

```
Node "House" received 5/5 power
Node "Office" received 80/80 power
Node "Office" received 80/80 power
Node "Train" received 100/350 power
Node "SolarPanels" output 5/7 power
Node "NuclearPowerStation" output 260/10000 power
Transferred 5/100 from SolarPanels to House
Transferred 180/400 from NuclearPowerStation to Office
Transferred 80/400 from NuclearPowerStation to Office
Transferred 100/100 from Office to Train
```

The corresponding illustration can be seen in Figure 2 a), while b) shows the result after the simulation. We first specify all the nodes in our grid, which can be either sources or sinks corresponding to suppliers and consumers respectively. For each node, we write a new line in the form: `node_number node_name node_power(kW)`. We make the power negative if the node is a consumer, and positive if it's a producer. In the case we wanted a node that is simply a transmitter, we need to set the power to zero. Since the first aim of the simulation is purely a demonstration, we do not put much weight on the exact numbers for each node's power so we use estimated values. Similarly, we do not put much weight on what the suppliers and consumers are – the names are given as an example of a real-life energy grid, but the simulation only focusses on the power at each node. Next, we define the links in our network – the transmission lines connecting the nodes. Each link is specified by the two nodes it connects and its maximum allowed flow; we write a line in the form: `from_node to_node capacity(kW)`.

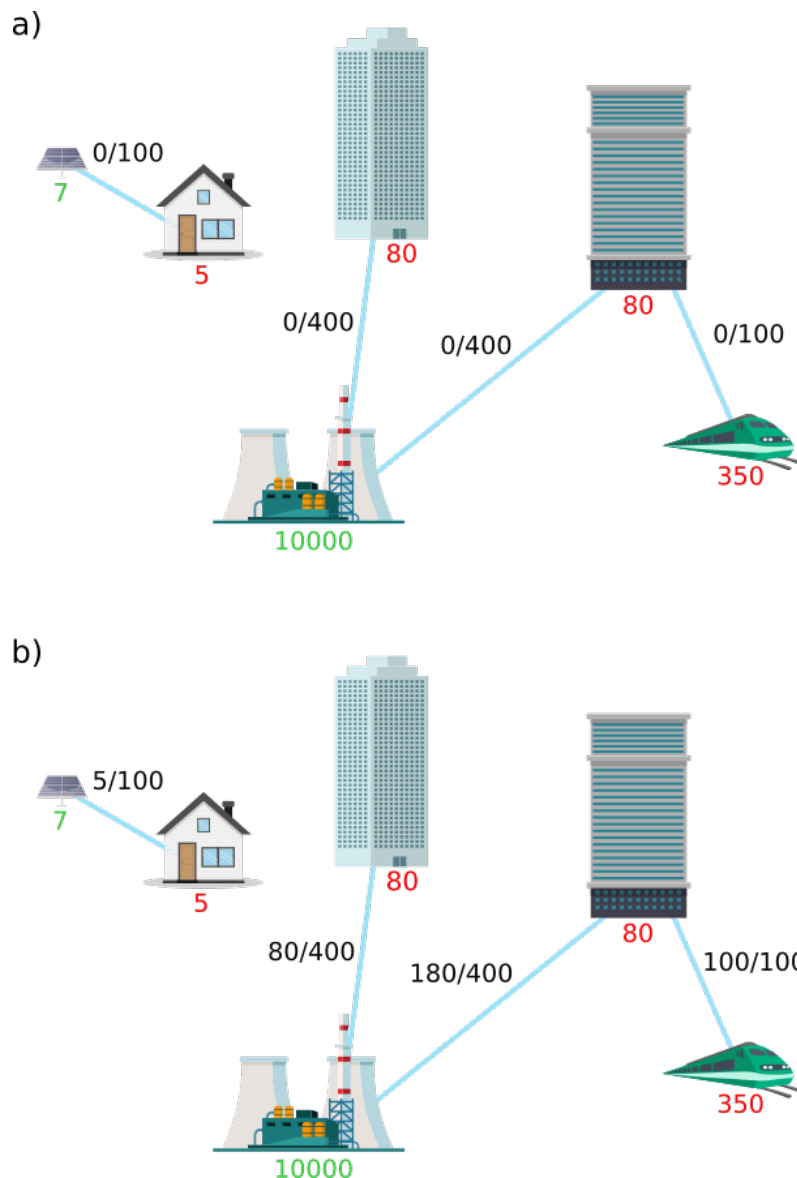


Figure 2: An example of an electricity network. Red numbers indicate how much power in kW consumers need, while green numbers indicate how much power in kW is supplied by the producers. a) Specification of how much power is produced and needed, and the capacities of the links. b) The flow through each link after running the smart grid simulation. We notice that the offices were prioritised over the train, because they are closer to the nuclear power station. The train does not receive the full power it requests because the link capacity is too small.

Next, using the file `energy_grid.py`, we load the energy grid from the text into a graph structure in our algorithm by creating a list of `GridNode` and a list of `GridLink` objects.

We use `resolver.py` to find a solution to the energy grid problem by computing how much power each producer needs to output, how much power is received by each consumer, and how much power was transmitted through each link.

The algorithm supports providing priorities to each of the consumers - this way we can control which consumers are satisfied first in the case that there is an insufficient amount of power.

For the purpose of the simulation we provide one such method for deciding these priorities. We simply decide that the closer a node is to a power source, the higher its priority. While this is unlikely to be a useful heuristic in reality, it gives a basis for a priority system, and provides a reasonable placeholder to demonstrate the algorithm's ability to account for more and less important consumers.

To calculate the priorities, we use a breadth-first search, as this visits nodes in-order. The code for this search is found in the function `bfs_priority`, which returns the list of consumers, ordered by this priority.

Next, we execute the main body of the algorithm. This algorithm is a minor adaptation of the Ford-Fulkerson method. As mentioned previously, we augment the energy grid with a super-source and super-sink node, where the edges out of the super-source and into the super-sink represent the producers' maximum output and consumers' maximum input respectively.

To find augmenting paths through the graph, we use a breadth-first search. However, naively, this will not respect our priorities. For this, we ensure that the next augmenting path always visits the highest priority consumer directly before the super-sink. The code for this procedure is found in the `bfs_augmenting_path` function.

There are three cases when such a path cannot be found:

1. The total power of the grid has been exhausted; we cannot provide any more power along this path
2. The total power which could reach this consumer has been exhausted
3. The consumer has already received the amount of power it requested.

When any of these conditions occur, we know that no more power can be delivered to this consumer. We then proceed by updating the highest priority consumer to the next highest priority, and repeating until we have attempted to supply to each consumer. Note that there may be multiple augmenting paths through one consumer, so we only revoke the priority when there are no more possible paths. The logic for maintaining the highest priority consumer is found in `find_next_augmenting_path`.

Intuitively, this appears like a safe approach at first glance: we keep providing power to the highest priority consumer until we cannot supply more, then we move to the second highest priority and so on. However, a fundamental trait of the Ford-Fulkerson algorithm is that later augmenting paths may actually *deduct* from the flow along edges – in particular, they may send flow the *opposite* direction. It now appears that in fact this priority algorithm is flawed – how can we ensure that no low priority consumers will “steal” power from the higher priority ones?

In fact, the algorithm is designed to overcome this flaw. In particular, we can prove that, while later augmenting paths may deduct flow along some links in the network, they will never steal power from a higher priority node.

The proof sketch is as follows. An augmenting path must be *acyclic*, meaning it never visits a node more than once. When we find an augmenting path, we only ever send a strictly positive flow along this edge. In order to deduct power from a given consumer *C*, we must therefore have an augmenting path with an edge from the super-sink to *C* – this edge is given a positive flow, which deducts power from that consumer. But this cannot be the case, since the path must end at the super-sink. Therefore, to contain an edge from the super-sink to *C*, it must contain a cycle, and thus is not a valid augmenting path. We can conclude from this that power-stealing is impossible, and the algorithm genuinely respects priorities.

With the augmented graph in place, and with our modified breadth-first search for creating priority-observing augmenting paths, we now execute the Ford-Fulkerson algorithm. The algorithm computes a flow matrix between each pair of nodes.

To compute the final solution, we want to find out how much power each source provided, how much power each consumer received, and how much power was sent over each network link. The algorithm is constructed in such a way that all this information is included in the flow matrix. The code for the final solution is found in `resolve_energy_grid`.

The power produced by each source is precisely the flow along the edge from the super-source to that source. This is because of invariant 3, which states the outgoing flow of a node is equal to the incoming flow. Similarly, the amount of power received by each consumer is equal to the flow from the consumer to the super-sink.

Calculating the transfer along each grid link is simple. We simply look up the flow in the flow matrix for each edge. The only caveat is that this flow may be negative, indicating there was power sent the other way down the cable – in this instance, we simply indicate that the flow travelled in the opposite direction.

3. Conclusion and future directions

In conclusion, smart grids are a great way of solving the issues with power distribution for future cities. They pave the way for a sustainable power model which is able to securely power homes and buildings in a city in a decentralised, fault tolerant fashion. In this paper, we discussed a method of resolving and simulating how a smart grid might function in a real example, indicating how participants might communicate their needs and work out how power should be distributed.

The simulation we provide here demonstrates how power can be distributed in a static city. Of course, in reality, the power requirements are constantly changing. One future direction may be to extend this idea with a notion of time steps, where at each point in time the energy grid can re-balance and update itself. This gives a more realistic simulation, and shows how the same system can handle a more complex setup. It also shows how we might achieve fault tolerance with this model – for example, if a network link becomes unavailable at some point in time, we will see how the grid automatically re-balances itself to account for the change.

Currently the nodes are classified in only two categories with different functionalities: providers and consumers. However, the real world is much more complex and there are many nuances within these categories. For example, let us consider two different power providers. A nuclear power station needs an independent power supply to operate and it cannot be switched on and off on demand. A wind turbine draws power upon start-up and its operation is flexible depending on whether there is wind or not. The future versions of the simulation should take these complexities into account to simulate more realistic scenarios.

The algorithm we provide also accounts for prioritising different consumers. This also ties in well with fault tolerance – if there is a partial loss of power, a priority system will ensure power is redirected to the crucial elements of the grid. Future work may introduce more sophisticated prioritisation of nodes, which need not even be static, and instead change over time.

It is interesting to introduce the idea of *smart buildings* into the system. Smart buildings contain sensors and other networked devices to optimise various aspects of the building. This is useful for deciding more precisely how much energy the building needs. This helps with integrating into energy grids, as more precise information about the building leads to a more efficient energy grid. It would be a useful direction to explore how to incorporate smart buildings into our simulation.

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RECONSTRUCTION OF PUBLIC LIGHTING IN THE MUNICIPALITY OF BRELA

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Abstract. Public lighting in Croatia is owned by municipalities and cities and frequently, due to the use of old technologies, does not meet the technical-light requirements and has high maintenance and replacement costs for worn-out light sources, as well a high electricity consumption. This paper proposes its complete reconstruction, i.e. replacement of the inadequate luminaires with high-efficiency LED lighting fixtures, on existing poles, as opposed to designing new lighting on new poles, which ensures significant savings in electricity consumption and reduction of the carbon footprint.

Furthermore, municipalities can transfer the investment costs to an ESCO company. The ESCO company would then finance the modernization of public lighting at its own expense and acquire its return on investment and its earnings by financing through savings in electricity consumption during an agreed period, after which the long-term earnings from the savings would be acquired by the respective city or municipality.

In addition, by applying to the tender of the Environmental Protection and Energy Efficiency Fund, it is possible to exercise the right to non-refundable investment funds in the amount of 40% to even 80%, for the poorest municipalities and cities.

As an example of a successful project carried out in the above manner, the public lighting reconstruction project of the municipality of Brela was analysed, with an already acquired return on investment and continuous long-term savings. An analysis of the project itself is given, in which simulations and calculations were performed in the Dialux program, and the energy balance of the replacement of street lighting was analysed, as well as the long-term financial and environmental contributions of the realized project.

Key words: *reconstruction of public lighting, LED, energy efficiency, Dialux, ESCO*

1. Introduction

Given the importance of a transition to LED public lighting, the European Union provides strong guidance that encourages the adoption of LED in public lighting. While mercury-based lamps have been completely forbidden, regarding sodium-based lamps, only high-efficiency sodium-discharge lamps may still be used. However, LED lighting, due to its longevity, good economic and ecological performance, improved lighting and technical characteristics, has globally proven itself as the best solution and has become the new world standard in street lighting.

In Croatia, The Environmental Protection and Energy Efficiency Fund co-financed over 300 public lighting projects of total value of over 300 million euros, with more than 15 million euros funded by the Fund, with the achieved CO₂ emissions reduction of over 10 thousand tonnes [1]. By combining the Fund's financing with the financing of one of the ESCO companies specialising in public lighting projects, many of the projects were completed with no investment costs by the municipality or the city what so ever. Moreover, after the period in which the ESCO company refunds its investment through energy savings, the municipality or city is to acquire significant further annual energy savings, usually between 40 and 80%, along with the additional maintenance savings. These energy efficiency and ecology benefits are achieved

without compromising the quality of public lighting, but, on the contrary, by making it safer, more environmentally friendly and while complying with the strict requirements of the technical and lighting professions.

The municipality of Brela executed the reconstruction of public lighting in the proposed manner. The first step was obtaining an energy audit of the public lighting, which was used as a base for the reconstruction project. The next step was the project application to the Fund, which resulted in the realisation of the 40% of the investment funds and the final step was engaging the ESCO company for the execution, which covered the remaining 60% of the investment. The municipality of Brela public lighting reconstruction project is an example of a well-executed project, with a long-term acquired savings in the municipal budget and a significant positive impact on the community.

2. Analysis of the existing public street lighting

The existing public lighting in the Municipality of Brela consisted of 799 lamps of outdated technologies of various types, which were ecologically, economically and technically unacceptable. An overview of the existing lamps, sorted by type, is given in Table 1, classified by areas of coverage, which are the substations.

Table 1 Existing luminaires sorted by technology [2]

	HPS			mercury vapour		Σ pcs
	150 W	250 W	400 W	125 W	125 W	
Substation 1	36	0	0	12	20	68
Substation 2	13	0	0	29	57	99
Substation 3	7	0	0	32	3	42
Substation 4	0	0	0	0	62	62
Substation 5	38	3	16	12	59	128
Substation 6	40	0	0	10	15	65
Substation 7	38	6	0	93	18	155
Substation 8	0	0	0	12	54	66
Substation 9	14	0	0	12	5	31
Substation 10	37	8	4	0	1	50
Substation 11	12	0	0	0	0	12
Substation 12	0	0	0	0	21	21
Σ pcs	235	17	20	212*	315	799

The existing lighting fixtures were powered by 12 standard and pole mounted substations. Out of a total of 799 lamps, as many as 527 were mercury vapour lamps, which are gas discharge lamps that contain mercury and as such are no longer being produced, nor can they be replaced with the same models, given that products containing mercury have been taken out of use and have ceased to be produced in the European Union. The rest of the lamps, 272 of them, were high pressure sodium lamps (HPS), that is, sodium discharge lamps, and as such, have not yet been completely phased out, although they also contain a small amount of mercury. Today, the manufacturers of the aforementioned outdated luminaires have not only stopped producing them and switched to LED, but have also removed the technical data and ies files of almost all mercury vapour lamps and almost all HPS lamps from the internet, so they made them unavailable to the public and highlighted their new high-efficiency and technically advanced LED technology lamps.

Also, as many as 212 mercury lamps were unshaded ball luminaires, highlighted in Table 1 with the symbol *. The specified lamps are of the type shown in Figure 1, which meant that they radiated light into the upper hemisphere, which is also prohibited for street lighting, where an Upward Light Ratio (ULR) of 0% is required. Although it was regarding ambient lamps along the promenade by the sea or within green areas, where removing the glare of such types of fittings experienced by the eyes of the driver was not a requirement, there was no reason not to include the mentioned lamps in the project, given that there are many quality shaded ball luminaires, such as selected lamps for the municipality of Brela, shown in Figure 2. Such lamps consume less electricity, do not contain traces of environmentally problematic mercury, by their design solution meet the lighting requirement for ULR of 0%, and are also pleasing to the eye.



Figure 1 Unshaded ball luminaire [2]



Figure 2 Shaded ball luminaire [3]

Also, due to the impossibility of acquiring lighting fixtures of the original type, in cases of outages or damage, the lighting fixtures were replaced with those available in the warehouse, which in some places further increased the installed power, while in others significantly reduced compliance with the lighting and technical regulations.

The installed power of the existing lighting fixtures was 141.72 kW, according to Table 2, classified by substations.

Table 2 Existing luminaires sorted by installed power [2]

Named power [W]	125	150	250	400	Σ kW
Installed power [W]	156.25	187.5	312.5	500	
Substation 1	32	36	0	0	11.75
Substation 2	86	13	0	0	15.88
Substation 3	35	7	0	0	6.78
Substation 4	62	0	0	0	9.69
Substation 5	71	38	3	16	27.16
Substation 6	25	40	0	0	11.41
Substation 7	111	38	6	0	26.34
Substation 8	66	0	0	0	10.31
Substation 9	17	14	0	0	5.28
Substation 10	1	37	8	4	11.59
Substation 11	0	12	0	0	2.25
Substation 12	21	0	0	0	3.28
Σ kW	82.34	44.06	5.31	10.00	141.72

Although in their names the lamps had markings of 125, 150, 250 and 400 W, respectively, the individual powers with the ballast were over 25% higher, which was shown by an insight

into the bills of electricity consumption paid for powering the municipality's public lighting. False advertising could not be hidden in the *ies* file, for example, for the lamps 150 W and 250 W in their names, according to Figure 3 and Figure 4, read when inserting the luminaire *ies* file into the Dialux program.

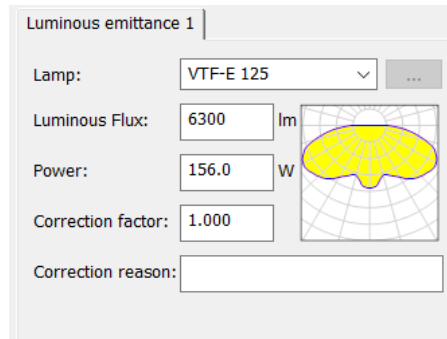


Figure 3 Lamp with named power of 125 W

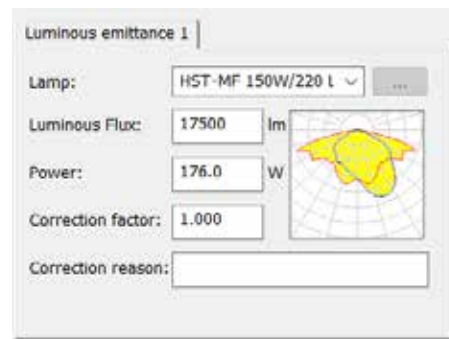


Figure 4 Lamp with named power of 150 W

The existing street lighting hasn't met the light-technical parameters in any street. In some streets the average luminance was too high, somewhere too low, somewhere the required uniformity wasn't met, in some cases the threshold increment (the glare) was too high.

As an example of unsatisfactory existing lighting, a summary of the lighting budget for the existing lamp in the segment 2 of Hrvatskih Branitelja street is given in Figure 5. The street is 341 meters long, 6 meters wide, the distance between the street light poles is 31 meters, and there were 12 lamps of HPS technology, with individual installed power of 187.5 W, and a mounting height of 6 meters. The road class is ME3b. The total installed power was 2250 W.

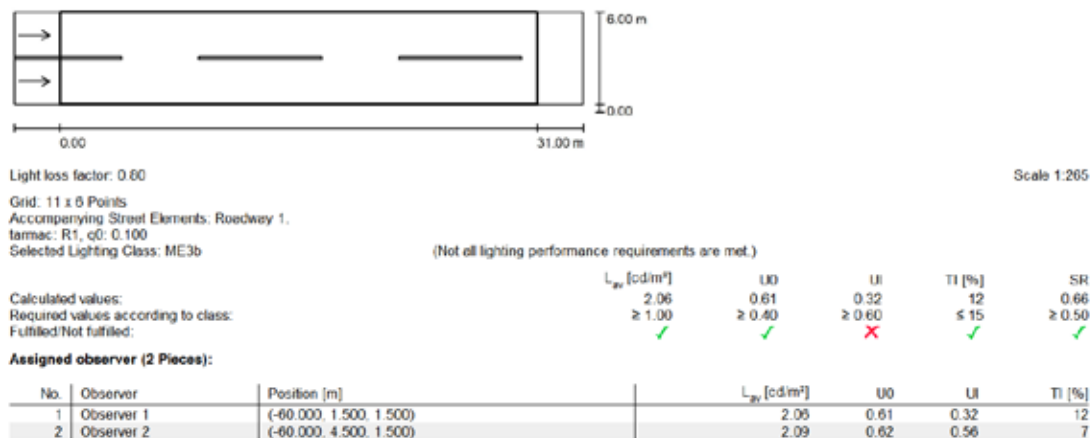


Figure 5 Existing street lighting calculation – Hrvatskih Branitelja street – segment 2

It can be noted that the existing lighting did not meet the standard regarding the longitudinal uniformity UI, calculated as the ratio between minimum luminance and maximum luminance, measured on the axis of the lane. In order to define compliance with the standard by keeping the existing technology, a calculation of the reference lighting was made, such that, with the existing technology, the placement of the poles meets the lighting technical requirements for the specified conditions and road class, according to Figure 6.

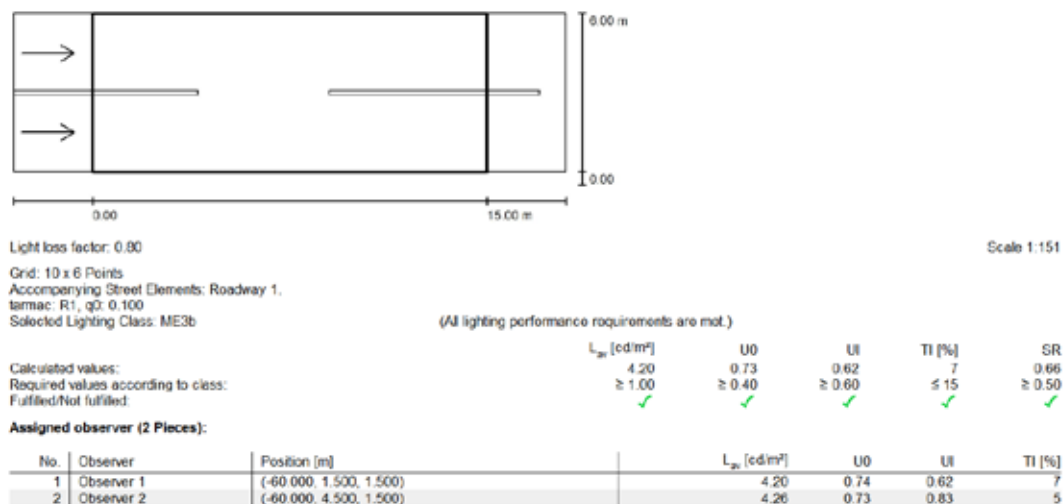


Figure 6 Reference street lighting calculation – Hrvatskih Branitelja street – segment 2

It can be seen from Figure 6 that the maximum distance between the poles that would meet the norm is only 15 meters, which would mean as many as 41 lighting poles in the street instead of the current 12, an installed power of as much as 7687.5 W, which is more than triple of the initially installed power of 2250 W. It is easy to conclude that it is economically unprofitable to keep the existing technology, because construction permits should be obtained for new poles and their placement, as well as for the displacement of the existing poles, the number of lamps and installed power would increase, thus increasing the cost of electricity.

As shown in this chapter, before the project implementation, public lighting in Brela was based on older technology solutions, with high maintenance and electricity consumption costs and many luminaires broken or inadequately replaced, which had negative effects on the environment and traffic safety. Also, most of the street lighting requirements weren't even fulfilled. To fulfil them while keeping the old technology would be overly costly, would take too long, because of the required pole displacements, and would also require doubling the power installed.

The need to replace old, inefficient lighting fixtures, which are dominant in a significant part of Croatia, is not only economic, but also ecological, and an obligation for Croatian municipalities and cities. In the European Union and most of the rest of the world, the complete elimination of mercury and sodium discharge lamps is in progress, because they contain the dangerous substance mercury, and such lighting fixtures are no longer to be produced and must be replaced with LED lighting or other high-efficiency lighting fixtures.

3. Analysis of the proposed new LED lighting

The new LED lighting project of the municipality of Brela is designed in such a way that all existing lighting fixtures are replaced with LED lamps without moving or installing new poles, at the positions of the existing poles, which eliminated the need for the eventual acquisition of building permits and prolongation of the project implementation time. LED technology, by using different combinations of optics, meets even the most difficult lighting requirements, without increasing the installed power or unnecessarily increasing the light flux. All the new lighting fixtures foreseen in the project are full-cut-off designs, without light radiation into the upper hemisphere. The selected lighting colour temperature is 3000K for all lighting fixtures, except for the intersections at the entrance to Brela, treated as conflict zones of the CE road

class in the calculations, for the bocce court, where the applied lighting colour temperature is 4300K, and for the promenade by the sea, with the selected lighting colour temperature of 4000K, due to the preservation of the existing atmosphere created by the old technology by unshaded ball lamps.

The powers of the new LED lamps provided for in the project are standard powers of 20 W, 25 W, 30 W, 35 W, 40 W, 45 W, 50 W, 55 W, 60 W, 65 W, 70 W, 80 W and 90 W. Although even the lamps of lower power could meet the project requirements, round values are provided, due to greater competitiveness and the achievement of more favourable prices in the public procurement process. LED luminaires proposed in the project, sorted by power and by substations, are given in Table 3. Table 4 provides the comparison between the existing and LED public lighting installed power, sorted by substations.

Table 3 LED luminaires sorted by installed power [2]

LED Power [W]	20	25	30	35	40	45	50	55	60	65	70	80	90	Σ pcs	Σ kW
Substation 1	23	24	0	0	12	0	0	0	0	0	9	0	0	68	2.17
Substation 2	24	32	9	1	15	0	16	0	0	2	0	0	0	99	3.12
Substation 3	10	11	10	0	11	0	0	0	0	0	0	0	0	42	1.22
Substation 4	0	2	0	7	30	0	15	8	0	0	0	0	0	62	2.69
Substation 5	14	25	30	4	5	0	0	0	22	20	16	0	11	147	6.88
Substation 6	0	21	16	0	0	0	0	9	19	0	0	0	0	65	2.64
Substation 7	0	6	18	26	21	57	0	0	9	0	0	0	21	158	7.44
Substation 8	16	11	0	17	22	0	0	0	0	0	0	0	0	66	2.07
Substation 9	5	26	0	0	0	0	0	0	0	0	0	0	0	31	0.75
Substation 10	0	15	0	0	0	0	0	31	0	0	0	8	0	54	2.72
Substation 11	0	0	0	0	0	0	0	12	0	0	0	0	0	12	0.66
Substation 12	0	21	0	0	0	0	0	0	0	0	0	0	0	21	0.53
Σ pcs	92	194	83	55	116	57	31	60	50	22	25	8	32	825	
Σ kW	1.84	4.85	2.49	1.93	4.64	2.57	1.55	3.30	3.00	1.43	1.75	0.64	2.88		32.86

Table 4 Existing and proposed LED luminaires installed power comparison [2]

	Existing lamps		Proposed LED lamps	
	pieces	[kW]	pieces	[kW]
Substation 1	68	11.75	68	2.17
Substation 2	99	15.88	99	3.12
Substation 3	42	6.78	42	1.22
Substation 4	62	9.69	62	2.69
Substation 5	128	27.16	147	6.88
Substation 6	65	11.41	65	2.64
Substation 7	155	26.34	158	7.44
Substation 8	63	9.84	66	2.07
Substation 9	34	5.75	31	0.75
Substation 10	50	11.59	54	2.72
Substation 11	12	2.25	12	0.66
Substation 12	21	3.28	21	0.53
Σ	799	141.72	825	32.86

Out of the 50 pieces of 60 W proposed LED lamps, as shown in Table 3, 28 were to be

mounted in pairs by means of two lamps on the same pole, out of the 25 pieces of 70 W lamps, 16 were to be mounted in this way, as well as all 8 pieces of the 80 W lamps, which is the reason for the increased number of lamps from 799 to 825, with the original number of poles retained. Out of 194 LED lamps with a power of 25 W, as many as 139 of them are orientation lighting, used as ambient lighting of green areas, promenades and gardens, with a total power of 3.84 kW.

Table 4 shows that, although the total number of lamps has increased by 26 compared to the existing lamps, the total installed power has been significantly reduced, from 141.72 kW to 32.86 kW, or by as much as 71.86%. The reason for this is that LED technology can more easily meet the lighting requirements, with significantly less installed power. As an example of a street with requirements that are harder to fill, Figure 7 shows the results overview from the lighting simulation of the Hrvatskih Branitelja street – segment 2 for the LED lamp of the power proposed in the project. The simulation of the same street with the same parameters was given in the previous chapter as an example of the calculation of existing lighting.

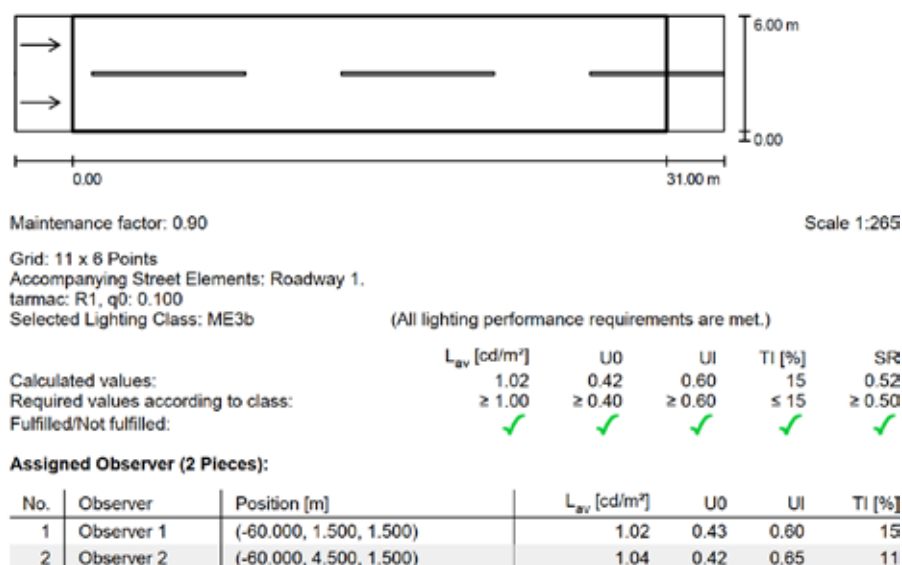


Figure 7 LED street lighting calculation – Hrvatskih Branitelja street – segment 2

It can be seen that for the mentioned road of class ME3b, the road width of 6 meters, the distance between the poles of 31 meters and the installation height of 6 meters, therefore, with the same arrangement and mounting position as the existing luminaires, the LED luminaire of a Croatian manufacturer of only 55 W fully satisfies all the lighting requirements. Other parameters taken into consideration in both simulations are the distance from pole to roadway of 0.5 meters, tarmac R1, while the light loss factor for the old technology was taken as 0.8, and for LED 0.9, which is the standard in street lighting projects.

From the point of view of the Environmental Protection and Energy Efficiency Fund, for the calculation of savings in electricity consumption and CO₂ emissions, the installed power of the proposed new lighting is not to be compared with the existing one, but with the reference lighting. Reference lighting is a lighting solution where, while maintaining the existing technology, by adding and distributing the poles, the lighting requirements are barely met, i.e., with a minimum of additional poles and lamps, that is, with a maximum distance between two poles at which the results of the light calculation will be satisfactory. The reason for such a comparison is that comparisons of the power, consumption and environmental pollution of two project solutions, one of which does not meet the standards at all, should not be made. Only two solutions can be compared, both of which are applicable in practice, i.e., permitted to be executed. Requirements for individual road classes must be met. For the municipality of Brela, simulations of all streets

and lighted areas were made for reference lighting defined in this way, with existing, and newly designed lighting, with LED technology, and savings calculations were made. In the example of the considered segment 2 of Hrvatskih Branitelja street, the reduction of the installed power of the newly proposed LED lighting, which is only 660 W, compared to the reference lighting power of 7687.5 W, is as much as 7027.5 W, that is, as much as 91.4%. The conclusion is that retaining the existing technology as a project solution is out of the question.

4. Energy efficiency of the project

By summing up the individual engaged powers of the reference lighting of all segments of all streets, all intersections, all orientation lighting and bocce court lighting of the Project of the public lighting reconstruction of the municipality of Brela, a total engaged power of 161648 W, or 161.65 kW, was obtained. For 4100 hours of operation of public lighting per year, the annual electricity consumption of reference lighting for the entire public lighting of the municipality is:

$$161.65 \text{ [kW]} * 4100 \text{ [h/year]} = 662765 \text{ [kWh/year]} \quad (1)$$

The total annual emission of polluting gases for reference lighting is:

$$662765 \text{ [kWh/year]} * 0.376 \text{ [kgCO}_2\text{/kWh]} = 249.20 \text{ tCO}_2\text{/year} \quad (2)$$

By summing up the individual powers of the proposed LED lighting of all segments of all streets, all intersections, all orientation lighting and bowling alley lighting of the Project of the public lighting reconstruction of the municipality of Brela, the total engaged power of 32860 W, or 32.86 kW, was obtained. For 4100 hours of operation of public lighting per year, the annual electricity consumption of the proposed LED lighting for the entire public lighting of the municipality is:

$$32.86 \text{ [kW]} * 4100 \text{ [h/year]} = 134726 \text{ [kWh/year]} \quad (3)$$

The total annual emission of polluting gases from the proposed LED lighting is:

$$134726 \text{ [kWh/year]} * 0.376 \text{ [kgCO}_2\text{/kWh]} = 50.66 \text{ tCO}_2\text{/year} \quad (4)$$

The annual savings in electricity consumption that would be achieved by the implementation of the LED lighting proposed by the project instead of supplementing the existing lighting in terms of the formation of reference satisfactory lighting would amount to:

$$662765 \text{ [kWh/year]} - 134726 \text{ [kWh/year]} = 528039 \text{ [kWh/year]} \quad (5)$$

Energy efficiency is defined as the percentage of electricity consumption savings of the lighting proposed by the project compared to the reference lighting of the existing technology and represents a reduction in annual consumption for the municipality, which amounts to:

$$528039 \text{ [kWh/year]} / 662765 \text{ [kWh/year]} = 79.68\% \quad (6)$$

With the price of electricity for public lighting of 1.09 kn/kWh, distributed by HEP in 2013, when the project was created, the annual consumption provided by the project reference lighting for the municipality of Brela would be:

$$662765 \text{ [kWh/year]} * 1.09 \text{ [kn/kWh]} = 722420 \text{ [kn/year]} = 95881.6 \text{ [€/year]} \quad (7)$$

For the new proposed lighting with LED technology, the annual consumption of el. energy would be:

$$134726 \text{ [kWh/year]} * 1.09 \text{ [kn/kWh]} = 146860 \text{ [kn/year]} = 19491.7 \text{ [€/year]} \quad (8)$$

Consequently, the annual financial savings for the Municipality of Brela foreseen by the project would be:

$$722420 \text{ [kn/year]} - 146860 \text{ [kn/year]} = 575560 \text{ [kn/year]} = 76389.94 \text{ [€/year]} \quad (9)$$

In conclusion, the energy efficiency of the project, which compares the new lighting solution with a reference one, is around 80%, which makes it an excellent project. Most of the reconstruction projects for cities and municipalities in Croatia would be of similar high quality, being that most of the luminaires are still of older technologies.

The actual energy consumption savings of public lighting in Brela municipality, which refers to changing the existing lighting with LED lighting and providing real savings, are rarely as high as the savings defined by the energy efficiency, but are often very close to it, for example, the actual savings calculated in this project were 71.86%.

5. Project execution and review

The Municipality of Brela, by submitting its public lighting reconstruction project to the Environmental Protection and Energy Efficiency Fund, received a subsidy of 40% of the total investment amount. After the public tender of the municipality of Brela, the implementation of the public lighting reconstruction project was executed by a private Croatian ESCO company, which secured the other 60% of the project's investment amount with a contracted energy service based on the principle of the ESCO model. The ESCO company from Split, also a Croatian manufacturer of street LED lighting fixtures, responsible for installation, has also taken over the responsibility for installed lighting fixtures for the next 5 years. In this way, the municipality collected the stated remainder of the investment only and exclusively from accomplished and verified electricity savings, i.e., without new budget debits.

As the project predicted the installed power of new LED lighting to be around 70% lower than the existing one, which the private company respected with its installed lighting, the expected real savings were about 70%, and the ESCO company guaranteed the municipality savings of 60%. This meant that within the five contracted years, the company made profit from the guaranteed savings of 60% of the money spent on electricity for public lighting, i.e. the municipality paid up to 40% of the previous energy consumption costs to HEP, kept the difference to 40%, around 10%, of the consumption as its own savings, and the savings over the contracted 40% were forwarded to the ESCO company. However, after the expiration of the contracted period of 5 years, the municipality itself began to earn the aforementioned electricity consumption savings of around 70%, which, according to the project for the installed power of the existing lighting of 141.72 kW, amounts to close to 60000 € per year:

$$0.7 * 141.72 \text{ [kW]} * 4100 \text{ [h]} * 1.09 \text{ [kn/kWh]} = 443338.77 \text{ [kn]} \quad (10)$$

$$443338.77 \text{ [kn]} / 7,5345 \text{ [€/kn]} = 58841.17 \text{ [€]} \quad (11)$$

The project was executed in 2016. Figure 8 shows the process of installing lighting fixtures, that is, replacing the existing lighting with new LED lighting.



Figure 8 Installation of lamps [4]

In 2016, the mayor of the municipality of Brela stated the amount of 388712 € as the total value of the project and the amount of 155485 €, as 40% of the total investment, donated to the municipality from EU funds by the decision on the selection of beneficiaries of the Fund for Environmental Protection and energy efficiency to the municipality. [2]

It was also publicly confirmed that the annual savings were up to 66360 €/year, which from 2021 belonged to the municipality, and made a significant contribution to new investments in the development of the municipality's infrastructure, for example, restoring almost all the roads in the town, investing in beaches, promenades, and the construction of a new kindergarten. The municipality, also, encouraged by the high-quality public lighting reconstruction project, continued to develop through other projects, for example, in 2018 and 2019, it became the first municipality in Croatia with optical technology internet, where every resident got access to superfast internet, up to 100 times faster than the previous speed. [5]

6. Conclusion

Where possible, it is recommended to carry out a public lighting reconstruction project instead of building a new one, because it is faster, does not require building permits or new poles. Although there are other high-efficiency technologies, LED should be the first choice, precisely for projects of reconstruction or modernization of public lighting, because by combining lenses on LED boards, it is possible to design and produce lamps that will meet even the most difficult requirements and regulations of street lighting design, which would be unattainable by other technologies without adding new poles or rearranging the existing ones.

The ecological advantages of modernising street lighting are the complete elimination of light radiation in the upper hemisphere, the complete elimination of mercury and sodium from lighting fixtures, as well as the reduction of CO₂ emissions into the environment due to the reduction of electricity consumption by 40-80%. The aforementioned reduction in electricity consumption is the main reason for recommending the modernization of street lighting to all cities and municipalities, as it minimises the investment return time due to earnings that would be obtained in the long term through savings.

By hiring an ESCO company, the modernization of street lighting becomes a project without investment, with a guaranteed significant profit from savings after the expiration of the contract with the company. In combination with co-financing from the Environmental Protection and Energy Efficiency Fund, the contracted period is further reduced. As shown in the example of the reconstruction of the public lighting in the municipality of Brela, in that case the municipality

or city could boast of new, high-quality, energy-efficient public lighting installed completely free of charge, but also of long-term profit from savings after the expiration of the period agreed with the ESCO company, which is itself assumed to be the entire investment and risk of the project.

The municipality of Brela, with the project implemented in 2016 and the specified agreed-upon period of 5 years, has begun to obtain the annual profit in 2021. By reducing the energy consumption by over 75%, significantly more than contractually guaranteed by the ESCO company, the municipality began to achieve a long-term profit of over 65000 euros per year, which it uses for additional investments in infrastructure and the quality of life of its citizens. The reconstruction process of public lighting in the municipality of Brela is an example that should be followed by all cities and municipalities in Croatia that have not yet modernised their public lighting.

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DESIGN OF A SMALL WIND TURBINE ELECTRIC DRIVE USING THE PSIM PROGRAM

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Abstract. This article describes a method for selecting wind turbine generators for small electric drives using the PSIM program. It details the modelling of wind turbine components: the turbine itself, gear ratio, generator, and voltage-frequency converter, considering different generator types. It provides the simulation of voltage and frequency regulation of the generator output using the inverter.

Key parameters, such as rotation speed, torque, and output voltage and current, were analysed for the intended 5 kW electric motor drive, simulated as a consumer. Results are presented through PSIM program diagrams, and a comparison of models with different generators is conducted.

This work demonstrates the use of PSIM for simulating wind turbines with desired generators and consumers, particularly for small electric drives. PSIM offers a user-friendly interface, fast simulations, clear graphical displays, and allows for quick testing and selection of wind turbine elements.

Key words: *PSIM program, generator, wind turbine, inverter*

1. Introduction

This paper provides brief instructions for creating an electric circuit model, starting a simulation and defining the display of output variables of interest in the PSIM program, which is available to teaching staff and students of technical universities. The program is primarily intended for simulations in the field of power electronics and electric motor drives and, as such, is ideal for designing small electric motor drives and power units. The program offers various models of electric machines, elements of power electronics, electrical and mechanical consumers, whose parameters can be adjusted at will, as well as elements of renewable energy sources, such as solar panels and wind turbines. In the model itself, the offered measuring devices can be placed at will, and the graphic displays of the measured quantities can be adjusted according to the performed simulation.

The emphasis was placed on the selection of the optimal electric generator that would be the heart of the power unit for the defined wind turbine and the considered consumer, using the PSIM program. Since the wind turbine is designed to power a small electric drive with a power of about 5 kW, representing a small private workshop, with a consumer such as a milling machine, an industrial sewing machine, a CNC machine or one of the woodworking machines, two simple solutions were proposed, by means of simulations of the associated models of wind turbines with different electric generators, typical for simpler and more affordable versions of wind turbine power units, with a classic synchronous generator with direct current excitation and with a synchronous generator with permanent magnets (PMSG).

2. PSIM software

PSIM is an electrical circuit simulation software package, designed specifically for use in power electronics and motor drive simulations, but can be used to simulate any electrical circuit, as well as electric power units. The PSIM uses the analysis and integration of trapezoidal rules as the basis of its simulation algorithm. PSIM provides a schematic recording interface and a *Simview* waveform viewer. PSIM has several modules that extend its functionality to specific areas of power circuit simulation and design, including control theory of electric motors, photovoltaic systems, and wind turbines. The PSIM program is used in industry for research and product development, as well as by educational institutions for research and teaching. [1] In order to start the project in the PSIM program, it is necessary to press the white icon that indicates a *New sheet* in the menu located in the upper left corner. Figure 1 shows the toolbar in the PSIM program.



Figure 1 Toolbar

The toolbar menu offers many tools that are used for assembling electrical circuits. It offers a tool for saving an image, a tool for saving a file, a drawing tool, a tool for moving objects, a tool for zooming in and out of the screen, which provides smoother work, and a menu for simulations of electrical circuits. When assembling the electric circuit begins, it is necessary to select the desired category and object in the menu of the desktop of the PSIM program within the *Elements* tab, for example, in the category of *Power* elements, to select the *Transformers* group and select the desired transformer, for example, a single-phase transformer, as shown in Figure 2. Program offers a large selection of objects in its elements base, for example, objects that represent sources of electrical energy, switches, transformers, resistors, capacitors, coils, tools for measuring voltage and current, etc. [1]

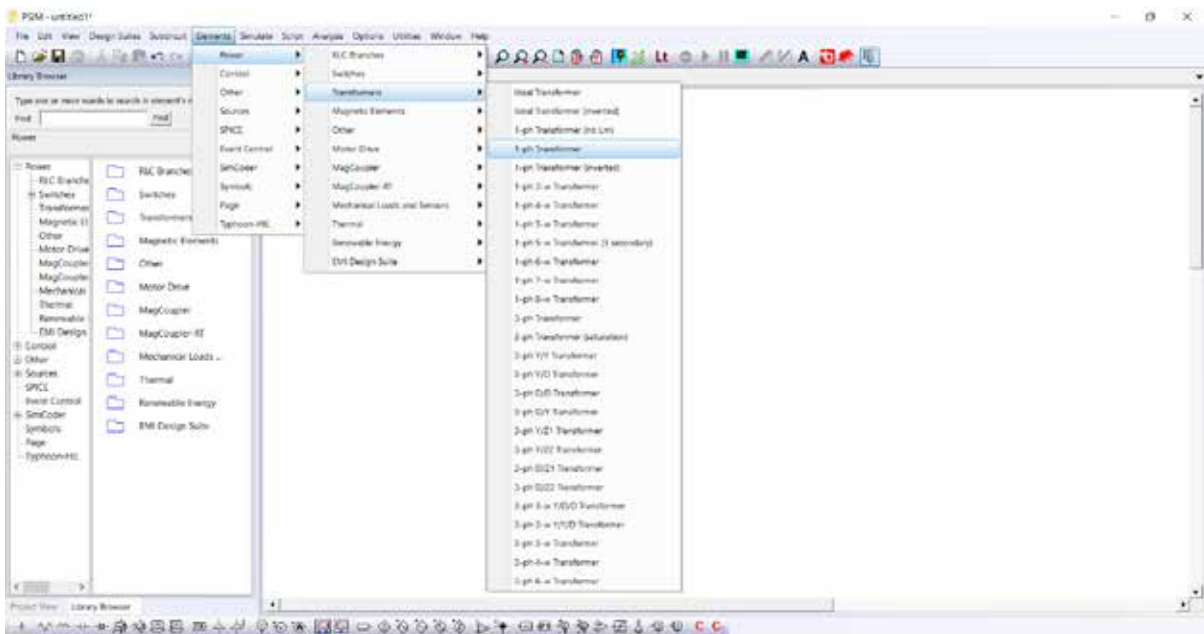


Figure 2 Elements tab in PSIM toolbar

The parameters of the elements in the simulation can be easily accessed by double-clicking on the element itself in the model space, which opens a pop-up window, in which they can be changed, for example, those of a single-phase transformer, according to Figure 3. When a certain

circuit is created, to start the simulation, it is necessary to select the *Run PSIM Simulation* option within the *Simulate* tab, according to Figure 4. Additionally, for time diagrams, the duration of the simulation can be selected in the previous step by selecting the Simulation control option within the same tab, which causes the clock to appear in the model itself. 20 ms was chosen for the sinusoidal values in the example.



Figure 3 Setting element parameters

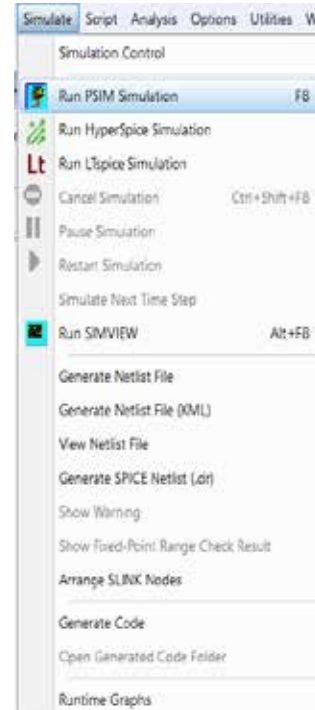


Figure 4 Starting the simulation

After starting the simulation, the *Properties* pop-up window opens, according to Figure 5. In it, one needs to select the quantities wanting to display, by clicking on their labels in the left part of the screen and on the *Add* button. Figure 6 shows an example of the result overview. Results can be viewed on a single or multiple diagrams for one or more measured quantities. [1]

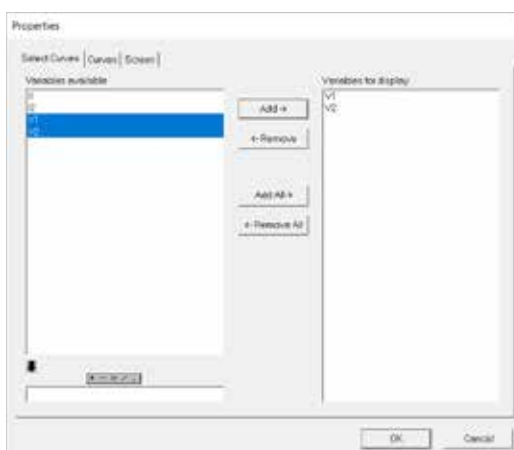


Figure 5 An example of quantities selection

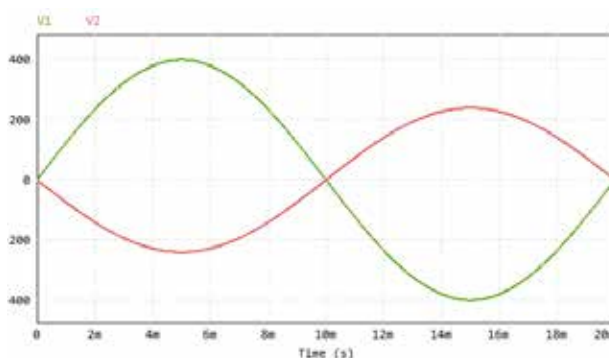


Figure 6 An example of a result overview

3. Simulation of a power unit with a synchronous generator with DC excitation

For the operation of a small electric drive powered by a wind turbine power unit, a model of a power unit with a synchronous generator with direct current excitation was created. The

simulation was performed in the PSIM program, in which graphical and numerical presentations of the simulation results were created. A synchronous generator was used as a source of electricity to power a small 5 kW electric drive. The generator's excitation was supplied by a DC source. The synchronous generator, which has a constant rotation speed, is directly connected to the frequency converter. The role of the frequency converter is to adjust the voltage and frequency to the desired values, in this case, a voltage of amplitude 400 V and a frequency of 50 Hz. The generator is driven by a mechanical source, which rotates at a speed of 100 rpm and is an approximation of a wind turbine.

Figure 7 shows the simulation scheme of a wind turbine with a synchronous generator with DC excitation.

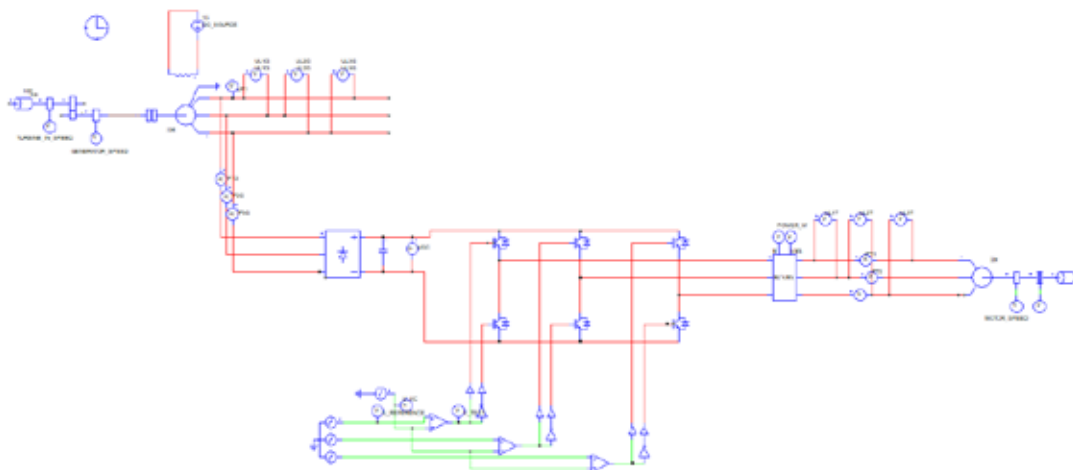


Figure 7 Simulation scheme of a wind turbine with a synchronous generator with DC excitation

The simulation is made of three parts: a wind turbine with a synchronous generator, a frequency converter and a consumer. In this case, the main power source for the drive is a classic synchronous generator. In order to start the rotor of the generator, it is necessary to bring a certain torque to it, which rotates at a certain speed. In this case, a constant rotation speed source of mechanical power was used, because in this simulation a constant rotation speed of the generator is considered. The speed of the mechanical power source for the generator to be in rated condition should be 100 rpm. A symbolic voltmeter, which represents any measuring device, in this case a tachometer, is connected to the sensor of the speed of rotation of the machine, so that it can be displayed graphically in the PSIM program.

Viewed from left to right, Figure 8 shows the mechanical source that drives the generator, representing the rotor to which the blades are connected, then the sensor of its rotation speed, the multiplier and the sensor of the rotation speed of the generator shaft.

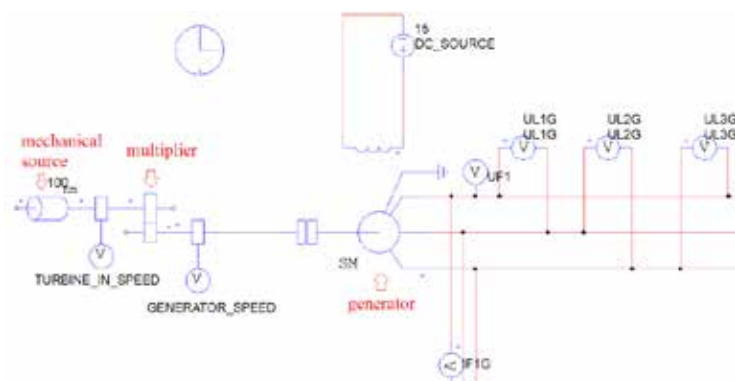


Figure 8 Adjusting the speed of rotation of the generator

The generator speed sensor is located on the output shaft of the multiplier, that is, on the generator shaft. Because the transmission ratio of the multiplier equals 1:15, according to Figure 9, the output speed, in the case of the rated speed of the turbine, will be 1500 rpm, which will enable the rated operation of the generator. Figure 10. gives a graphic presentation of the generator and turbine rotation speeds, and it can be read that the generator rotation speed is 1500 rpm for a mechanical source speed of 100 rpm.

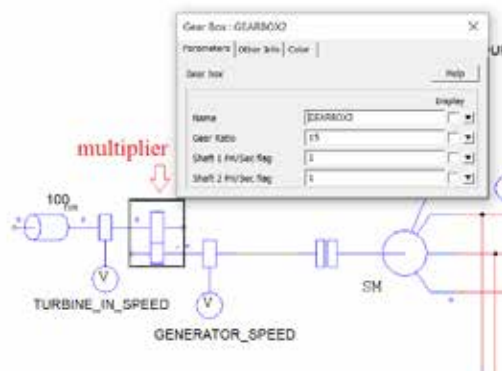


Figure 9 Multiplier

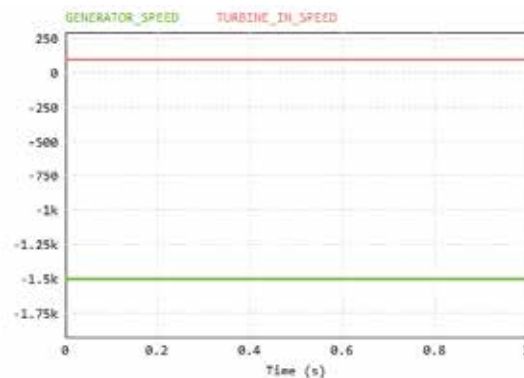


Figure 10 Input and output multiplier speed

Although the program provides a wind turbine in its base of elements, for simplicity purposes, a simple mechanical source with a constant rotation speed of 100 rpm was selected for the simulation. To ensure a constant rotation speed of the generator shaft in practice, a multiplicator with a planetary gear mechanism could be used, which, for certain deviations of the rotation speed of the wind turbine from the predicted 100 rpm, for example, for an increase to 110 rpm, adjusts its transmission ratio to the desired output speed of 1500 rpm in real time.

The generator is connected to the output shaft of the multiplier using a clutch, which enables a rigid connection. In this simulation, a classical three-phase generator is used. For direct current excitation, it is necessary to have an auxiliary DC source of electricity, that will supply the excitation winding of the synchronous generator, or else a static rectifier that would be powered by an independent AC source or from the terminals of the synchronous generator. [2] On the stator, there are terminals for the ends and beginnings of the armature winding, which can be connected in a star or delta connection, as desired. In this case, only the output three phases of the generator are shown. Figure 11 shows the electrical parameters of the synchronous generator, and Figure 12 shows the power supply of the excitation winding.

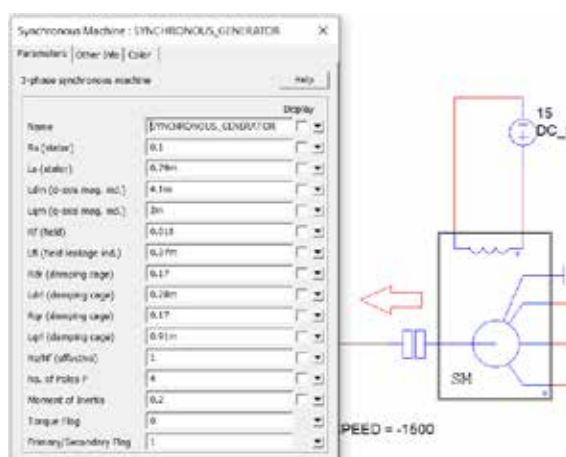


Figure 11 Parameters of a synchronous generator

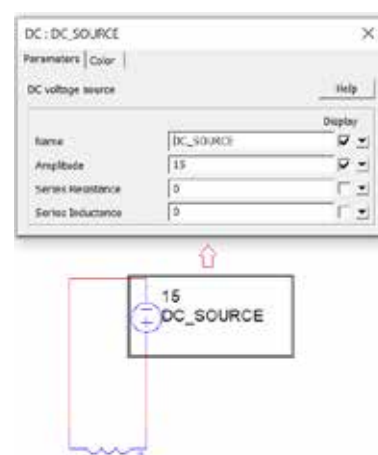


Figure 12 Excitation winding power supply

It can be noted that the active resistance of the stator winding is 0.1Ω , the inductive resistance of the stator winding is $0.79 \text{ m}\Omega$. The number of poles on the rotor is 4. According to the number of poles, it can be concluded that the nominal speed of rotation is 1500 rpm. It can be seen that the DC power source of the excitation winding provides a voltage of 15 V. The voltage measured by a voltmeter at the output of the generator is the line voltage between the two phases and is about 2000 V of maximal value. The output voltages of the generator are phase-shifted by 120 degrees, that is, they form a three-phase symmetrical voltage system. The transient phenomenon of voltage increase is shown in Figure 13.

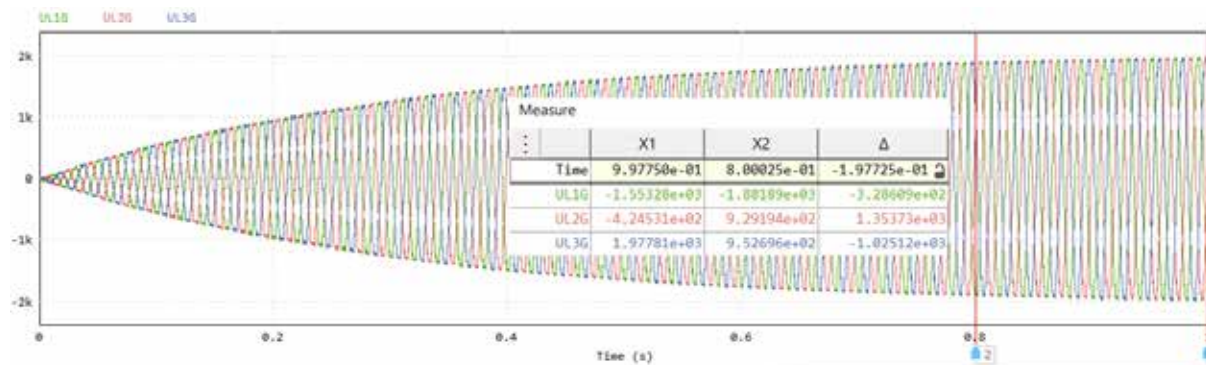


Figure 13 The transient phenomenon of generator voltage

Figure 13 shows how the voltage gradually increases to a certain value, how the duration of the simulation time increases and reaches a stationary maximum value of 2000 V within 1 s of the simulation. A separate presentation of the output voltages of the generator is given in Figure 14.

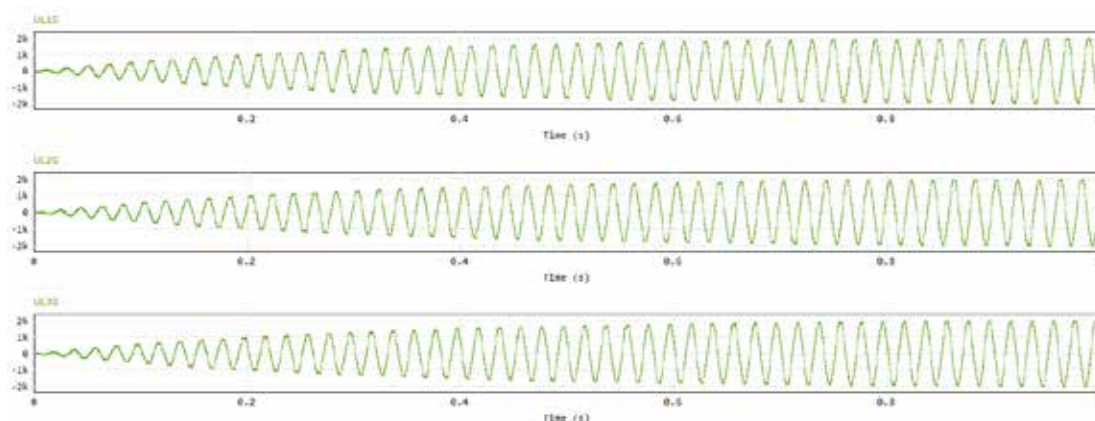


Figure 14 Line voltages at the output of the generator

The output terminals of the generator are further connected to the three-phase inverter, which has the important role of transforming the voltage given by the generator to the voltage required by the electric drive, in this case a three-phase AC voltage of maximal value of 400 V, frequency of 50 Hz. A motor power factor of between 0.8 and 1 should also be provided. Figure 15 shows the currents that the generator delivers to the frequency converter.

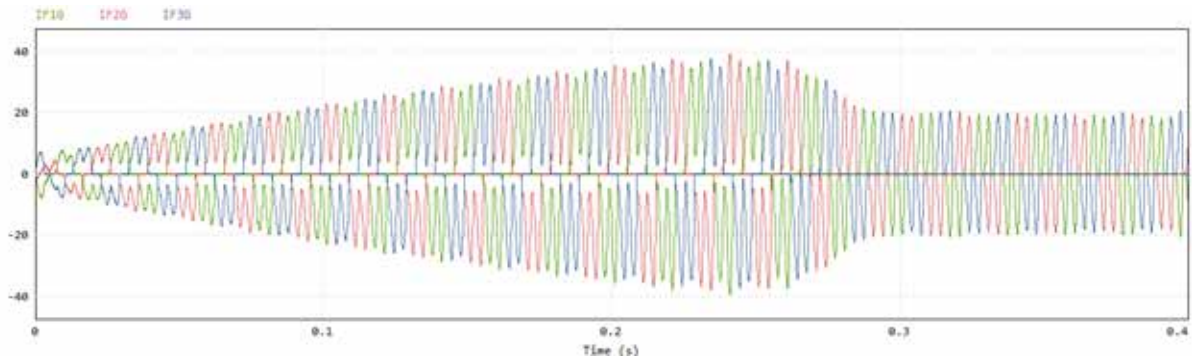


Figure 15 Line currents at the output of the generator

The figure shows that the current increases to a maximum amplitude of 40 A and that after 0.3 s it drops to a current of a maximal amplitude of 20 A and remains constant. The currents are also phase-shifted by 120 degrees, as they form a three-phase symmetrical system of currents. Figure 16 shows the scheme of the frequency converter, which consists of three parts: a rectifier, a filter and a converter.

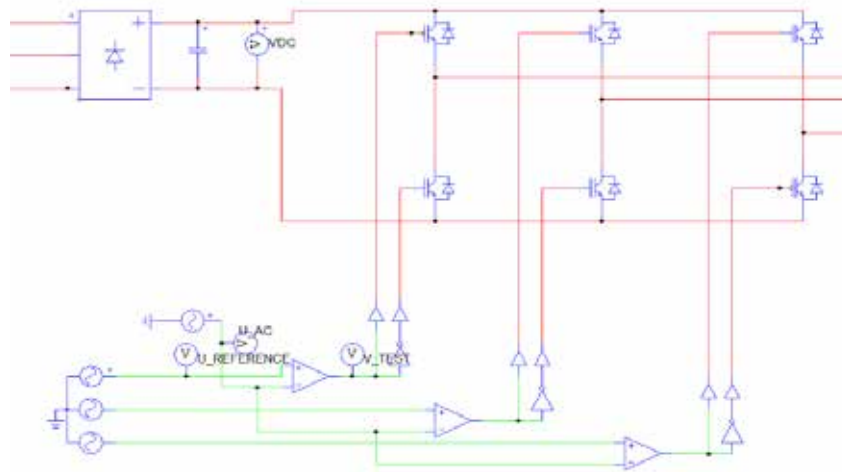


Figure 16 Frequency converter

The rectifier is an electronic part of the converter circuit directly connected to the input three-phase AC voltage of constant amplitude and frequency, which is usually 50 or 60 Hz. In this paper, a three-phase rectifier is presented, and there are versions of rectifiers for connection to single-phase voltage. The rectifier can be composed of diodes, thyristors, or their combinations. By using only diodes in its composition, the rectifier is uncontrollable. [3]

The DC intermediate circuit is an important part of the frequency converter, because it is not possible to efficiently and directly convert a voltage of one amplitude and frequency into a voltage of another amplitude and frequency. The role of the DC intermediate circuit is to “smooth” the pulsating DC voltage provided at the output of the rectifier. [3]

The inverter is an electronic circuit that changes the frequency and voltage and its output is directly connected to the electrical network or electrical consumer. Its task is to modify the input DC voltage into a three-phase symmetrical alternating voltage of the required frequency and amplitude at the output. [3]

The inverter can provide a variable amplitude output voltage only if it receives a constant DC voltage. The inverter is controlled by *Pulse Wide Modulation* (PWM). The inverter consists of 6 IGBT transistors, assembled in such a way that their collector and emitter are connected

to the DC voltage U_G , while the gate is connected to the control circuit that controls the system of turning the switches on and off. In this simulation, a three-phase sine source, a single phase sine source, a comparator and an on-off regulator were used to control the transistor. A high-amplitude voltage is not required to power the transistor, so a three-phase symmetrical voltage supply system with an amplitude of 10 V is used for this reason. The frequency of the sinusoidal source is 50 Hz, which also controls the output frequency of the frequency converter (inverter).

A comparator is a type of controlled switch that works on the principle of two inputs, negative and positive. A constant voltage is applied to the positive input, which has the desired frequency that is to be achieved at the output of the frequency converter. A voltage is applied to the negative input, which controls the operation of the transistor. A high-frequency voltage of up to several thousand hertz is applied to the negative input. When the negative input voltage is greater than the positive input voltage, the comparator sends a pulse to the transistor, which acts as a switch. When the positive input is low, the comparator does not send a pulse. If the values of the two inputs are equal, the output is undefined and will retain the previous value. [4] Figure 17 shows the output pulse that is delivered to the transistor and it is defined as V_{TEST} and it is thus distributed and delivered to other comparators and voltages used to control the frequency converter.

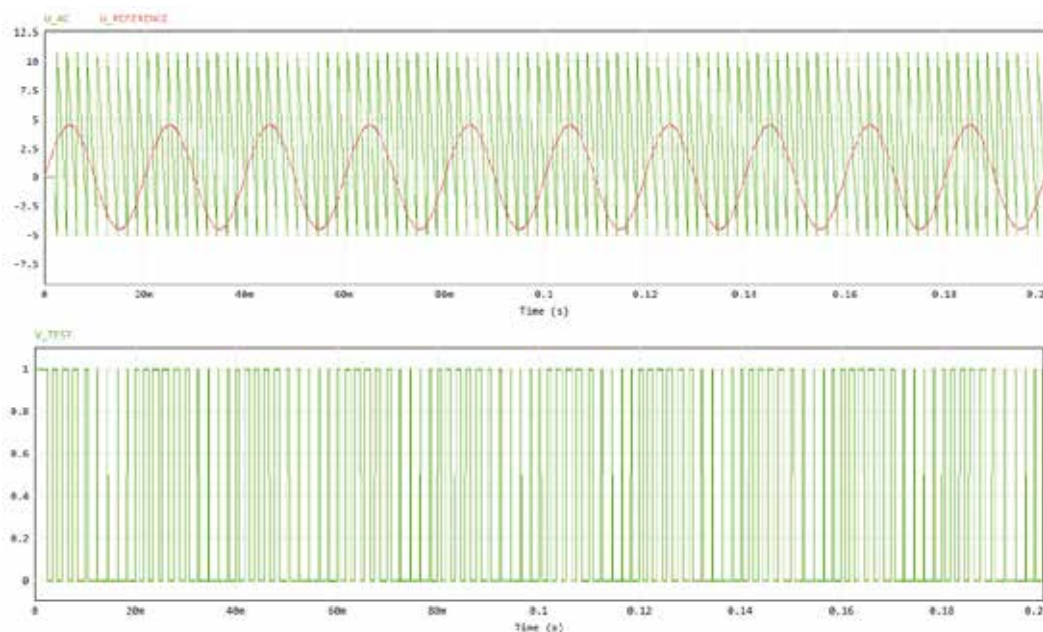


Figure 17 Comparator input and output voltages

Figure 18 shows the voltages at the output of the frequency converter, i.e., the motor supply voltages, and it can be seen that they are set to an amplitude of 400 V.

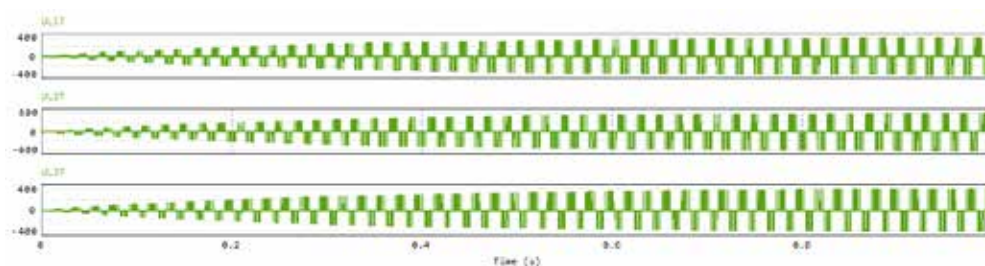


Figure 18 Voltages at the output of the converter

In addition to devices for measuring voltages and currents, a wattmeter and a device for

measuring $\cos\phi$ or the power factor, which is the ratio of active and apparent power of the consumer, in this case of a squirrel-cage induction motor, are connected to the output of the inverter. The program, using the mentioned element, also enables the measurement of electricity consumption during the duration of the simulation for which it was set, but, as it is a short-term simulation, the consumer consumption is not analysed in detail. Figure 19 shows the wattmeter used in the simulation and Figure 20 shows the active component of the power supplied to the consumer.

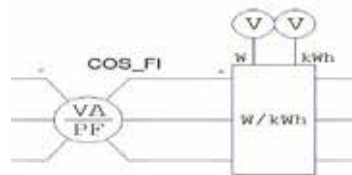


Figure 19 Wattmeter

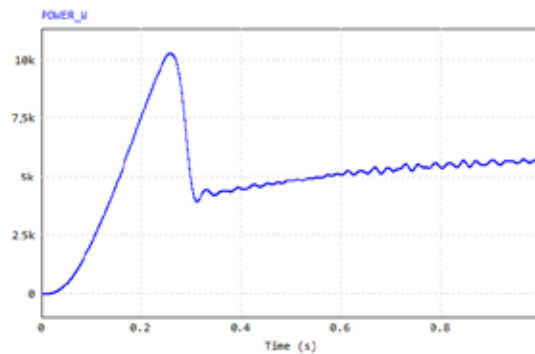


Figure 20 Active power of the consumer

It can be seen from Figure 20 that the active electric power equals 5486 W and, by looking at the simulation data, the electric motor will deliver a mechanical power of 5000 W to a consumer, which enables it not to be loaded over the rated power. Namely, an induction motor with a power of 5 kW and a speed of 1434 rpm was used for this simulation, which means that it has two pairs of poles and its slip is 4.4%. Knowing the output and input power, it can be concluded that the efficiency of the electric motor connected to the frequency converter equals 91%.

Figure 21 shows the electrical parameters chosen for the electric motor drive, i.e., the parameters of the squirrel-cage induction motor with a rated voltage amplitude of 400 V. The active resistance of the stator is 1.9Ω and the inductance is 5.4 mH. The number of poles is 4, which means that the rotation speed of the rotating magnetic field is 1500 rpm, and the moment of inertia of the rotor is equal to 0.0133 kgm^2 . The resistance of the rotor equals 1.5Ω . Figure 22 shows the start-up of the motor to the rated speed.

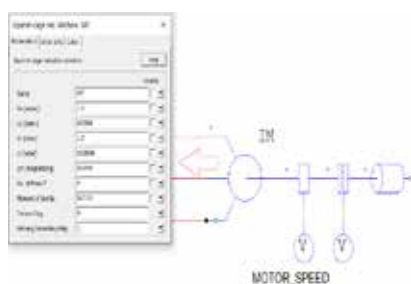


Figure 21 Induction motor

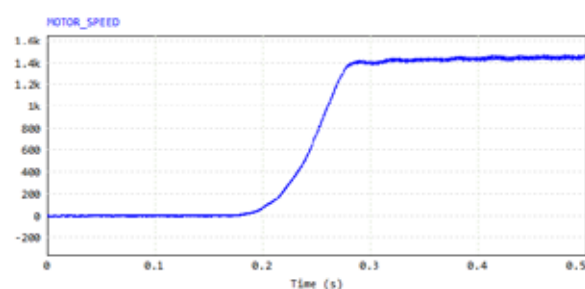


Figure 22 Motor speed

The speed of the electric motor increases from zero to 1434 rpm, which is achieved in 0.35 seconds, after which it maintains a stationary value. This diagram shows the rotation speed of the electric motor for the rated load of the electric motor in the simulation. The electric motor will rotate at a speed of 1434 rpm if a load connected to it that has a torque equal to the rated electric motor load. In the case of consumers of higher mechanical power, the speed of the electric motor will be further increased. The nominal torque at the output of the electric motor is 32 Nm. The motor torque during the startup is shown in Figure 23.

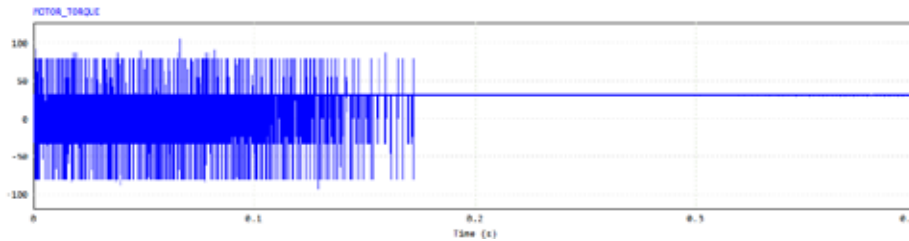


Figure 23 Motor torque

It can be seen that the electric motor initially has a large starting torque, which is 2 times larger than the nominal one, and that after 0.2 s it reaches a constant torque at the output, which is 32 Nm. From the simulation it can also be seen that the power factor during takeoff reaches a value of 0.86.

4. Simulation of a power unit with a PMSG

For the second simulation, instead of a synchronous generator with DC excitation, a synchronous generator with permanent magnets was used. The simulation is completely analogous to the previous one, only the generator has been replaced and the frequency converter has been slightly adjusted. [5]

Figure 24 shows the simulation scheme of a power unit with a synchronous generator with permanent magnets.

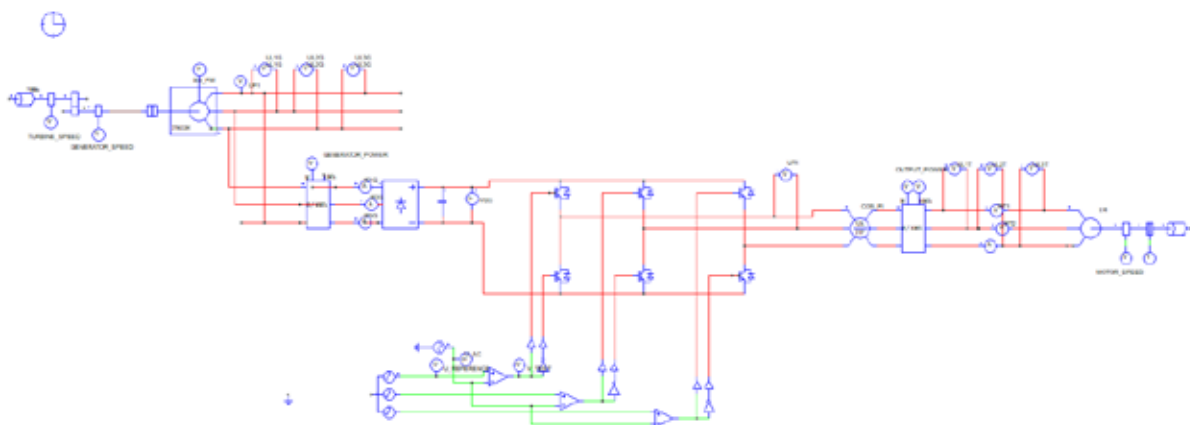


Figure 24 Simulation scheme of a wind turbine with PMSG

Figure 25 shows a three-phase synchronous generator with permanent magnets and its parameters. 26 shows the rotation speed of a synchronous generator with permanent magnets. The speed of rotation of the generator is 1500 rpm and is constant.

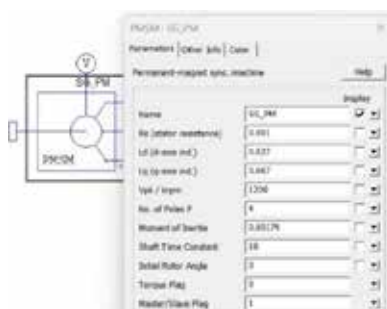


Figure 25 Parameters of a PMSG

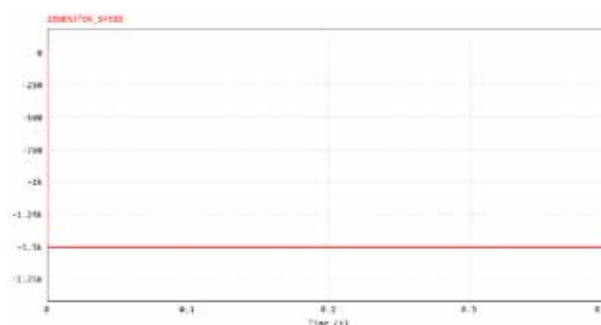


Figure 26 Generator speed

It can be seen from the figures that a synchronous generator with permanent magnets does not require a DC excitation power supply, which makes the whole system simpler and more economical. The resistance of the stator winding is 0.001Ω . The inductance of the stator winding along the d axis is 0.027Ω and along the q axis is 0.067Ω . The generator has 4 poles, which means that its synchronous rotation speed equals 1500 rpm. The moment of inertia of the generator is 0.00179 kgm^2 .

Figure 27 shows the PMSG voltages. A synchronous generator with permanent magnets is three-phase, which means that its stator windings are placed in such a way as to create a three-phase symmetrical voltage system. It can be seen that the voltages are phase-shifted by 120 degrees and that the voltage has an amplitude of 1630 V. At the beginning of the simulation, the voltage is zero and, as the generator is started, the voltage increases almost linearly for 15 ms, when it reaches the stationary nominal alternating value.

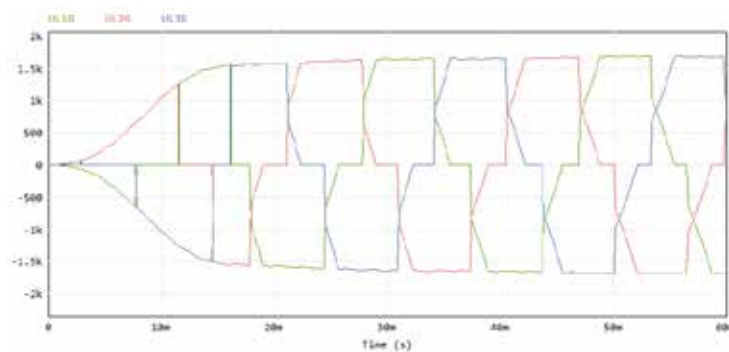


Figure 27 PMSG voltages

The generator currents are shown in Figure 28. The generator also creates a three-phase symmetrical system of currents of amplitude 4.44 [A].

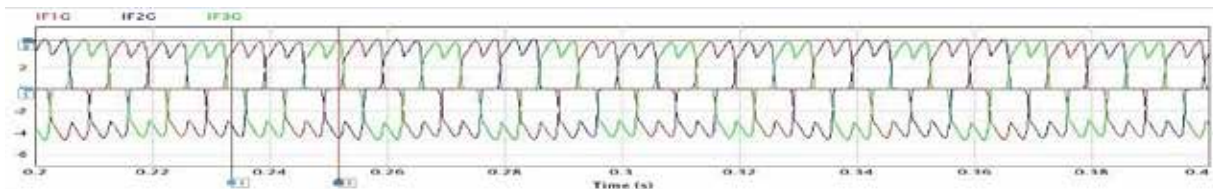


Figure 28 PMSG currents

After the start, within 0.3 s, the current drops to the nominal value and remains constant. The electrical active power that the generator delivers to the frequency converter is approximately 6300 W.

In the case of a synchronous generator with permanent magnets, it was necessary to adjust the frequency converter for different generator voltage. Figure 29 shows the output line voltages of the frequency converter, adjusted to the desired amplitude of 400 V, required by the consumer.

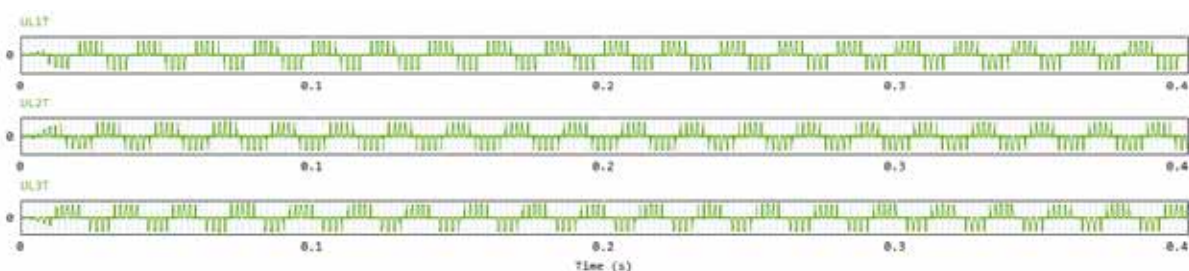


Figure 29 Voltages at the output of the converter

In this case, the rotation speed of the electric motor is slightly lower than in the first simulation and is 1430 rpm, which is shown in Figure 30. The torque is also slightly lower and is 24.15 Nm, according to Figure 31.

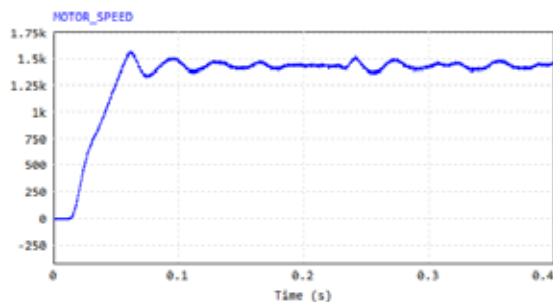


Figure 30 Motor speed

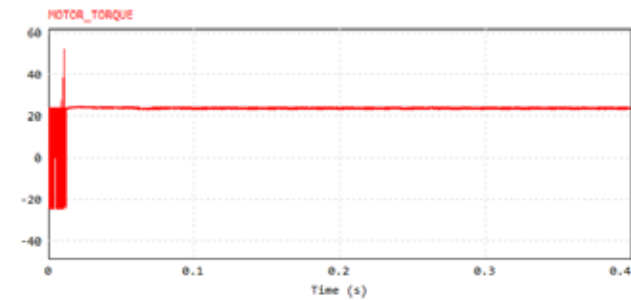


Figure 31 Motor torque

The speed of the electric motor increases from zero to 1430 rpm and it achieves this in 0.35 seconds. This diagram shows the rotation speed of the electric motor for an electric motor load of 24.15 Nm. The slip in this case is 4.6%. The power factor in the case of generators with permanent magnets is 0.83. For loads lower than the rated load, the speed of rotation would increase, the motor would draw a lower current, and the voltage and frequency at the output of the converter would still be exactly the values corresponding to the rated values for the motor, i.e., a voltage of maximal amplitude of 400 V and a frequency of 50 Hz.

5. Conclusion

The intention of this work is to encourage the use of the PSIM program for educational purposes and as a tool for designing wind turbines for powering smaller electric drives, usually privately owned, where the operation of wind turbines with renewable energy sources would contribute to the increased economic stability of small entrepreneurs.

For this purpose, the paper presented and analysed two simpler designs of power units, designed as direct systems. The offered solutions involve lower investment costs, but are still safe and stable enough to power a small plant for many years. Between the two options, a power unit with a PMSG is preferred over a power unit with a classic synchronous generator with DC excitation, because it does not require an additional DC power source.

For use in drives of greater power or of greater importance, the next step would be to work out the improvement of both models in terms of generator output voltage and frequency regulation, and possibly consider other electric generators as part of power units in project solutions of more complex designs, such as a three-phase doubly fed induction generator (DFIG).

While the educational license of the PSIM program provides a valuable resource that complements the process of learning, it has some limitations and a paid license would be recommendable for professional use.

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ARTIFICIAL INTELLIGENCE IN JUDICIAL DECISION-MAKING: CHALLENGES OF BIAS AND LACK OF TRANSPARENCY OF PREDICTIVE ALGORITHMS

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Abstract Artificial intelligence (AI) has infiltrated many aspects of contemporary life, including the criminal justice system. AI systems can be helpful tools when predicting criminal activity, analyzing large amounts of digital evidence, or making court decisions. However, in addition to the indisputable advantages provided by the use of AI technology, its application in criminal justice has actualized the issues of the bias of its algorithms and the lack of transparency in decision-making processes.

Algorithm bias can arise from several factors, including implicit biases in the design of the algorithms themselves or biases in the data that are imputed. These factors can result in algorithms that unfairly target specific groups or communities, increasing the risk of discrimination in the criminal justice system. The lack of transparency in the functioning of complex AI algorithms and machine learning models makes it difficult to understand how the algorithms make their decisions and consequently makes it difficult to analyze and valorize the obtained results. The above can make it challenging to recognize and correct biases in algorithms but also lead to a lack of confidence in the fairness of decisions based on machine learning algorithms. Finally, AI decision-making procedures' implicit bias and lack of transparency collide with the core principle of criminal procedure - the right to a fair trial. The purpose of this research is to use the example of the case study - State of Wisconsin v. Loomis (2016) - to show the extent of the potential bias of AI algorithms, as well as the impossibility of contesting a court decision based on machine learning algorithms, due to the non-transparent internal functioning of the AI system. The contribution of this research is a deeper understanding of the complexity of the application of AI algorithms in the criminal justice system, the use of which must not come at the expense of the defendant's fundamental rights, especially the right to a fair trial. The internal functioning of the AI system should be understandable to the end user so that the predicting output values of such algorithms are subject to (human) validation and critical review.

Keywords: *artificial intelligence, criminal justice system, algorithmic bias, algorithmic transparency, human rights*

1. Introduction to AI and machine learning

Machine learning is a branch of artificial intelligence (from now on: AI) that deals with the development of techniques and algorithms that enable computers to learn how to solve tasks directly from examples, data, and experience without explicit programming (The Royal Society, 2017). The main idea of machine learning is that by using a large set of data stored in the system, the system learns how to apply the best solution to achieve the most optimal effect, whether making a decision, setting a forecast, or performing another type of analysis. Over time, learning from experience, learned patterns can provide helpful predictions. Advances in this area allow computers to recognize patterns, automate tasks, and make complex decisions in ways that were unimaginable using traditional programming approaches.

AI techniques (such as machine learning and data analysis) can be used in criminal justice in predicting risk of recidivism or deciding on incarceration and determining the severity of the punishment. This is often called predictive analytics in criminal justice and can be based on profiling criminal patterns to make informed decisions about incarceration, sentencing, or parole. Data profiling enables the analysis and prediction of an individual's habits and behavior. Thus, the police use predictive algorithms to estimate the place and time of the commission of criminal offenses or to assess the risk of violent crimes. Courts use algorithms to aid incarceration and sentencing decisions (Berry-Jester & Goldstein, 2015). Parole boards and prisons use risk assessment algorithms to make parole decisions (Freeman, 2016).

However, a practical problem with algorithms, especially those used in profiling human characteristics and behavior, is that their inner workings can be protected as a trade secret, therefore remaining opaque to the end user (Hogan-Doran, 2017). It is practically impossible to explain how and in what way the algorithms decided in a particular case.

Today, systems based on machine learning are an integral part of our everyday life. They are used in recognition systems (e.g., tagging photos on social networks), voice recognition (e.g., virtual personal assistants such as Google Assistant or Siri), recommender systems (e.g., Amazon and Netflix), organizing information (e.g., search engines and spam filtering), machine translation, in the healthcare or the criminal justice system (predictive policing or predictive justice).

2. Development of actuarial instruments

With the development of technology, the clinical assessment of predicting the offender's risk of recidivism gave way to actuarial instruments (Carlson, 2017). Actuarial instruments apply statistical methods and mathematical models to predict the risk of recidivism based on information of the offender, primarily by analyzing the history of criminal behavior, socioeconomic factors, personal characteristics, and other factors to generate the probability of reoffending. Actuarial risk assessment is "statistical prediction about the criminality of groups or group traits to determine criminal justice outcomes for particular individuals within those groups" (Harcourt, 2007, p. 17). The use of actuarial instruments in predicting an offender's risk of recidivism can help judicial authorities to identify individuals who are at higher risk of reoffending and to develop risk prevention strategies. Although proponents of algorithmic assessments argue that such practice is effective because it is devoid of human bias, such predictive algorithms can be problematic in practice, given that the secrecy of the algorithms' functioning (due to trade secrets) makes it impossible for interested parties to challenge the accuracy of such a calculation. Therefore, these tools must be used with caution and in compliance with ethical and legal guidelines to avoid discrimination and unfair treatment.

3. The problem of machine algorithm bias

Since the programming of predictive algorithms is in human hands, which have inherent implicit or explicit biases and values, they can be unwittingly embedded in software instructions, known as source code and predictive algorithms (Citron & Pasquale, 2014). The potential bias of algorithms results from the intrinsic but unintentional bias inherent in algorithm creators and is "not a conscious choice of its programmers" (Barocas & Selbst, 2016, p. 671). "Systems trained to make decisions based on historical data will naturally inherit the past biases" (Zemel et al., 2013, p. 325).

Ironically, the advocacy of risk assessment arose from the need for transparency in decision-making in criminal justice (Eckhouse et al., 2019), but the use of non-transparent risk prediction algorithms, without the possibility of validation and critical review based on such algorithms of decisions made, *de facto*, contributed precisely the opposite.

Several factors can contribute to the bias of algorithms, such as:

1. Imbalanced data sets - If the data set used to train the algorithm is not representative or contains very little relevant data, the algorithm may make incorrect or biased decisions.
2. Data bias - The data used to train the algorithm may contain implicit or explicit bias toward certain groups.
3. Bias in the modeling process - How the algorithm is modeled, or feature selection can also contribute to bias.
4. Lack of transparency - If the algorithm is not clearly explained and it is impossible to understand how it makes decisions, it is difficult to identify and solve bias (Grimm, Grossman & Cormack, 2021).

4. The need for interpretability and transparency of algorithms

Very often, due to the complexity of the AI system itself, the decision-making process or the functioning of AI remains opaque and incomprehensible to the end user. Therefore, even though an AI system can make decisions or perform tasks, the decision-making process or task performance is not clearly explained or understood. In other words, although such systems can produce statistically reliable results, the end user (affected parties) will not necessarily be able to understand and explain how the stated results were reached or which features were crucial for the decision-making (The Royal Society, 2017). Because of the above, many machine learning systems are 'black boxes' whose methods are accurate but difficult to interpret. Thus, it's only possible to observe the input and output data while the data processing process itself takes place "in the dark" (Hogan-Doran, 2017, p. 31) and is called the AI "black box" (Brevini & Pasquale, 2020, p. 2; Von Eschenbach, 2021, p. 1608; Durán & Jongsma, 2021, p. 329). For the stated reason, there are difficulties with the interpretability of such processes, especially the ability to understand model predictions based on the provided inputs (PortalCrypto, 2023).

The opacity of machine learning (ML) results from various factors. First, opacity can be a consequence of the "deliberate hiding of the source code and relevant test data" as "part of a trade secret or intellectual property rights of the technology company that developed the software" (Hildebrandt, 2018, p. 28). Second, the opacity may be a consequence of the fact that neither the end users (the court or a party in criminal proceedings) have the necessary knowledge or skills to examine these systems (Hildebrandt, 2018).

Understanding how a solution or decision was reached is essential for several reasons. First, understanding how machine learning works increases transparency, which can help uncover cases of bias and be of direct help in developing better algorithms (The Royal Society, 2017). Second, increased transparency increases trust in such a way of decision-making. Third, in certain situations, fairness of the (criminal) procedure that due process mandates requires an explanation of the arguments underlying the decision. When a (judicial) decision is made based on algorithms' predictions, a certain level of transparency and interpretability of the algorithm is necessary to enable the individual, concerning whom the decision was made, to evaluate the correctness of the algorithm based on which the decision was made, and critically review its correctness (The Royal Society, 2017).

5. Testing algorithms before putting them on the market

Research conducted in the USA supports the conclusion that many jurisdictions have fully implemented risk assessment tools without first testing their validity (Angwin et al., 2016; Carlson, 2017), which resulted in the denial of defendants the opportunity to challenge the accuracy of the results obtained. Some states have tried to solve problems with proprietary trade secrets by developing their own risk assessment algorithms (Carlson, 2017). For example, Pennsylvania created a Sentence Risk Assessment Instrument that is used in criminal sentencing decisions and has been effective since July 1, 2020 (Pennsylvania Commission on Sentencing 2020). In Ohio, the Ohio Department of Rehabilitation and Correction created its own statewide risk assessment system, the Ohio Risk Assessment System, to avoid problems associated with commercial risk assessment instruments. This risk assessment is “a statewide system to assess the risk and needs of Ohio offenders” (Latessa et al., 2010, p. 16). Instead of having “universal applicability across various offending populations,” the Ohio Risk Assessment System was designed “to predict recidivism at different points in the criminal justice system in Ohio” (Latessa et al., 2010, p. 17). It can be more precise in predicting recidivism for the local population of the state

There are currently more than 60 different types of risk assessment tools in use in courts across the US (Carlson, 2017; Liu et al., 2019). Risk prediction tools often comprise a questionnaire that scores certain factors, such as demographic characteristics, family background, or criminal history (Carlson, 2017).

6. Correctional Offender Management Profiling for Alternative Sanctions - COMPAS

One of the most widely used risk assessment tools in the US is COMPAS, a commercial software system used to assess recidivism risk (Lee Park, 2019). It was developed by the private equity firm Northpointe Inc. and is used by courts across the US to aid the alternative sanctions decision-making process. COMPAS uses machine learning algorithms to analyze defendant data and generate recidivism risk scores (Carlson, 2017; Eckhouse et al., 2019; McKay, 2020). The COMPAS assessment of the risk of recidivism is based on a complex analysis of the “defendant’s criminal file and an interview with the defendant” (State of Wisconsin v. Loomis, § 13; Gordon, 2017, pp. 7-8), primarily through a 137-question questionnaire that collects data on “felony and parole history, age, employment status, social life, education level, community ties, drug use and beliefs” (Beriaín, 2018, p. 45; Palazzolo, 2016). Some of the questions require respondents to answer yes or no (such as: “Did the parent who raised you ever have problems with drugs or alcohol?”) or for respondents to agree/disagree with a particular statement (such as: ‘Hungry person has the right to steal’). The obtained answers are then scored on a numerical scale, and the examiner determines the defendant’s level of risk (Harcourt, 2007). Risk assessment is usually carried out after conviction during a pre-sentence investigation. It is attached to the defendant’s Pre-sentence Investigation Report (PSI) and submitted to the sentencing judge (Carlson, 2017). COMPAS assigns defendants grades from 1 to 10 that correlate with the level of reoffending risk, but it does not provide details on exactly how the risk is calculated. Thus, defendants rated as medium (5 to 7) or high risk (8 to 10) are more likely to be detained while awaiting trial than low-risk defendants (1 to 4) (Corbett-Davies et al., 2016; Lee Park, 2019). Initially, risk assessment tools in the US were used in parole decisions, but over time, their use has expanded to all stages of criminal proceedings, including sentencing. Virginia was the first state to apply an actuarial risk assessment tool in sentencing with the goal of replacing short-term prison sentences with alternative sanctions for low-risk offenders (Kern & Bergstrom, 2012; Carlson, 2017). On the other hand, Wisconsin has been a leader in advocating the use of

the COMPAS risk assessment tool in sentencing decisions, which it implemented into its state sentencing procedures in 2012 (Angwin et al., 2016; Lee Park, 2019). The effect of actuarial risk assessment instruments will be analyzed in the case of *State of Wisconsin v. Loomis* (2016), in which the judge (fully) accepted the use of risk assessment results when sentencing the defendant.

7. *State of Wisconsin v. Loomis* (2016)

The case *State of Wisconsin v. Loomis* (2016) is a stark indicator of the lack of transparency of algorithms used to assess risk in the sentencing process and, consequently, of the lack of opportunity to challenge and critically review the decision made (Gordon, 2017, Criminal Law Sentencing Guidelines, 2017). In early 2013, Eric Loomis was indicted as a repeat offender on five counts related to a drive-by shooting in La Crosse¹ (Wisser, 2019; Liu et al., 2019). Loomis denied involvement in the shooting but later pleaded guilty to two lesser charges: “attempting to flee a traffic officer and operating a motor vehicle without the owner’s consent” (*State of Wisconsin v. Loomis*, § 12; Burke, 2020, p. 282; Carlson, 2017, p. 320). After accepting Loomis’ confession, the circuit court ordered a pre-sentence investigation report (PSI), to which the offender’s risk assessment was attached, based on the COMPAS algorithms. Loomis was identified in a risk assessment as a “high risk of recidivism” (*State of Wisconsin v. Loomis*, § 16). Although COMPAS scores were to be used only to determine the terms of probation, not the severity of the sentence (*State of Wisconsin v. Loomis*, § 19-20; Lee Park, 2019), risk assessment was used as a reason for denying probation and as one of the sentencing factors (Wisser, 2019). Concerning predicting the risk of recidivism, the court did not sentence the offender to the sentence agreed to, but a prison sentence of “six years of imprisonment and five years of extended supervision” (Criminal Law Sentencing Guideline, 2017, p. 1531).

Loomis questioned the use of COMPAS “because it was developed for allocating correctional programming resources, not for sentencing purposes” (Wisconsin State Public Defender, 2015). Loomis appealed the court’s decision, explicitly challenging the use of COMPAS’ risk assessment in sentencing, claiming that it violates a defendant’s right to due process (*State of Wisconsin v. Loomis*, § 23). Loomis contested the use of COMPAS on three grounds. First, he claimed that the algorithm violated his right to be sentenced based on accurate information (because the proprietary nature of COMPAS prevented him from assessing its accuracy) (*State of Wisconsin v. Loomis*, § 34). Second, he claimed that using risk assessment in sentencing had violated his right to an individualized sentence (since risk assessment compared the defendant to a national sample). Third, Loomis claimed that the algorithm “improperly used gendered assessments in sentencing” (*State of Wisconsin v. Loomis*, § 34; Freeman, 2016.; Carlson, 2017; Beriain, 2018; Wisser, 2019). Namely, the algorithms on which COMPAS is based were considered a trade secret (*State of Wisconsin v. Loomis*, § 51, Pasquale, 2017). Therefore, it was impossible to reveal how the algorithm got the calculation, i.e., the risk result (Washington, 2018). Consequently, Loomis could not analyze the accuracy or challenge the risk assessment’s validity because the algorithms were and remain a secret, both to him and the sentencing judge (Wisser, 2019). “No one knows exactly how COMPAS works” (Israni, 2017), and algorithmic risk assessments are equivalent to “an anonymous expert,” whom the offender “cannot cross-examine” (Pasquale, 2017).

1 Loomis was charged with (1) first-degree recklessly endangering safety; (2) attempting to flee or elude a traffic officer; (3) operating a motor vehicle without the owner’s consent; (4) possession of a firearm by a felon; and (5) possession of a short-barreled shotgun or rifle (*State of Wisconsin v. Loomis*, § 11).

However, despite the above, the Wisconsin Supreme Court upheld the lower court's sentencing decision based on the COMPAS risk assessment report and dismissed the defendant's appeal (Liu et al., 2019). The Wisconsin Supreme Court ruled that the trial court's use of an algorithmic risk assessment at sentencing did not violate the defendant's due process rights, although "the methodology used to produce the assessment was disclosed neither to the court nor to the defendant" (Criminal Law Sentencing Guidelines, 2017, p. 1530). The court acknowledged that the risk scores did not explain how the COMPAS program used the information to calculate them but held that the defendant's right to access accurate information was not impaired because the defendant was able to access the information included in Northpointe's 2015 Practitioner's Guide to COMPAS that explains that "the risk scores are based largely on static information (criminal history), with limited use of some dynamic variables (i.e. criminal associates, substance abuse)" (Beriaín, 2018, p. 47; Grimm, Grossman & Cormack, 2021, p. 64). Regarding the violation of the defendant's right to an individualized sentence, the Court emphasized that the COMPAS report was only one of the parameters that the court considered when determining the sentence. Therefore, the sentence was sufficiently individualized because the courts have the discretion not to agree with the risk assessment when appropriate.

Although the Wisconsin Supreme Court affirmed that the use of the COMPAS recidivism risk assessment did not violate a defendant's right to due process, the Court cautioned against several significant limitations. First, it warned that due to the trade secrecy of the program, it was not known how the data was processed. Second, risk assessment compares the defendant to a national sample, and not exclusively with a Wisconsin population. Third, there are doubts regarding the bias of the algorithms towards certain minority groups or the gender of the defendant. Finally, risk assessment tools should be constantly monitored and revised for accuracy due to changing populations (State of Wisconsin v. Loomis, § 66). Thus, the Supreme Court recognized the problematic nature of the algorithm, the use of which should be limited in such a way that risk assessment should not be a decisive factor in sentencing, and courts are required to state the reasons that, in addition to risk assessment, influenced the severity of the sentence. (State of Wisconsin v. Loomis, § 98-99). Also, the Supreme Court stated that courts should not use risk assessments when deciding on incarceration or determining "the severity of a sentence" (Martin, 2017, p. 22; Wisser, 2019, p. 1815). What makes this judgment particularly relevant is that it was the first to deal with the "constitutionality of the use of risk assessment algorithms during sentencing" (Freeman, 2016, p. 89) in the way that the "proprietary nature of COMPAS violates the constitutional right to due process" since the defendant cannot dispute the accuracy of the algorithm, considering that the internal way of their functioning is not known (Washington, 2018, p. 142). However, "the United States Supreme Court declined to hear the case, allowing the Wisconsin Supreme Court's ruling to stand" (Washington, 2018, p. 142).

The court's above decision vividly illustrates the extent to which judges rely on algorithmic predictions of the risk of recidivism when sentencing and what are the consequences of not knowing how algorithms work. It is clear that equality of arms is thwarted when the prosecution uses unfathomable algorithmic tools against the defendant. At the same time, the impossibility of refuting the algorithm on which the risk prediction system is based threatens the right to defense.

8. Criticism of the Wisconsin Supreme Court decision

The State of Wisconsin v. Loomis decision has been the subject of much criticism. The judicial use of automated risk assessment tools has been criticized in a way that undermines the fundamental values on which the rule of law rests, especially "values of due process, equal protection and transparency" (Liu et al., 2019, p. 141). Hogan-Doran (2017) states that the

internal structure of algorithms, especially those based on deep learning, is almost impossible to decipher due to the layering of processing units. This leads to a ‘black box’ problem where the inputs and outputs may be clear, but the process itself remains opaque. Wisser (2019) considers the decision of the Supreme Court wrong because it clearly shows the court’s misunderstanding of how COMPAS works in the absence of guidelines on whether and to what extent COMPAS risk assessment should be used when the court decides whether the accused will be incarcerated or when assessing the severity of the sentence. Freeman (2016, p. 78) also believes that the Wisconsin Supreme Court incorrectly evaluated the impact of the COMPAS algorithm and that “courts should not use risk assessment algorithms during sentencing proceedings without stronger due process protections.” Eckhouse et al. (2019, p. 200) criticize Loomis’s decision because the Court does not deal with the trade secret of the COMPAS instrument, so it “failed to remedy the fact that predictive models in criminal justice are typically secret,” thus it prevented judges and defendants from “vetting the algorithms and evaluating the fairness” of the procedure. Liu et al. (2019, p. 133) note that the Court only addressed the problem of the lack of transparency because of the proprietary nature without further analyzing “how the outputs were derived anyway.” Carlson (2017, p. 329) claims that using risk assessment tools such as COMPAS in criminal justice should be subject to “the same transparency requirements as public agencies” instead of protecting the commercial interests of a private supplier. Predictive tools should be “testable and contestable” (Hildebrandt, 2018, p. 34).

9. Conclusion

AI has infiltrated many aspects of contemporary living, including the modern criminal justice system. Police use predictive algorithms to assess the risk of violent crimes. Courts use algorithms as an aid when deciding on incarceration and sentencing. Parole boards and prisons use risk assessment algorithms to make parole decisions. It is clear that AI systems can be valuable tools when predicting criminal activity or making court decisions. However, it is necessary to ensure that the mechanisms on which such a prediction is based are explainable, understandable, transparent, and subject to judicial control and validation.

The State of Wisconsin v. Loomis decision raised several critical questions regarding the use of AI algorithms in the justice system. First of all, it updated the issue of the non-transparency of the algorithms used to calculate the recidivism risk assessment, which resulted in the decision-making process being incomprehensible to the end user (the court and the defendant). Furthermore, the question of biased algorithms has been raised, resulting from imputed prejudices or inequalities on the part of the creators of AI algorithms. Another question that was brought up to date was the extent to which algorithms can be used in making court decisions, that is, whether the court can make decisions based only on the evaluation of algorithms or should consider some other (and which) relevant facts. Finally, this case indicated the need for more explicit legislation to determine how AI algorithms can be used in the judicial system while ensuring due process rights and procedural fairness. To ensure the right to due process and fairness of the procedure, guidelines are necessary on the transparency of AI systems and the responsible use of these technologies, where the defendant’s right to a fair procedure should take precedence over the protection of the proprietary rights of companies on the secrecy of the internal functioning of the system.

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CONNECTION OF HOUSEHOLDS WITH OWN PRODUCTION TO THE NETWORK

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Abstract. The electrical connection to the electrical distribution network enables the delivery of electricity to users. The possibilities of connecting the consumer to the distribution power network will be presented in a way in which the consumer is also a customer with its own production. The rules on connection to the distribution network are issued by HEP - Distribution System Operator d.o.o. based on the Electricity Market Act with the prior approval of the Croatian Energy Regulatory Agency.

The network user can request changes to the connection, such as increasing the connection power, sharing one billing metering point or connecting more than one, repositioning the billing metering point, or connecting a household with its own production. The procedure for connecting a household with its own production is carried out by submitting a request for checking the possibility of connection and an offer for equipping the billing metering point. After that, a proposal for a new contract is made, costs of the billing metering point are paid, and a request is submitted to change the status of the user.

In the process of connection to the network, it is necessary to define the feasibility of connection, determine the optimal technical solution and technical-economic conditions. According to the complexity, the connection procedure is divided into simple and complex connection.

Simple connection type is carried out in the case of connection to a low voltage network (0.4 kV). It is sufficient for the customer to request a connection from the distribution system operator and obtain an electric power consent and an offer (agreement) on connection to the electric power network.

Complex connection type is carried out in the case of connection to the medium-voltage network, i.e. to the low-voltage network if the necessary technical conditions in the network are not met, or property-legal relations are not resolved. With this type of connection, it is necessary to produce a study and sign a contract in order to obtain the connection approval.

Key words: *electric power network, energy, metering point, connection to the network*

1. Introduction

Electricity distribution networks are the basis of the energy system, which enables reliable distribution of electricity to end consumers. With the advancement of technology and the global focus on sustainability, the number of households that decide to implement their own electricity production systems, such as solar panels, is continuously growing. This creates opportunities to reduce dependence on centralized energy sources and fossil fuels, but also creates new opportunities and challenges for the integration of distributed production into existing power networks.

Connecting households with their own production to the distribution network represents a step towards achieving a higher level of energy independence and efficiency. The regulatory framework, which consists of initiatives and rules set by the Croatian Electric Industry (HEP) and the Croatian Energy Regulatory Agency, plays a fundamental role in the process of approval, regulation, and facilitation of this process. By studying connection procedures, differentiating between simple and complex connections, and analysing technical and economic advantages, the goal is to investigate how to achieve the successful integration of households with their own production into the wider power grid environment. In this way, it contributes not only to individual, but also to collective energy security and sustainability.

2. Technical aspects of connection

Connecting households with their own electricity production to the distribution power grid is a complex process that requires preparation, compliance with technical standards and cooperation with the relevant energy authorities. It is necessary to ensure reliable, efficient, and proper connection of production units to the grid, enabling consumers to meet their own energy needs and to contribute to the energy system. The connection procedure includes an elaboration of the optimal technical connection solution (EOTRP), special conditions, electric power consent (EES), connection contract and confirmation of the main project. Conditions such as connection possibilities, location conditions, technical solutions for connection, and costs and conditions for realizing the connection are also considered.

In order to connect a household with its own production, it is necessary to submit a request for consideration of the possibility of connection, followed by a determination of the possibility of connection, a notification about the possibility of connection, an offer to equip an OMM (calculated metering point), payment, equipping an OMM, a request to change the status of a network user, and certificate of change of status or certificate of permanent operation. These documents contain technical solutions and costs related to connection, including payment dynamics and details related to location, connection power, and type of network user, including special conditions that the building must meet for connection. Deadlines for the preparation and delivery of contracts, offers, EES and special conditions are crucial for the timely implementation of the connection. (The deadline for creating a contract or offer is usually 15 days, while the validity period is different for simple and complex connection.) The validity period of the conditions also varies depending on the complexity of the connection.

The process of submitting a request for connection begins with the completion and submission of the request for the issuance of the preparation of the optimal technical solution for connection (EOTRP) shown in table 1. After that, the user receives the electricity approval (EES) and the offer for connection, which contains details of the optimal technical solution, connection costs and payment terms. Through this process, the Distribution System Operator (HEP ODS), together with the Croatian Energy Regulatory Agency (HERA), ensures that all

network users meet strict technical and safety standards, thus contributing to the safety and efficiency of the distribution network.

All steps are regulated in detail and enable a systematic approach to the connection process, ensuring that all technical and regulatory conditions are met before the user acquires the right to connect. Clear guidelines and procedures are given for simple and complex connections, ensuring transparency and efficiency in the process of connection to the distribution network.

Table 1 Types of EOTRP-a

Type of EOTRP-a	Voltage level on OMM	Description of power flow calculation in EOTRP-u
EOTRP LV	LV	$KpNN(+KpSN)+SpNN$
EOTRP MV	MV	$KpSN^{*}(+SpSN)$
	LV	$KpNN(+SpNN)+KpSN^{*}+SpSN$
EOTRP HV	MV	$KpSN^{*}(+SpSN)+SpVN$

Legenda:

KpLV – control calc. of LV network

KpSN control calc. of MV network

SpNN - complex calc. of LV network

SpSN - complex calc. of MV network

KpSN* - control calc. of MV network that does not have to be performed if SpMV is not used

3. Categorization of connections

In the connection process, the operator of the distribution system assesses the possibilities that determine the optimal technical solution and determines the technical, economic, and other conditions for connecting the object to the network. In the categorization, simple and complex connection, and connection of households with their own production are distinguished, which will be considered separately in this paper.

3.1. Simple connection

With this connection, the consumer is connected to the low-voltage distribution network with minimal administrative and technical obstacles. The connection procedure is shown in Figure 1. It is carried out through two approaches, with and without trial work. It is necessary to carry out several steps, which begin with the submission of a request for the issuance of an electric power license (EES), and end with the establishment of a physical connection to the network and confirmation of the start of network use.

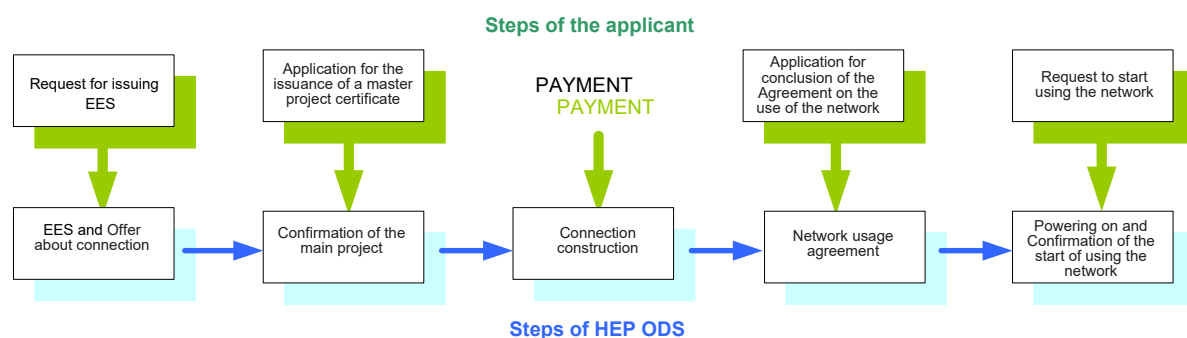


Figure 1a Presentation of the steps for simple connection to the distribution network without trial operation

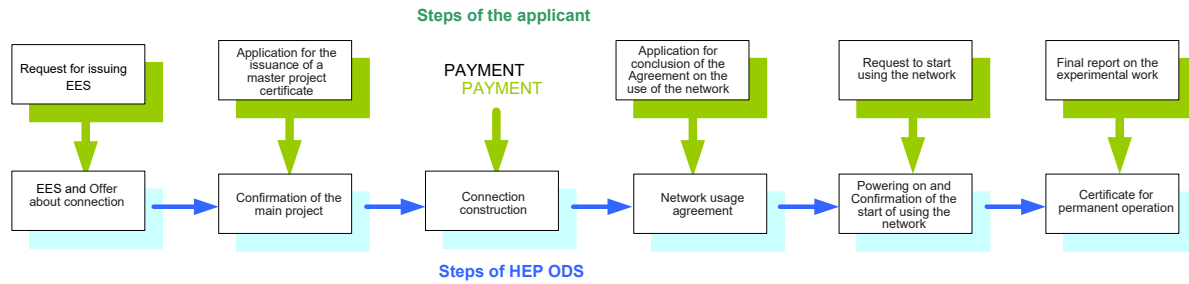


Figure 1b Presentation of the steps for simple connection to the distribution network with trial operation

For implementation, the following must be requested:

- issuance of EES and offers for connection,
- payment of the connection fee,
- realization of connection i
- signing of a network usage contract and connection activation.

During the implementation of the procedure, it is necessary to meet certain technical and administrative conditions, which include compliance with the project solution and technical specifications defined in the EES. The operator checks all the set conditions before the final approval for the connection. Simple connection enables users to have faster access to electricity and lower costs. However, the process may involve the need to comply with comprehensive technical and regulatory requirements. The following is an example of calculating the fee for connecting a customer to the distribution network with a simple connection.

- determine the amount of required power (e.g. 7.36 kW)
- unit price is €179.18/kW (for the city of Zagreb it is €225.63/kW)
- include the fee and VAT (the fee for the city of Zagreb is €1,660.63/kW)

3.2. Complex connection

Complex connection (Fig. 2) is a procedure by which a connection to the power grid is established while meeting the requirements for detailed preparation, elaboration of technical connection solutions (EOTRP) and is applied to more complex technical and administrative requirements. It is suitable for users who require higher capacities or specific technical connection conditions.

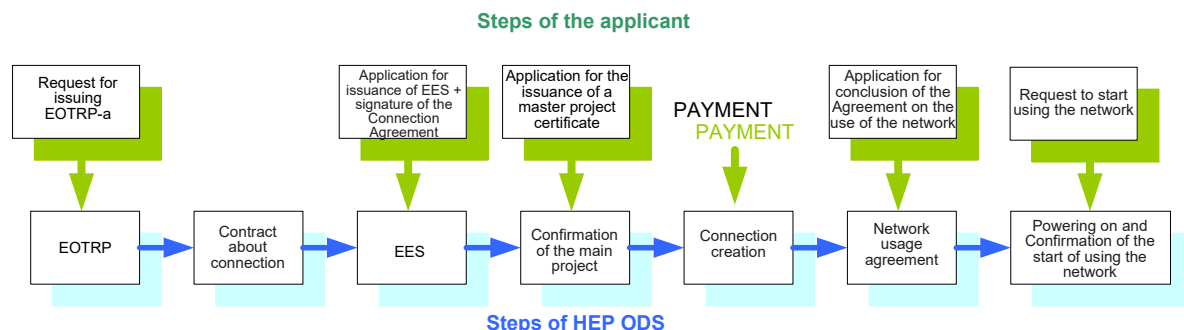


Figure 2a Presentation of the steps for simple connection to the distribution network without trial operation

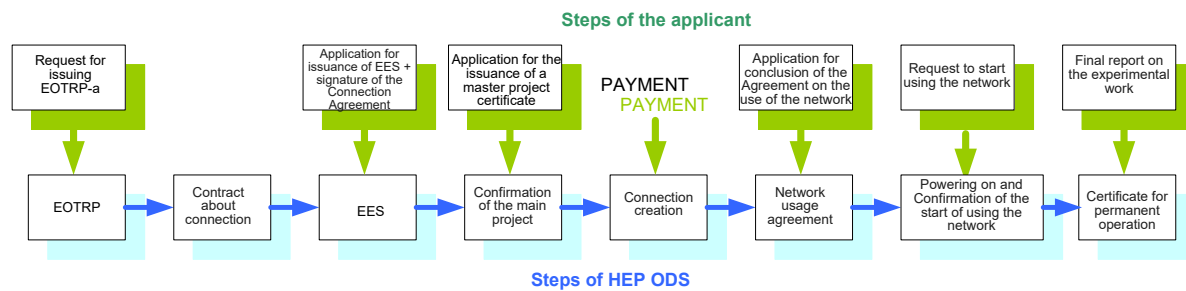


Figure 2b Presentation of the steps for simple connection to the distribution network with trial operation

The process begins with the submission of a request for the preparation of the Elaborate on technical solutions of the connection (EOTRP), a document that contains the technical specifications and plans necessary for the implementation of the connection. The preparation of this document ensures consideration of the technical aspects of the connection, which are harmonized with the existing infrastructure and regulations.

After the EOTRP is drawn up and accepted, the connection contract is concluded. This contract is an agreement between the user and the operator of the distribution system. It defines the conditions, obligations and financial aspects related to the construction of the connection. At the same time, the electric power approval (EES) and the main project certificate are issued, documents that confirm the compliance of the planned connection with technical and safety standards.

When the necessary documents have been issued and the financial obligations have been fulfilled, the implementation of the connection begins. Therefore, the necessary infrastructure is set up and network conditions are harmonized for safe and reliable connection of users. However, during this process, the need for additional works in the form of adaptation to the existing network may occur, in accordance with any specific needs and requirements of the connection.

After construction, the user and the operator of the distribution system enter into a contract on the use of the network. This provides access to the electricity infrastructure and delivery of electricity to the user. The technical part of the connection process is completed by putting the connection under voltage and issuing a certificate of beginning to use the network. In some cases, if it is stipulated by the electric power agreement, a trial operation is carried out to ensure the correctness of the connection. After the trial work is completed, the user will receive a confirmation for permanent operation, and the complex connection of the user to the network is completed.

3.3. Connecting a household with its own production

A customer with his/her own production is an existing or new user of the network who has a power plant connected to his installation that he uses for his own needs, and transfers excess electricity to the power grid. This is a user who has an approved connection power in the direction of the customer and connection power in the direction of production at the same billing metering point.

If the end consumer of the household category requests the connection of the production plant to the existing installation, and if the installed power of the production plant does not exceed the amount of connected power of the accounting metering point, the procedure is carried out according to the steps shown in Figure 3. First, the existing user submits a request

to check the possibility of connecting the production plant. After that, a notification about the possibility of connection is awaited, and offers are requested for equipping the billing metering point with a proposal for a new network usage contract.

For the purposes of equipping the accounting measuring point, additional payments for the costs of the works must be made. At the end, it is necessary to sign a new contract on the use of the network, and a request to change the status of the network user is submitted. Once the steps have been completed, a certificate for permanent operation will be issued.

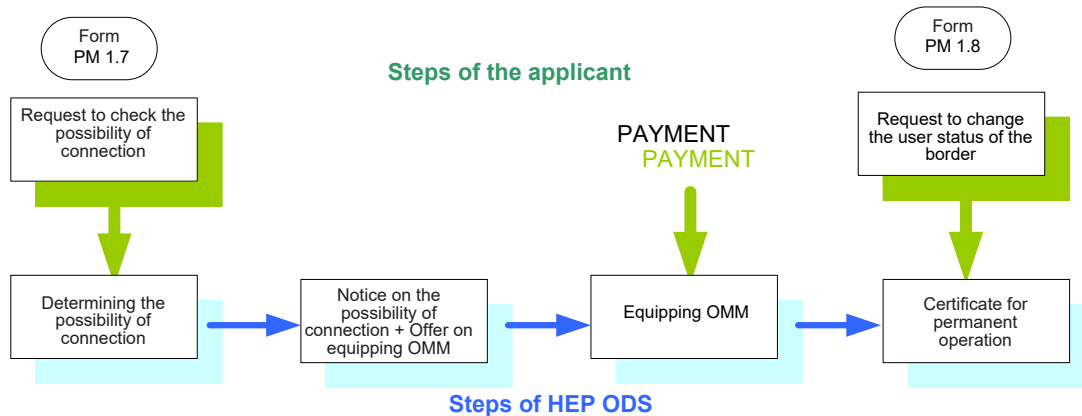


Figure 3. Presentation of the steps for simple connection to the distribution network with own production

For customers with their own production, connection fees are defined by Article 3 of the Ordinance on fees for connection to the electric power network and for increasing the connection power. The fee is calculated according to the customer's connection fee and the manufacturer's connection fee. The buyer is obliged to pay a higher amount of compensation. By signing the contract on the supply of the end customer with its own production, the distributor undertakes to take over excess electricity from customers with its own production.

According to the Law on Renewable Energy Sources (Article 44) and high-efficiency cogeneration, electricity suppliers should take over excess electricity from customers with their own production that meet the following conditions:

- have the status of a privileged producer of electricity,
- have exercised the right to permanent connection to the electric power network,
- the total connected power of all production facilities at one calculation measuring point does not exceed 500 kW,
- the connection power of the end customer with its own production as a producer does not exceed the connection power as a customer. [1]

If a customer with its own production does not meet the conditions for concluding a contract on the supply of the end customer with its own production, there is a possibility of concluding a contract on the purchase of electricity. Then, according to the clauses of the contract, the electricity supplier determines the minimum value of the electricity taken from the end customer with its own production C_i in the accounting period, according to the expressions:

- if it $E_{pi} \geq E_{ii}$ is valid for the accounting period

$$C_i = 0.9 * PKC_i$$

- if it $E_{pi} < E_{ii}$ is valid for the accounting period

$$C_i = 0.9 * PKC_i * E_{pi} / E_{ii} \text{ is true}$$

With:

E_{pi} - total electricity taken from the network by the customer within the accounting period i , expressed in €/kWh;

E_{i} - total electricity delivered to the network by the production facility owned by the customer, within the accounting period i , expressed in €/kWh;

PKC_i - the average unit price of electricity that the customer pays to the supplier for the electricity sold, without fees for the use of the network and other fees and taxes, within the calculation period i , expressed in €/kWh.

In accordance with the Law on Renewable Energy Sources and High-Efficiency Cogeneration, the supplier of electricity to the final customer with its own production can offer more favourable terms of purchase compared to the minimum prescribed ones.

4. PRODUCER CONNECTION

The producer connected to the grid must meet the ability to actively contribute to maintain the voltage within the prescribed limits. The manufacturer's plant and installation connected to the grid should have the safety of the facility with a power factor of 0.9 inductive (under-excited) to 0.9 capacitive (over-excited). The user of the network can change the voltage regulation setting only with the approval of the ODS, as it is thus protected against unauthorized changes by a seal, passwords and the like.

In case of deviation from the prescribed conditions for parallel operation, the protection of the power plant must separate the production plant from parallel operation with the grid. Synchronization of the production plant/production unit with the network must be fully automatic. The device for disconnection at the interface between the producer and the grid, for producers with connected power above 100 kW, should be in the remote control system of the distribution system operator. [1]

Depending on the voltage level and connected power, the conditions for connecting the manufacturer to the network are defined. An individual producer of connection power up to and including 500 kW is connected to the LV network. Under these conditions, an individual producer of connection power of up to and including 100 kW can be connected to the LV network, while an individual producer of connection power of up to and including 500 kW can be connected to the LV buses in TS MV/LV. [1]

An individual producer of connected power up to and including 20 MW can be connected to the MV network, and to the MV line, TS MV/LV busbars and switchgear in the MV network, an individual producer of connected power up to and including 10 MW can be connected, and to the MV busbars in TS VN/ An individual producer of connection power up to and including 20 MW can be connected to MV, with the condition that for connection power above 10 MW, additional analyses are carried out in cooperation with the transmission system operator. [4]

In accordance with the provisions of Hrvatska Elektroprivreda, HEP, Distribution System Operator, DSO is obliged to inform the transmission system operator when considering the possibility of connecting to the distribution network of producers with a connected power above 5 MW, but also when connecting wind farms to the MV network. For the connection of wind farms, it is necessary to define the conditions in accordance with the general act governing the Network rules of transmission system operators, which apply to wind farms with a total installed capacity above 5 MVA and wind turbines with an installed capacity above 0.5 MVA. [2]

However, consumption management is a strategic issue in the energy management system.

The goal is to develop a consumption management algorithm that reduces peak consumption and manages device operation according to network instructions. With this, we focus on the use of energy-saving technologies, electricity tariffs and monetary incentives. The main benefits of consumption management are cost reduction, environmental improvement and protection, reliability, and improved market. [3] Consumption management techniques are shown in Figure 4. Load characteristics show the daily or seasonal demand for electricity of different network users. Data from peak times to off times are displayed. The change of data is observed through six different techniques:

- reduction of peak consumption (Peak clipping),
- consumption in times of lower consumption levels (Valley filling),
- load shifting (Load shifting),
- strategic conservation (Strategic conservation),
- strategic load growth (Strategic load growth) i
- flexible load shape (Flexible load shape). [3]

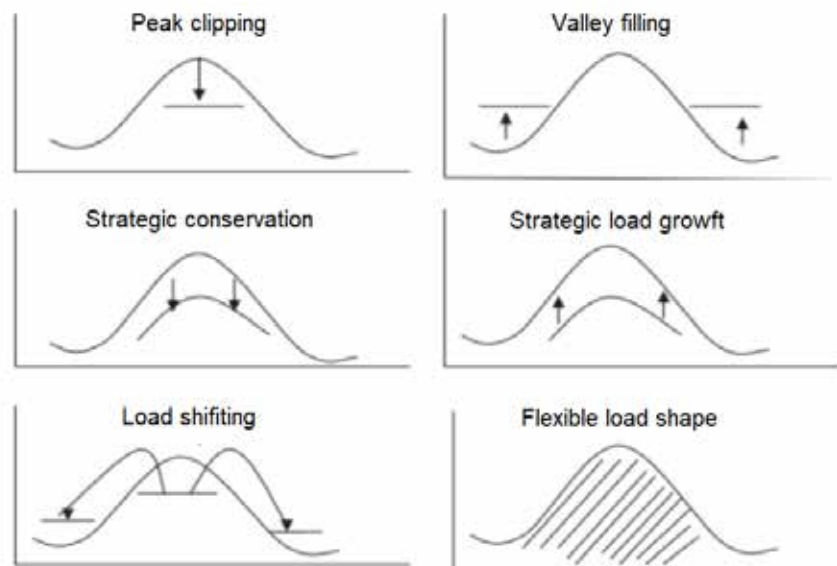


Figure 4. Consumption management techniques [3]

The technique of strategic load growth optimizes in case of introduction of high demand in the period of peak load. The technique when consumption is expressed in periods of lower consumption levels focuses on reducing the differences between peak and valley load levels in order to reduce or mitigate peak consumption. The flexible load shape technique mainly refers to the reliability of the smart grid, which can reduce the user's load demand if necessary. In order to meet their requirements, that is, their needs, the user must produce his/her own electricity or use another source of energy. The load shifting technique is currently the most effective power management technique and is widely used. It has the advantages of time independence and shifts loads from peak periods to off-peak periods. [3]

It is determined by trial, i.e. it checks whether the plant and the installation of the network user meet the conditions of the distribution system operator for parallel operation with the network in accordance with the electric power agreement and valid regulations that regulate the connection conditions. The obligation to carry out experimental work has: power plants, plants with their own power source for which short-term parallel operation with the grid is approved, electricity storage tanks and grid user plants for which the EOTRP, i.e. in the power consent, is conditional on the preparation of the Network Impact Elaboration.

If the network user is subject to trial operation by the EOTRP or electric power agreement, the network user is obliged to carry out tests in trial operation, in accordance with the provisions of the Network Rules and the Connection Rules, which regulate the testing of plants and installations. [3] The user of the network is obliged to prepare a proposal for the operational plan and test program of his plant and installation with the network in trial operation and submit it to the DSO for approval. The network user, in coordination with the DSO, conducts tests during trial operation with the network according to the agreed test plan and program. The user of the network bears all the costs of testing in the trial operation as well as possible damages that occur in the network or on the plants and installations of other network users or on his/her own plant and installation, which are a consequence of the trial work. [2]

After carrying out tests in trial operation with the network, the test manager is obliged to create a report on each test, and if the test did not achieve the expected result (the test was unsuccessful), the test report must list the observed defects, a proposal for corrective measures necessary to eliminate the defects, deadlines for their implementation and re-examination dates. After all the tests have been successfully carried out, the test manager issues to the network user a final report on testing the permitted parallel operation of the network user's plant and installation with the network, with a statement that the network user's plant and installation is ready for appropriate permanent parallel operation with the network, in accordance with the agreed plan and testing program. [1]

5. CONCLUSION

The network rules of the distribution system are in the process of final harmonization with HERA. The connection is hereby regulated according to the amendments to the Connection chapter in the Network Rules, so that these Rules fully regulate the connection and fully define the connection conditions. The task of the Distribution System Operator is to supervise network users, primarily regarding checking whether the user complies with the connection conditions established in the power agreement.

According to the Network Rules, the user should dimension his plant and installation exclusively according to the requirements established by the provisions of the Network Rules, technical recommendations, and norms. The plant and installation should have operational and protective earthing, short-circuit and insulation level, fault protection, power factor and feedback to the network. The plant is designed in such a way as to ensure resistance to disturbances and influences from the network, including power interruptions.

The user with his own production should ensure protection against the occurrence of reverse voltage to and from the network and have project documentation with technical data on his own power source and a description of how to block the parallel drive of his own power source with the network. At the time of commissioning, the user is obliged to submit proof of functional testing and the effectiveness of blocking the parallel drive of their own power source with the network, by an authorized contractor. In the event of a malfunction of the parallel drive block, if the own power source causes damage to the network and/or plants and installations of other network users, the network user is responsible for the resulting damage. In addition to the general and technical conditions, additional conditions must be met for the connection of the manufacturer's plant and installation, which are valid for customers with their own production and customers with their own production without delivery to the network.

Accordingly, each customer (consumer and/or producer) must fulfill the connection requirements in order to be able to connect to the network. System operators are responsible for connection. The HEP Distribution System Operator (HEP-ODS) is responsible for connection to the distribution network, and the Croatian Transmission System Operator (HOPS) is responsible for the transmission network.

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MANAGEMENT AND SUPERVISION SYSTEM OF MILJACKA HYDROELECTRIC POWER PLANT

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Abstract. Hydroelectric power plants have the ability to store energy and connect it to the grid in a very short time, thus contributing to the stability of the entire power system. The pass-through derivation Miljacka hydropower plant is built and commissioned in 1906 on the Krka river basin and in continuous operation ever since. Due to the specific location, the entire hydroelectric power plant was built manually.

Until 1910, it was the power plant with the largest installed capacity in Europe. At that time Miljacka HPP was the only power plant from which the generator voltage of 30 kV was taken to a factory 35 kilometers away. Due to its characteristics, it represents an important energy, industrial and cultural heritage, and in 2018 it was included in the Hydro Hall of Fame.

The observed basin of the Krka River has four waterfalls, with a total height difference of 106 meters. The total installed capacity of Miljacka HPP is 24 MW, and the available constructive drop of water is 102 meters. Energy is supplied via 35 kV and 10 kV networks. The average annual electricity production is 122 GWh. The maximum production of 147 GWh was recorded in 1974.

HPP Miljacka conforms to and is certified in accordance with "Environmental, Quality and Energy Management System" ISO 14001:2015, 9001:2015 and 50001:2018 standards.

In particular, it is necessary to emphasize the conditions for the creation of the SCADA system of the hydropower plant, i.e. the components that must be included in the SCADA program package for the creation of the application for the monitoring of the hydropower plant. The supervisory control and data acquisition system (SCADA) enables the functional unit of data, information, and command exchange.

Key words: *hydroelectric power plant, regulation, management, supervision, electricity production*

1. Introduction

The Miljacka hydroelectric plant is a high-pressure derivation plant built in 1906 on the Krka River. The available power is 24 MW.[1] It uses a height difference of 106 m, which consists of four waterfalls: Čorića buk, Manojlovac, Rošnjak and Miljacka. Water capture was achieved by building a dam that forms Lake Brljan for daily flow equalization (Figure 1).



Figure 1 Krka river basin from Lake Brljan to Miljacka HPP [2]

HPP consists of an artificially constructed dam with an intake and a supply tunnel that connects the intake with the water chamber. Inside the engine room building there is primary equipment, switching equipment, equipment with protective functions and control equipment. Miljacka HPP (picture 2) is one of the oldest hydroelectric power plants in Europe that is still commercially exploited. The Miljacka HPP originally had a capacity of 17.6 MW, and it supplied electricity to the carbide factory in Šibenik. The technical data of the power plant are shown in table 1.



Figure 2 Miljacka HPP

Table 1 Basic technical specifications of existing Miljacka HPP [3]

Gross Head	105 m
Mean Net Head	102 m
Installed discharge	30 m ³ /s
Installed capacity	3 x 6,7 + 1 x 4,0 = 24,1 MW
Turbine type	Francis
Generator type	Three- phase synchronus generator
Generator power	3 x 8 MVA (A, C, D) i 1 x 6 MVA (B)
Power factor	cos φ = 0,8
Generator voltage	6,3 kV
Block transformer type	Trofazni dvonamotni
Block transformer power	4 x 8 MVA
Block transformer ratio	6,3 / 35 kV

In 1907, the main Miljacka HPP had four horizontal aggregates installed with horizontally installed Francis turbines (mirror design) with a power of 4.5 MW, 420 rpm and a generator with a power of 4.4 MW. [4]

In the engine room building of Miljacka HPP, five uninterrupted power supply systems are located in three locations (AKU battery room, TK room and control room).

- SBN 220 VDC is used for powering USZMR appliances and emergency lighting and as an energy source for powering SBN 230 VAC PROCIS (picture 3).
- SBN 230 VAC-PROCIS serves to power the process computer equipment located on the control desk.
- SBN -48 VDC is used to power part of the ICT equipment and as an energy source for powering SBN 230 VAC-ICT.
- SBN 230 VAC-ICT serves to power most of the ICT equipment.



Figure 3 SBN 220 VDC

SBN 230 VAC-PROCIS is an uninterrupted power supply system (230 VAC/4.5 kVA) located in the cabinet (+Y BRA01) on the control panel, behind the control panel next to the sub-distribution cabinet of the control panel and emergency lighting (+Y BUA30). It consists of two inverters type INV222-220/230 “Eltek Valere” (220 VDC/230 VAC, 2.25 kVA), electronic switch type STS207-230LV (230 V, 7 kVA) “Eltek Valere”, connecting equipment and main distribution. The converters are powered from the main distribution SBN 220 VDC. So, from common AKU batteries, the autonomy time of both systems will be the same.

The main distribution consists of six single-pole AC circuit breakers. Process computers and associated monitors are powered from the four power sockets on the control desk connected to the main distribution of SBN 230 VAC-PROCIS.

“Eltek Valere” in the electronic switch STS 207 HV (230 V, 7 kVA) is the control unit of the system, which monitors the DC power supply -48 VDC at the converter inputs, the output alternating voltage from the converter and the 230 V, 50 Hz network voltage. The electronic switch synchronizes the mains voltage with the output voltage of the exchanger, controls the operation of the exchanger, continuously supplies the consumers from the network in case of failure of the exchanger or overload, measures voltages and currents and displays them on the built-in LCD display. Also, communication with the oversight computer via the communication interface is enabled. The SBN 230 VAC-ICT is remotely monitored from the process computer on the switchboard.

2. Management, signaling, protection, measurement and regulation

Correct management of signaling, protection, measurement and regulation systems is necessary for the safe and reliable operation of the power plant. So it is necessary to clarify the USZMR system and to define the aggregate management system and turbine regulation.

2.1. Aggregate management

Aggregate management system (fig 4) is realized by one *Programmable Logic Controller*, PLC per aggregate and a workstation with SCADA system installed. [5] The control base is the operator's station, and the backup control point is the cabinets in the engine room (one per unit). From the operator station, control is possible in automatic mode, while from the control cabinets, both automatic and manual control is possible.



Figure 4 Central aggregates control

The control and turbine regulation cabinets (Figure 7) in the engine room are the central/local control point for the systems that control the aggregates. The control buttons on the cabinet can be used to control the ball shutter, the drive circuit, the butterfly shutter in the bolt chamber and the generator switch. The unit can be controlled locally using the buttons on the door and the operator panel.

The hydraulic power unit and the ball valve have their own control cabinets that manually control the hydraulic power unit and the ball valve.

The electrical protection of the aggregates is located in separate cabinets. The control system is directly connected to the protection systems of the power plant (independent of the PLC). In the event of a malfunction, the quick-close signal acts directly on the relay part of the control system, which activates the quick-close valve.

The aggregates have the possibility of manual and automatic synchronization. For manual synchronization, one set of instruments is used for all four aggregates, which are located in the switch box. The automatic synchronizer SYNCHROTECT 4 by ABB is installed in the protection cabinet +CHA01 and is connected to the digital voltage regulator and the turbine regulator.

2.2. Turbine regulation

The turbine regulation system (Figure 5) consists of three functional units: the control assembly, the actuating element (hydraulic cylinder) and the mechanical escape protection assembly. The control system includes:

- Control block with proportional valve of hydraulic cylinder PV-HC i
- Electrohydraulic valve block for fast electric closing EHV-BZE.

The hydraulic cylinder is controlled by the proportional valve PV-HC, which opens and/or closes the turbine drive circuit, and the mechanical escape protection engages the rapid closing sequence. In the event that the system detects that the permissible rotation speed is exceeded, mechanical protection is also activated.

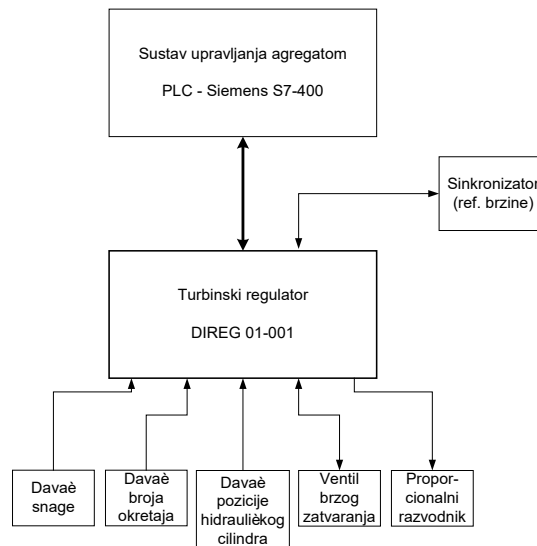


Figure 5 Display of connections between the turbine regulator and the aggregate control system [6]

The control part of the turbine includes the turbine regulator and sensors for continuous and discrete measurement of the opening of the drive circuit, rotation speed, pressures, temperatures, etc. The measuring sensor provides information directly to the turbine regulator, which controls the proportional valve PV-HC. For the purpose of turbine regulation, the following measurement signals are supplied to the control cabinets of the turbine regulation of the aggregate:

- Generator currents and voltages from measuring transformers,
- Current and voltage of the excitation system,
- The temperature of the package, the winding and the output and input air of the generator,
- Temperatures of bearings, hydraulic oil and block transformer oil.
- Opening of the drive circuit (measured using a linear position sensor),
- Speed of rotation (measured by an encoder at the head of the shaft),
- Pressure in the pipeline and spiral, etc.

The turbine regulation functions are realized using the turbine regulator, which is a separate microprocessor circuit located in the turbine regulation control cabinet. [7,8]

The microprocessor, manufactured by ABB, is made exclusively for the purpose of turbine regulation and is located in a separate metal case. The controller is controlled indirectly through the control system implemented in the PLC, which means that the operator never issues commands directly to the turbine controller. The turbine regulator enables the following functions:

- Fast closing,
- Island operation with adjustable statics,
- Network operation with power adjustment,

- Independent switching from grid to island mode of operation in case of generator outage from the grid,
- Quick closing valve monitoring and
- Connection with the superior management system.

In front of generator turbines A, C and D, there are pre-turbine ball shutters, which are fed from the hydraulic aggregates of the turbine regulation system. All four aggregates are equipped with their own hydraulic aggregate. Aggregate B, along with the control cabinet for the hydraulic aggregate and the pump control system, is used for lubrication and cooling. The ball valve can be open or closed, which means that it is not used for flow regulation.

3. Measurement of levels and flows

The flow measurement system through pressure pipelines is based on ultrasonic measurement of the water flow rate, digital processing of the measured signals and volume flow calculation. The read measured flow and the digital alarm for exceeding the permitted flow is sent to the SCADA system via the process station of the water supply system (Figure 6). The manufacturer of the equipment for the flow measurement system is the company Hydrovision.

Flow measurement with an ultrasonic measuring system is based on measuring the time required for an ultrasonic wave to establish a connection between two transceivers, downstream (in the direction of water flow) and upstream (opposite to the direction of water flow), as seen in Figure 7. From the measured signal flow times and the geometrical parameters of the pipe, the speed of water flow through the pipeline, and subsequently the volume flow, can be calculated. For the needs of greater precision, it is possible to use several pairs of transceivers on one measuring section, which can be arranged in different geometric configurations. The performance of the system for ultrasonic flow measurement on pressure pipelines is based on the Ductus TT COHP solution from Hydrovision GmbH.



Figure 6 Water supply system – main display

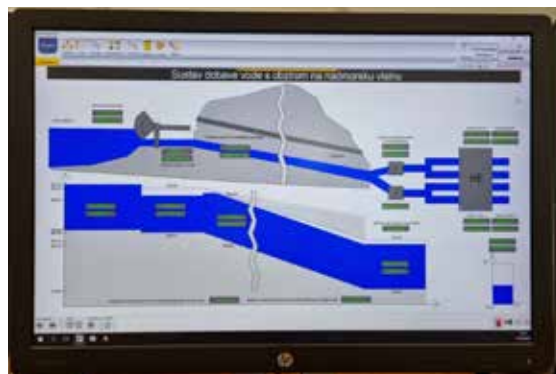


Figure 7 Water supply system level high

The so-called clamp-on type of ultrasonic sensors, which are attached to the outer surface of the pipe using installation cables and tensioners, is used. The advantage of using clamp-on sensors is easier installation, because it is not necessary to drill holes in the pipeline and it is not necessary to access the inside of the pipeline.

Also, there is no abrasive effect on the sensor due to the flow of water and no accumulation of limescale, which facilitates system maintenance.

The processor unit generates excitation high-voltage signals for ultrasonic transmitters and collects response signals from the receiver. Based on these signals and the necessary parameters, the processing unit calculates the speed of the water flow in the pipes and the volume flow

with the given algorithms. The processor unit is equipped with a precisely defined number of standard digital/analog inputs/outputs for the transmission of analog and/or digital signals (measured values, alarms, action on executive elements in protection systems, etc.) between all installed systems in the plant (superior control systems /surveillance, SCADA, etc.) according to user needs.

The following are connected to the cabinet of the substation of the water inflow system at the Brljan dam:

- Pressure probe for measuring the level in the tunnel,
- Pressure probe for measuring the accumulation level,
- Ultrasonic probes for measuring the level behind the nets.

The measuring equipment of the water chamber consists of pressure probes for the water level in the water chamber, level switches that have three contacts at different heights that define significant changes in the water level in the water chamber (overflow, pipeline filling and quick closing). There is a PLC S7-300 in the grating clogging measurement system.

The water supply management system was put into operation in 1998 and consists of:

- Input device (control cabinet with substation and sensors),
- Water chambers with level sensors of analog and discrete values,
- Central stations with control panel.

The substation is managed and monitors the operation of segmental shutters, measures the hydraulic characteristics of the regulation of the Brljan reservoir and the tunnel with a proportional-integral, PI power regulator.

The following are connected to the substation cabinet:

- Pressure probe for measuring the level in the tunnel,
- Pressure probe for measuring the accumulation level,
- Ultrasonic probes for measuring the level behind the grates and
- Potentiometer sensors for the position of segment shutters.

The measuring equipment of the water chamber consists of pressure probes of the water level in the water chamber, level switches that have three contacts at different heights that define significant water levels in the water chamber (overflow, pipeline filling and quick closing). There is a PLC S7-300 in the grating clogging measurement system.

The central station controls the system in the sub-levels of power regulation and level regulation. It processes the data obtained from the substation and the water chamber and displays them on the panel. Communication with aggregate PLCs, communication with substation and remote control (panel and SCADA) is realized at the central station. It is connected by an optical cable to the measuring equipment of the water chamber. The central station has an electrical connection to the panel.

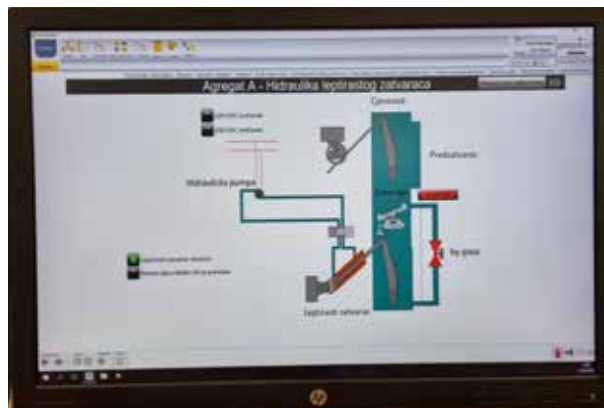
Two SIEMENS S7-400 PLCs are installed in the water supply system, between which data is continuously exchanged via the *Profibus* network (optical cable). The water supply system is connected via an Ethernet network to the aggregate PLC - it also has a SCADA control point. Signal conversion (optical/electrical) in the *Profibus* network was realized by installing SIEMENS OLM S4/1300 optical converters.

4. Control methods

The water supply system can be managed in automatic, manual and direct mode of operation.

In the manual control mode, segment shutters on the input device are activated by manual rotation of the lever. During operation in manual control mode, operation with electric engine start is disabled. In the direct control mode, segmental shutters are started using the control buttons from the cabinet on the input device. During operation in direct control mode, only the quick closing command is enabled from the panel, while other functions are disabled. In automatic mode, the system can be in sequential control, power regulation and water chamber level regulation (fully automatic).

Sequential control means the control of segmental shutters (Figure 8) from the panel and the ordered control point of the SCADA. Segment shutters in sequential operation can be operated individually or synchronously.



Slika 8 Hydraulics of the butterfly shutter

The permissible error during the control of the shutters in the subsequent work is 1 cm. By interrupting the request for manual or direct operation, the automatically controlled system returns to sequential control. The power is regulated via the appropriate PI regulator located in the substation. When switching from one control mode to another, the value of the tunnel flow is kept as a constant value. Level regulation is a complete regulation of the Miljacka HPP water supply system. The power from all generators is received in the central station of the water supply system, sent to the substation, and the flow of the tunnel is regulated based on the total required power of the generators. In addition to regulating the flow of the tunnel, the level in the water chamber is also regulated according to the set value from the panel.

4.1. System for monitoring, control, and data collection

The system for supervision, control, and data acquisition (Supervisory Control and Data Acquisition, SCADA) can be seen as a part of the control system and/or as a system of remote control of the power plant. The supervision of management is realized at any time by PLC, regardless of the place of management (local or remote). In the case of local management of the aggregate, SCADA is used to display data and record it in databases. With the remote control mode of the aggregate, SCADA is used for the purpose of sending the control command to the PLC, which enables the monitoring of the implementation of the commands. All signals collected by the PLC control system are forwarded to the SCADA.

The SCADA system of Miljacka HPP is controlled by the "Proza Net" system (installed by the company "Končar").[9] The system itself was installed in 2010, while the National

Instruments system was installed in 1998. Three screens have been installed through which the plant is controlled and monitored. Figure 9 shows the block diagram of the process information system of the power plant.



Figure 9 Head Room

4.2. Monitoring and management system

A programmable logic controller from the company Siemens was used in the aggregate management system at Miljacka HPP. Programmable logic controllers are from the S7-400 series and consist of the following components:

- Housing for 18 modules,
- Central processing unit (CPU 412),
- A communication processor for Industrial Ethernet, while the PLC for the water supply system also has a communication processor for *Profibus*-FMS,
- Three digital input units,
- Two digital output units,
- Three analog input units,
- Three analog output units,
- Power supply unit for 24VDC and
- Communication protocol MultiPoint Interface, MPI according to the operating panel, which is used for management at the local level.

The hardware control system and SCADA are connected using an optical bus, and the protocol they use to communicate is INDUSTRIAL ETHERNET (old name SINEC H1) with the following features:

- the physical medium is an optical medium - multimode fiber,
- data speed 10 Mbit/s,
- IEEE802.3 standard – CSMA/CD logic (Carrier Sense Multiple Access/Collision Detect).

With the installation of SCADA, we got better control and monitoring of the power plant, and in addition, there is the possibility of upgrading the existing system, that is, integrating other systems that will be automated later. [9]

SCADA has two basic purposes, monitoring and managing the power plant and recording events. SCADA is connected to PLCs through the SINEC H1 network, which has the function of

managing the production process. This connection made it possible to manage and monitor the operation process of the power plant from the SCADA. The management and guidance program consists of about fifty control screen graphic displays of individual parts of the process. The basic screen (Figure 11) contains all the data that is essential for the management and monitoring process, and it enables the management of the process itself. From the basic screen, you can switch to other graphic displays that represent the sub-processes of an individual aggregate. From each display, you can directly return to the basic screen, and you can set a request.



Figure 10 Initial screen ProzaNet SCADA-e

Control and monitoring of the system in normal operation is carried out from the operator's station on the switchboard, while in the event of failure or unavailability of the switchboard, it must be transferred to the spare control point, i.e. the control panel of the aggregate in the engine room. During testing, control can be performed locally or remotely.

In the local operating mode, all generator control functions are performed via the control cabinet in the engine room. Only remote monitoring is done through the SCADA system. In the local SCADA control mode, it is possible to set "Emergency stop" commands and fast closing for all aggregates (each separately). Alarms are confirmed by pressing the alarm confirmation switch, and the horn is activated for each unit separately. In case the operator tries to enter any other command (except those listed), it will not be executed.

Remote automatic control is carried out from the SCADA computer in the power plant command. It is important to point out that with this revitalization, the local manual control of aggregates has been eliminated. In addition to the main computer, a redundant computer has also been installed, which is being prepared to take over supervision in the event of a main computer failure. The mode of operation is such that the main computer monitors the operation of the power plant while the redundant computer monitors the operation of the main computer. When the redundant computer stops receiving feedback from the main computer within a certain period of time, it automatically takes over control of the power plant. For the purpose of synchronizing the computer to the exact time, a system for acquiring the exact time with a GPS receiver is installed.

Control of switches in the switchgear is enabled locally from the switchgear and remotely from the control panel. Control of the breakers is possible only from the cells of the switchgear, because the breakers have only a manual drive. Equipment for signaling the status of switches and breakers, as well as display instruments, are also located on the control panel. The electrical protection devices of water fields and transformers are located on relay boards in the switchboard in the plant itself.

The testing of the SCADA part for managing aggregates needs to be done at several levels, and all tests are performed for each aggregate separately.

Testing of work in local mode is done in three stages.

Testing the impossibility of issuing commands when SCADA is in local mode (for each unit separately):

- testing of the change in the operation mode of the aggregates (island/mains), by pressing the switches of individual aggregates
- Power setting test (increase/decrease, set by typing in the input field or by pressing the power increase/decrease switches)
- testing of setting requests for START aggregates
- testing of setting requests for aggregate STOP

Testing commands that can be given from SCADA in local mode:

- submitting a request for “Emergency Suspension” (quick closing)
- resetting of the horn of an individual unit (examined during the SCADA communication interruption test with PLCs)
- Confirmation of alarms of individual groups for all aggregates

Visual overview of the operation of individual aggregates according to their screens:

- Aggregates 1, 3, and 4 have 12 screens on which there are quantities monitored in the process (aggregate 2 has 10 screens)
- Visual overview of the state of individual objects, which show parts of the process (pre-closers, butterfly shutters, etc. on all screens)

Testing of work in remote mode is done by issuing commands from SCADA:

- testing of the change in the operation mode of the aggregates (island/mains), by pressing the switches of individual aggregates
- Power setting test (increase/decrease, set by typing in the input field or by pressing the power increase/decrease switches)
- testing of setting the request for the START of the aggregate (the aggregate can be started from SCADAs only when it is ready to start - signaling is present on the screen of each aggregate so that the message “Aggregate ready for start” appears)
- testing of setting the request for the STOP of the generator (thereby decreasing the power of the generator, disconnecting it from the network, closing the supply circuit and stopping the generator)

5. Conclusion

The flow-through derivation hydroelectric Miljacka HPP has been operating without interruption since the moment it was put into operation. It was built on the Krka river basin, and due to its specific location, the hydroelectric power plant was built manually.

Until 1910, it was the power plant with the largest installed capacity in Europe. At that time, it was the only power plant from which a generator voltage of 30 kV was taken to a factory 35 kilometers away. Due to its characteristics, it represents an important energy, industrial and cultural heritage, and in 2018 it was included in the Hydro Hall of Fame.

HPP Miljacka has adopted and is certified to the “Environmental, Quality and Energy Management System” in accordance with ISO 14001:2015, 9001:2015 and 50001:2018 standards.

Correct management of signaling protection, measurement and regulation systems is necessary for the safe and reliable operation of the power plant. It is necessary to define the

aggregate management system and turbine regulation, as well as the conditions necessary for creating the SCADA system of the hydroelectric power plant. The components of the SCADA software package are adapted to create a hydropower plant monitoring application. The supervisory control and data acquisition system (SCADA) enables the functional unity of data, information, and command exchange. With the installation of SCADA, we got better control and monitoring of the power plant, and in addition, there is the possibility of upgrading the existing system, that is, integrating other systems that will be automated later. Testing of the part of SCADA for the management of aggregates is performed at several levels, for each aggregate separately.

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IMPLEMENTATION OF KNX SYSTEM IN SMART CHARGING POINTS FOR ELECTRIC VEHICLES

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Abstract. Transport of goods and people is based mostly on internal combustion engines and causes more than a third of all CO₂ emissions. Consequently, it is necessary to reduce CO₂ emissions in the transport sector by approximately one quarter by 2030, and the European Commission has given clear guidelines that stipulate zero emissions by 2050.

It is encouraging the development of new technologies. The increase in the number of electric vehicles (e-vehicles) inevitably leads to an increase in the need to install new electric charging stations (e-charging stations). There are e-charging stations with fast and slow charging, depending on the needs of the user and/or the capabilities of the infrastructure. With the increase in the costs of other energy sources, the price of electricity also increases, and it is necessary to explore new concepts for creating economically acceptable e-charging stations. In order to manage energy consumption at e-charging stations, one of the conceptual solutions is the implementation of the KNX system. The implementation of the KNX system would enable autonomous regulation of charging according to priorities and type of e-vehicle.

There are KNX devices on the market for integrating the e-charger into the system. New technologies are continuously being developed and tested, which will enable the management of additional information such as: the availability of unoccupied e-charging stations, the current status and duration of charging of occupied stations, limiting the charging power depending on the current state of the network. With the system of smart e-charging stations, it is possible to monitor and inform users about total energy consumption, last charge, etc.

Also, KNX offers support for protecting users from unauthorized access to e-charging stations and e-vehicles, by implementing “KNX Secure” technology.

Key words: *electric charging station, KNX, electric vehicles, ecology*

1. Introduction

In order to protect the environment, there is an effort to switch to environmentally friendly forms of transport. Electric vehicles are the future of global transport. Electrification of vehicles is inevitably encouraged by the development of infrastructure intended for charging them. Charging stations for electric vehicles are the connection between the vehicle and the electric grid. Charging stations differ in capacity, speed, size, etc. One of the most important items when installing charging stations is the range of electric vehicles. Charging stations are designed so that they are easily accessible and that the distance between them is not too great.

With the development of electric vehicle technology, the technology is perfected so that maps with the locations of charging stations are available. One can also get information about the charging method, the number of parking spaces, etc.

2. Electric vehicles and ecology

Due to negative emissions and the development of environmental awareness, the transition from conventional to fully electric vehicles is initiated. Currently, barriers can be attributed to operational and management challenges rather than technological limitations. The aim of this paper is to present the issues of energy supply.

The increase in transport consequently causes an increase in greenhouse gas emissions, which must be reduced to a minimum. It is expected CO₂ emissions to be reduced by approximately one quarter by 2030, and the European Commission has given clear guidelines that envisage net-zero emissions by 2050. Environmental protection, technological development and environmentally friendly forms of transport are the reason for assuming that most of the global traffic will be realized using electric vehicles.

Currently, most lithium-ion batteries are installed in electric vehicles due to their service life and capacity. The first electric vehicles stored energy in lead batteries, which are bulky. Figure 1 shows an example of an old electric vehicle. In order to protect nature and to reduce the emission of harmful gases in Europe, a ban on the sale of vehicles powered by diesel and gasoline is being considered to be implemented by 2035. This law would help the development of electric vehicle infrastructure in less developed countries [1].



Figure 1. Edison's electric automobile from 1913. [2]

There are currently three types of electric vehicles (Figure 2), namely:

- fully electric vehicles,
- hybrid electric vehicles (HEV) and
- plug-in hybrid electric vehicles.

In fully electric vehicles, the electrical energy for starting and propulsion is stored in batteries. Such vehicles do not emit harmful gases, do not make noise and are pleasant to drive.

Hybrid electric vehicles use a combination of a classic engine powered by diesel or gasoline and an electric motor. The electric drive is mainly used to reduce the emission of harmful gases or to improve the performance of the vehicle. HEV vehicles produce significantly less harmful gases compared to classic vehicles because their engines are smaller and do not directly power them. Such engines can be adjusted to be the most efficient, so that their fuel consumption drops a lot [3].

Plug-in electric vehicles are similar to hybrid vehicles. They have a significantly higher battery capacity that can be charged, which enables transport over short distances, but with 100% electric drive [3].

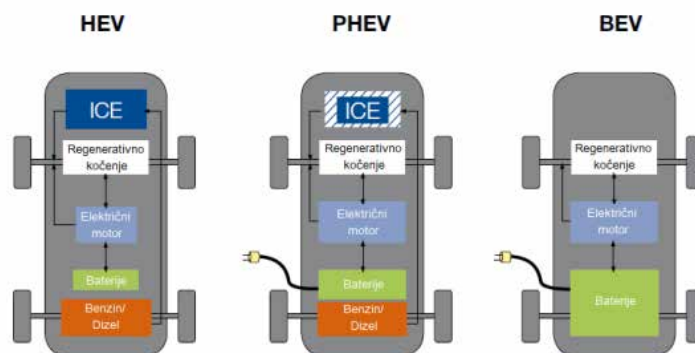


Figure 2. Comparison of technologies and performance of electric vehicles [1]

When electric car batteries wear out, they need to be replaced with new ones. Old batteries are thrown away, which can lead to environmental pollution, so they need to be recycled. Batteries contain heavy metals, lithium, aluminium, nickel and cobalt. When batteries are thrown away or disposed of improperly, some substances may leak out, thus endangering nature and the environment.

In order to recycle batteries, they must first be collected so that batteries do not end up in the waste. After collecting the batteries, it is necessary to dismantle them in order to separate the different materials. Recycling yields materials such as lithium, nickel, aluminium, etc., which are used to manufacture new cells. In this way, environmental pollution is prevented, and new or old raw materials are made available for the production of new batteries.

3. Charging stations

Charging stations for electric vehicles (Figure 3) are facilities/stations where charging and charging control equipment is located. On the outside, there is a line with a connector that serves to connect to the vehicle. Two connection lines can be placed on one station pole. Each station has its own concrete base according to the conceptual design [4].

Charging stations for electric vehicles can be built in parking lots, on traffic infrastructure, at home, and in garages of workplaces or shopping centres. On the highway, the distance between two charging stations is 40 - 50 km:

- As convenience for drivers,
- For increasing the number of charging stations,
- Because of infrastructure improvement,
- To reduce crowding at charging stations and
- To encourage people to buy electric vehicles.

The batteries of e-vehicles are charged with direct current and converters from alternating

current to direct current are required. Rectifiers are found in fast chargers, and they can be of large size, and therefore of greater power.



Figure 3. ELEN charging station in Split [5]

3.1. Types of charging stations for electric vehicles

Charging stations differ in terms of capacity, speed, size and charging speed. According to the method of contact between the charging station and the electric vehicle, we distinguish charging stations with conductive and inductive charging. Figure 4 shows a car connected to a conductive charging station with appropriate cables and plugs. An inductive charging station is shown in Figure 5; the vehicle is charged by energy transfer using an alternating electromagnetic field between a transmitter at the charging station and a receiver on the car. This kind of charging is slower and has higher losses than with conductive charging.



Figure 4. Example of conductive charging [6]

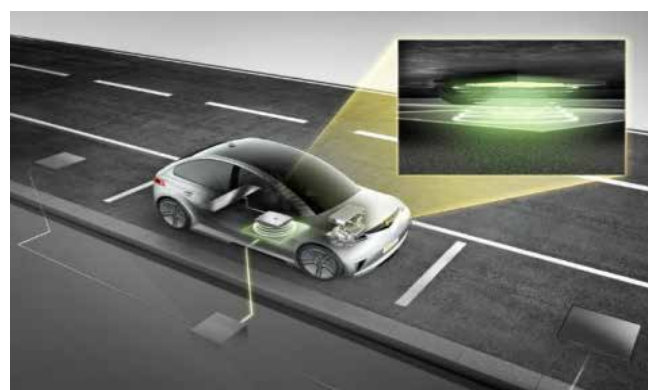


Figure 5. Example of inductive charging [4]

Charging stations with alternating current (AC) and direct current (DC) are distinguished depending on the type of current. AC chargers are slow and are mostly used in private, home chargers, connected to a household plug. DC charging stations are fast and mostly used in public charging stations such as parking lots, highways, etc.

According to the charging method, there are two standards for charging electric cars: SAE (Society of Automotive Engineers) J1772 - for the American automotive industry and IEC 61851 - for Europe. Standards define voltage levels, currents and charging protocols. Also, they determine the method of connecting the e-vehicle to the e-charging station and determine the communication method between the electric car and the charging station [7].

The SAE J1772 standard has three charging levels for AC and DC charging. Each charge level indicates how much electricity is supplied to the vehicle during charging [7]. The division of levels is shown in table 1.

At levels 1 and 2 AC stations are used mainly for domestic use. Car charging at these stations is done mostly overnight. Such stations do not have charging options. The biggest advantage is actually simplicity, because charging is done by connecting a line that has a J1772 connector to the car [8].

For AC stations of level 2 and 3, the charging power is much higher, so the connector must contain control signals. Communication between stations and vehicles is very simple and the safety of handling the charging station is ensured and the required power is defined. This type of charging station, more precisely level two of the station, is used mainly in shopping centres or near some workplaces where cars would be parked during working hours or shopping [8]. DC stations are more suitable for fast charging, and the power of the station is determined by the level of the station, charging time depending on the battery capacity and the maximum allowed charging current. This type of station is most suitable for places such as roads and highways [8].

Table 1. Charging level classification [8]

Level	Specifications	AC	DC
Level 1	<i>Output voltage</i>	120 V / 240 V	200 to 450 V
	<i>Maximum power</i>	3,5 kW	36 kW
	<i>Maximum current</i>	16 A	80 A
	<i>Average charging time</i>	17 h	1,2 h
Level 2	<i>Output voltage</i>	240 V	200 to 450 V
	<i>Maximum power</i>	3,3 kW to 20 kW	90 kW
	<i>Maximum current</i>	16 A to 80 A	200 A
	<i>Average charging time</i>	7 h to 1,2 h	20 min
Level 3	<i>Output voltage</i>	240 V	200 to 600 V
	<i>Maximum power</i>	20 kW	240 kW
	<i>Maximum current</i>	80 A	400 A
	<i>Average charging time</i>	1,2 h	10 min

International standard IEC 61851 (International Electrotechnical Commission) is used in Europe and China. The IEC 61851 standard is derived from the SAE J1772 standard, adapted to the European AC network. Unlike J1772 which has levels, these standards use charging modes. Modes in this case describe the safety communication protocol between the vehicle and the charging station. In this standard, there are 4 charging modes, namely [7]:

- mode 1 – slow charging from an regular socket and without special protection (picture 6.)
- mode 2 – slow charging from a regular socket, but with built-in protection (picture 7)
- mode 3 – slow or fast charging via a special socket with control and protection functions (Fig. 8)
- mode 4 – fast charging using special versions of the charger (Fig. 9)



Figure 6. Mode 1 [7,8]



Figure 7. Mode 2 [7,8]



Figure 8. Mode 3 [7,8]



Figure 9. Mode 4 7,[8]

3.2. Charging station safety

In order for electric vehicle charging to be safe, the system should have several safety functions. Constant communication with the vehicle should be carried out during charging and connecting the charger to the vehicle. Public charging stations have current sensors that register whether the station and the vehicle have been connected and communicate when the vehicle is no longer supplied with electricity. When the vehicle is no longer supplied with electricity, they are disconnected. These sensors are crucial because suddenly disconnecting the vehicle from the charger can be very dangerous [9]. Figure 10 shows the safety elements found in chargers for electric vehicles.

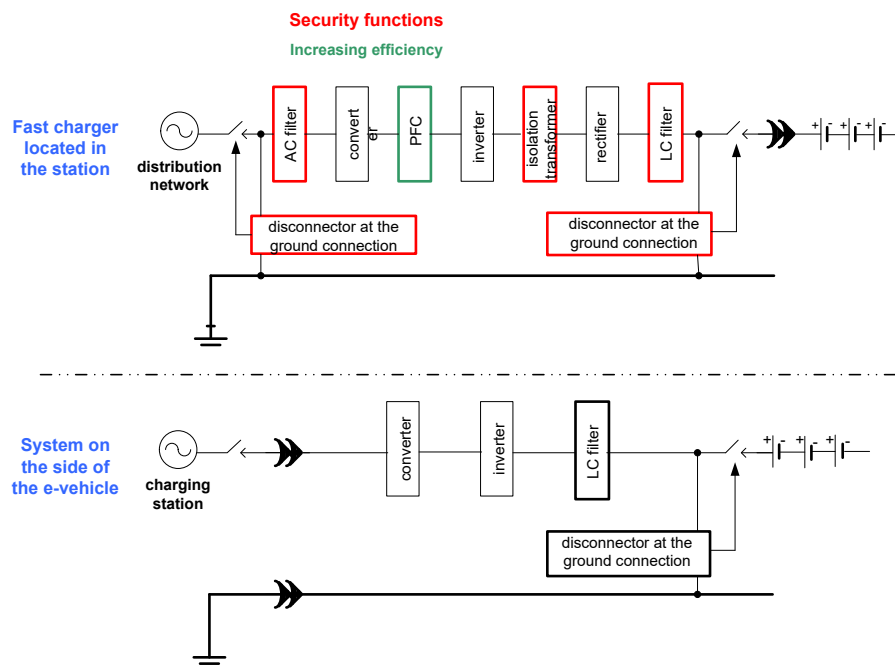


Figure 10. Safety elements in chargers [9]

4. Smart charging with KNX

In order to manage energy consumption at e-charging stations, one of the conceptual solutions is the implementation of the KNX system. The implementation of the KNX system would enable autonomous regulation of charging according to priorities and type of e-vehicle.

There are KNX devices on the market for integrating the e-charger into the system. New technologies are continuously being developed and tested, which will enable the management of additional information such as:

- availability of free e-charging stations,
- current state and duration of charging of occupied places,
- limiting the charging power depending on the current state of the network.

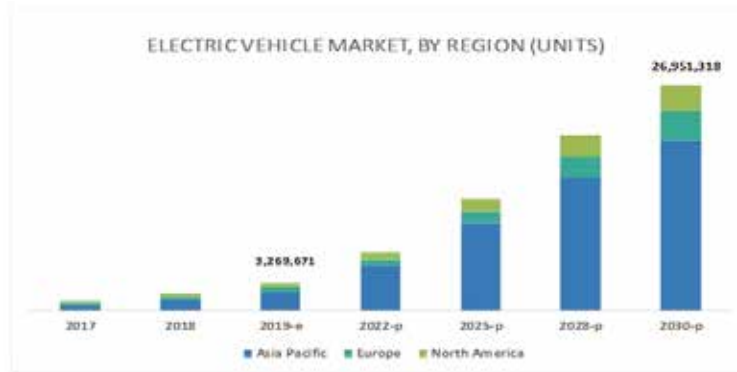


Figure 11. Real growth and anticipated growth of electric vehicles market [10]

Despite the positive aspects, there are also disadvantages that are manifested through:

- CO2 emissions (production of e-cars, batteries),
- the cost of electric vehicles (if you drive less than 15,000 km per year, it is cheaper to get a non-electric car),
- lack of charging infrastructure,
- materials used in batteries and
- range/mileage.

The goal of e-car production is the economic justification of the price and the reduction of CO2 emissions, that is, to develop technology with the domain of application and integration of charging stations within the KNX system. Since the attitude is towards a sustainable system, i.e. the energy management system, existing KNX devices are defined that enable charging stations to be connected to the KNX system, but new KNX devices with charging capabilities are also being developed.

With the system of smart e-charging stations, it is possible to monitor and inform users about total energy consumption, last charge, etc. Also, KNX offers support for protecting users from unauthorized access to e-charging stations and e-vehicles, by implementing “KNX Secure” technology. Figure 12 shows the SMART CONNECT KNX e-charge II device. [11]

SMART CONNECT KNX e-charge II is a simple and safe integration of charging points into the KNX system. Devices from different manufacturers can be integrated. This procedure enables fast charging of the vehicle thanks to dynamic load management, and no additional adapter is required. As it is possible to connect devices from different manufacturers at the charging points, maximum flexibility is ensured, up to five charging points can be connected (Figure 13). The possibility of e-billing is achieved with dynamic load management (DLM), i.e. it is possible to use the maximum charging current on all chargers at the same time regardless of the manufacturer and model. It is continuously monitored and controlled: the number of cars being charged at charging stations, the amount of electricity currently flowing into the car, the amount of energy used to charge the vehicle and when charging can be done or the place can be locked. Since the integration of five charging points is possible, with this device connected

to the KNX system, priority can be defined for one charging point. Also, charging points from different manufacturers can be used at the same time.

Charging currents, energy consumption and last charge duration can be continually monitored.

In addition, status value data (connected, charging, charging completed, charging status), start/stop, locking, interrupting, or unlocking the charging process, temperature value and temperature warning, vehicle ID and RFID tag data, data can be requested about the serial number and charging location. Error messages from the charging station and the device are also registered. The system includes an integrated RS485 adapter and an IP switch (double). Connection with KNX means security and complete configurability in ETS.



TECHNICAL DATA

Nominal Voltage 24 V to 30 V

Consumption: 2,3 W

IP communication: Ethernet 10/100 BaseT

KNX SPECIALIST

Connector: connecting bus terminal

Medium: TP1, S mode

Instantaneous: typ. 6mA

IP

Connectors: 2 x RJ45 (integrated switch)

Communication: Ethernet 10/100 BaseT (100/100

Mbit/s)

RS485

Connection: Screw terminal, 3-pin (GND, A+, B-)

Communication: Modbus

Data rate: Maks. 500 kbps

Cable length: Up to 1200 m

Electrical isolation: 3 kV DC

Ambient temperature: 0 °C to +45 °C

Dimensions: 2 HP (DRA plus)

Note: Supply via external DC 24 V. For ETS 5.7.5 or higher

Ordering info: Order no. 1-000F-003

Figure 12. SMART CONNECT KNX e-charge II [11]

Energy consumption is often a problem. However, SMART CONNECT KNX e-charge II and the use of DLM smart home technology means evenly distributed electricity, preventing overloading and enabling the management of several charging stations at once. The implementation of SMART CONNECT KNX e-charge II and a smart meter enables: download of devices with high energy consumption, avoidance of peak loads, prioritization as well as additional benefits for a wide range of uses. If we look at the energy transition, which is based on the transition from non-renewable energy sources to renewable ones, it is necessary to accept new laws, harmonize policies and tax incentives respecting international obligations (Paris Agreement, European and national laws). When choosing an option, the starting point is personal interest, which is mainly related to economic justification. The integration of renewable sources is a consequence of media attention and cost subsidies. It is inevitable to face a series of obstacles such as: production costs, the cost of the transition itself, the realization of permanent production plants, grid imbalance (periods with a lot of solar energy/wind energy compared to times of limited supply), mobility (electric cars need batteries for example) and

transition to fully electric installations. Since the main goal is to reduce consumption, reduction is approached, because it is always better than changing the energy source. Also, it is inevitable to harmonize sustainability with own energy and its storage in order to optimize the system.

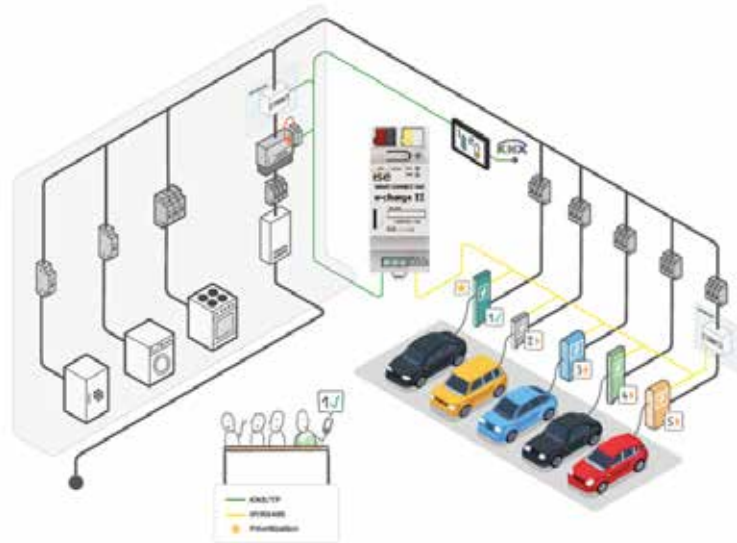


Figure 13. Connecting devices at charging points with maximum flexibility[11]

A truly smart charging station with flexible energy management can help not only the owner and user, but also the electricity grid provider and the energy transition in general. It is concluded that the more aware the user is of his energy consumption, the less energy he uses.

Energy monitoring and management is essential for effective management of energy consumption and production, recording installations and monitoring energy consumption through possible losses on installations. The choice of lighting and weather sensors on the roof enable information on prices and weather forecasts, as well as predictive management of the e-charging station (maintenance, failure monitoring, etc.). A good control system reduces energy and costs while maintaining a high level of comfort. With the open KNX standard (ISO/IEC 14543), it is easier to make all available data within one system. There are KNX products (gateways) for obtaining data from electricity meters and sensors from the building. [9] There are also types of direct KNX meters (temperature measurement, heat pump settings, information on the production of solar panels, etc., depending on needs). For products that do not support the KNX protocol, bridging products are available. Energy storage systems can be connected to KNX and end devices that use energy can be controlled, e.g.:

- heating system
- the dishwasher is turned on every afternoon
- the electric car is charged in the morning
- if you want the endpoint to be ready earlier, priority can be requested
- endpoint control can be added based on collected data, keeping in mind maximum limits, storage systems and a more efficient way of using own energy based on weather forecast and tariff information
- KNX - smart control system

KNX is completely local and not dependent on the Internet, resulting in better privacy and security. Another problem with cloud management solutions is that in most cases they are controlled by the owner of the energy network as the first and most important stakeholder, not the owner of the installation. KNX “manages” energy by combining all available data, automatically analysing, predicting, and controlling.

5. Conclusion

In the future, the number of electric vehicles and thus the number of charging stations will increase, primarily due to accelerated industrialization and the desire to reduce environmental pollution. Accordingly, it is necessary to develop the infrastructure to ensure 100% safety of reaching the destination. The development of technology has enabled modern charging stations with multiple modes and charging speeds for electric vehicles. When designing the charging station, it is necessary to consider its location, make a financial analysis and examine the safety of workers and the charging station, and take into account the lifetime of its correct operation. Due to the development of tourism in the Republic of Croatia and the incentives provided by the state for the purchase of electric vehicles, an increase in the number of charging stations is expected. One of the biggest problems of electrification is the development of infrastructure and the storage of worn-out batteries, because batteries also pollute the environment. This problem is solved by recycling end-of-life batteries. Recycling batteries saves them from throwing into waste and releasing harmful gases and substances. The implementation of the KNX system ensures the integration of EV charging within the energy management system and achieving correct operation of e-charging stations.

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WEB-BASED MOTOR CONTROL AND ENVIRONMENTAL MONITORING SYSTEM

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Abstract. The project involves the implementation of a web-based system for controlling a motor and displaying temperature and humidity data from sensors. The system utilizes a web server to host a user interface accessible through a web browser. Users can interact with the interface to remotely control the motor's operation. Additionally, real-time temperature and humidity readings from sensors are collected and displayed on the web server interface, providing users with insights into environmental conditions. This integration of motor control and environmental monitoring enhances the system's utility and allows for remote management and monitoring from anywhere with internet access.

Key words: ESP32, HTTP protocol, Web server, Augmented Reality, IOT

1. Introduction

In today's digital era, the inevitability of connecting devices over the internet has enabled remote control and monitoring of various systems. This paper investigates the implementation of a motor control system through a web interface using the ESP32 microcontroller. The ESP32 provides the capability to establish a web server, enabling users to remotely control connected devices via a web browser on any internet-enabled device. Additionally, augmented reality (AR) technology is utilized to grant access to the web server, enhancing user interaction and accessibility. By simply scanning a QR code with an AR-enabled device, users can access the web interface and control the motor remotely. The system also integrates a temperature sensor that automatically activates the motor when the temperature exceeds a certain threshold. Throughout this paper, we delve into the steps required to implement the system, from initializing the ESP32 microcontroller to setting up the web interface and monitoring the temperature. Finally, we evaluate the system's performance and discuss its applicability in various scenarios.

2. Internet of Things

Internet of Things (IoT) is a network of physical objects or people called “things” that are embedded with software, electronics, network, and sensors that allows these objects to collect and exchange data [1]. This concept is designed to make everyday things easier by automating various processes. There are 3 types of communication in IoT:

DEVICE TO DEVICE – communication between the devices themselves on the network without the need for an intermediary such as a central server or cloud. For example, the temperature sensor can communicate directly with the smart thermostat for temperature control.

DEVICE TO CLOUD – communication between device and cloud. Data is sent from the device to the cloud for analysis or storage. For example, the smart camera sends videos or photos to the cloud, and we further analyse or store them.

CLOUD TO DEVICE – communication between the cloud and the device, the reverse of the previous one. In this case, commands are sent from the cloud to the device. For example, the cloud platform sends a command to the smart bulb to turn on or off.

All three communications take place in 3 processes: Data collection, data analysis and final instructions.

3. Augmented Reality

The technical means it uses include Multimedia, 3D-Modelling, Real-time Tracking and Registration, Intelligent Interaction, Sensing and more. Its principle is to apply computer-generated virtual information, such as text, images, 3D models, music, video, etc., to the real world after simulation [2].

AR is mainly divided into three types: marker-based, marker-less, and location-based. Marker-based AR uses the recognition of specific features or markers in the real world to place virtual objects or information in specific positions. On the other hand, marker-less AR does not require the recognition of specific markers but utilizes sensors such as the camera and motion sensors to align virtual content with the environment. Location-based AR utilizes geolocation data to place virtual objects or information at specific locations in the real world, usually via GPS or other location technologies.

4. Design Procedure

The design of this project aims to create a stand-alone asynchronous ESP32 web server that combines temperature and humidity monitoring and DC motor control. The ESP32 stands out as a key element due to its ability to manage diverse IoT applications. Through this project, users will be able to access data via the Internet, and an additional tool that facilitates interaction with the web server is the integration of augmented reality (AR). Through the AR interface, the user will be able to access the web server by simply scanning a QR code, providing an intuitive way of interaction. After scanning, the user will have access to all functions of the web server, including control over temperature, humidity and starting the DC motor.”

4.1. Hardware Requirements

This work is accomplished using the following hardware components: ESP32, DHT22, I2C LCD (Liquid Crystal Display), VDC Motor and L293D motor driver.

Figure 2 DHT22 sensor

Technical specification [4]:

Communication Protocol	One-wire
Power supply Range	3 -6 V
Temperature Range	-4 to 80°C (+/- 0.5 °)
Humidity Range	0 to 100% (+/- 2%)
Sampling Method	2 Second
Arduino Libraries	Adafruit DHT library
Interchangeability	fully interchangeable

LCD (Liquid Crystal Display)

I2C LCD (Liquid Crystal Display) is a text display that is controlled via I2C communication and is used to display text, numbers, and messages. The difference between an I2C LCD and a standard LCD is in the number of pins. An I2C LCD only needs 4 pins (SDA, SCL, GND, 5V) to connect to ESP32 while a standard LCD needs more pins depending on the size (16x2, 20x4).



Figure 3 I2C LCD display

Technical specification [5]:

Display Type	Negative white on Blue backlight
I2C Address	0x38-0x3F (0x3F default)
Supply voltage	5V
Interface	I2C to 4bits LCD data and control lines
Contrast Adjustment	built-in Potentiometer
Backlight Control	Firmware or jumper wire
Board Size	80x36 mm

VDC Motor

VDC motors are used to convert electrical energy from a direct current source into mechanical energy by rotation.



Figure 4 VDC motor

Power supply	The motor operates in the range of 1.5V-3V
Current	At a voltage of 3V, the motor consumes a current of 300mA
Speed of revolutions	At a voltage of 3.3V, the nominal speed is 14200 revolutions per minute
Variable voltage	the motor is adaptable because it can operate in the range of 1.5V-3V and is used in applications that require variable motor speed

4.2.2. L293D motor driver

The L293D motor driver is a chip used for simpler control of the speed and direction of one or two DC motors. The L293D is available in various packages and versions. In this project, a 16-pin driver was used. Can be used to run Two DC motors with the same IC.

Speed and Direction control is possible.



Figure 5 L293D driver

Technical specification [6]:

Motor voltage Vcc2 (Vs):	4.5V to 36V
Maximum Peak motor current:	1.2A
Maximum Continuous Motor Current:	600mA
Supply Voltage to Vcc1(vss):	4.5V to 7V
Transition time:	300ns (at 5V and 24V)

4.3. Software Overview

The software used to successfully realize the objectives of the work include: Web Server and Web-AR.Studio.

4.4. Arduino IDE

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them [7].

The Arduino IDE is a popular tool for programming ESP32 microcontrollers due to its ease of use and support for the ESP32 platform. Through the Arduino IDE, it is possible to use the Arduino programming language and access a rich library and code examples that facilitate the development of various projects. In addition, the Arduino IDE allows easy compiling and uploading of code to the ESP32 microcontroller, which makes the development and testing process faster and more efficient.

4.5. HTML, CSS and JavaScript

By incorporating HTML, CSS, and JavaScript, the web server was able to deliver a seamless and engaging user experience. HTML provided the structure and content of the webpage, CSS enhanced its visual presentation, and JavaScript added interactivity and real-time updates, resulting in a well-rounded and functional web application. This combination of technologies enabled the creation of a user-friendly interface that effectively served its intended purpose of monitoring temperature and humidity data.

4.6. Web-AR.Studio

Web AR Studio is a platform that enables the creation of augmented reality (AR) directly through a web browser, without the need to download additional applications or install special programs. This platform provides the tools and resources needed to create rich and interactive AR experiences, including adding 3D models, animations, sound, and textures to the real world. AR projects can be easily integrated into websites or applications through simple APIs or by using QR codes.

Web AR Studio often offers an intuitive user interface that enables quick and easy creation, editing and distribution of AR content. In addition, this platform often supports different types of devices and browsers, which allows for wide availability and compatibility.

One of the key benefits of using Web AR Studio is accessibility. AR content can be accessed via mobile devices or computers without the need for additional software or special equipment.

5. Implementation

5.1. Hardware setup

The circuit schematic diagram shown on figure 6 provides a detailed guide on how to integrate the DHT22 temperature and humidity sensor and DC motor with the ESP32 microcontroller. In this setup, the data pin of the DHT22 is connected to GPIO 23 of the ESP32, allowing the microcontroller to receive sensor data. Additionally, the VCC (power) and GND (ground) pins of the DHT22 are connected to the corresponding supply voltage and ground pins of the ESP32, ensuring proper power supply to the sensor.

Furthermore, the DC motor is connected to GPIO pins 26 and 27 of the ESP32 for control purposes. GPIO 26 is designated as the motor control signal pin, while GPIO 27 serves as the power supply pin for the motor.

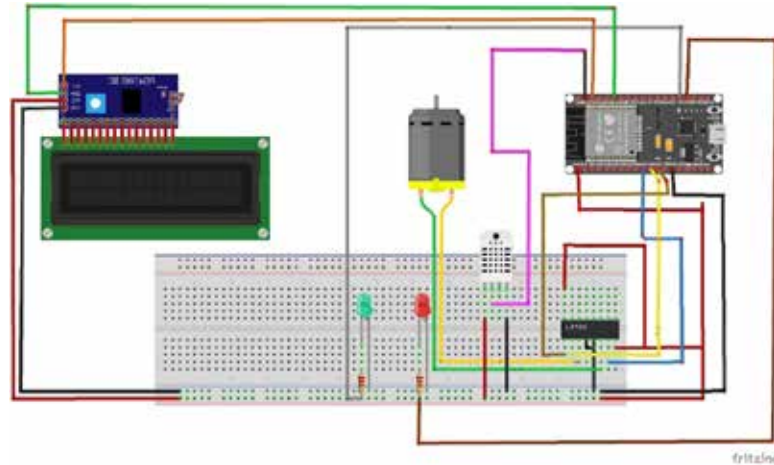


Figure 6. Electrical circuit diagram

5.2. Software configuration

Once the hardware connections are established, the code is written in the Arduino IDE.

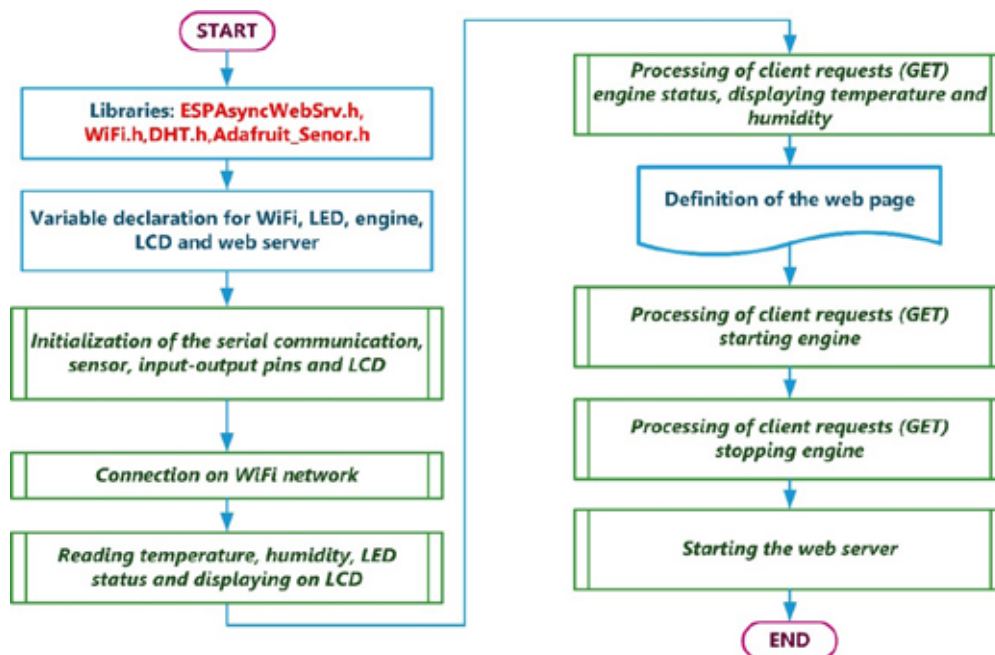


Figure 7 Flowchart of the program

In the initial step, the necessary libraries are included. These libraries, which are included in the code, encompass the WiFi.h library for connecting the ESP32 to a Wi-Fi network, the ESPAsyncWebServer.h library for handling HTTP requests, the DHT.h library for interfacing with the DHT temperature and humidity sensor, and the LiquidCrystal_I2C.h library for controlling the I2C-compatible LCD display. These libraries provide the requisite functions and methods for establishing a Wi-Fi connection, configuring a web server, interfacing with sensors, and controlling peripheral devices.

```
#include <Wire.h>
#include "ESPAsyncWebSrv.h"
#include <WiFi.h>
#include <DHT.h>
#include <LiquidCrystal_I2C.h>
```

Next is the configuration of the WiFi network that the ESP32 will be connected to.

```
const char* ssid = "your_SSID"; // Network name
const char* password = "your Password"; // Network password
```

The ESP32 operates in three modes: Access Point (AP), Wi-Fi station, or both Access Point and Wi-Fi station simultaneously. In this project, the ESP32 is configured as a Wi-Fi station, while the router serves as the access point. To control the ESP32, it is necessary to connect to the local network. STA mode is activated when a device connects to a wireless network as a client, enabling tasks such as network enrollment or communication between devices within the network. This mode serves as a foundational configuration for many Wi-Fi-enabled devices, providing flexibility, seamless connectivity, and operational versatility across various network environments.

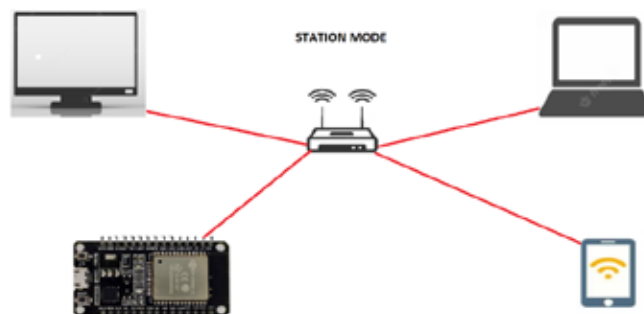


Figure 8 ESP32 as a WI-FI station

Port initialization for the web server.

```
AsyncWebServer server(80);
```

Finally, after the entire code is written and the HTML, CSS, and JavaScript files are added, the program sketch is flashed into the ESP32 microcontroller using the Arduino IDE.

5.3. Integration of Augmented reality

In WebAR Studio, a QR code is generated to access augmented reality. In augmented reality (AR), the image generated by artificial intelligence is seamlessly integrated into the virtual space, along with a button image that is set as a link to a web page merging computer-generated elements with real-world scenes.

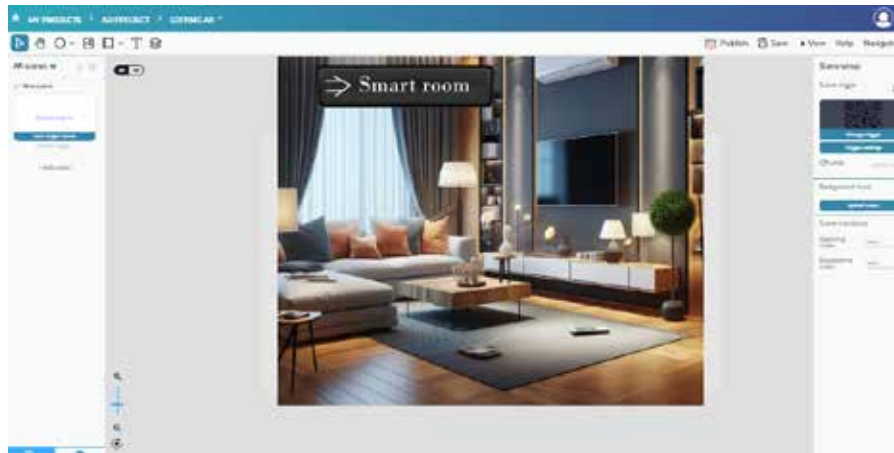


Figure 9 Web-AR.Studio

5.4. Implementation results

To access the web page, the IP address must be identified by opening the serial monitor on the Arduino IDE.



Figure 10 Serial monitor

To access the web page, the IP address must be identified by opening the serial monitor on the Arduino IDE. Once the IP address (198.168.165.134) is obtained, it can be entered into any web browser of any web client connected to the same network. Alternatively, users can scan a QR code to access the web page directly. This enables users to view the webpage, which displays sensor data for temperature and humidity. Additionally, the web page features buttons to turn the motor on or off, allowing users to control its status. The current status of the motor (on or off) is also displayed on the webpage, providing users with real-time feedback on its operational state.



Figure 11 Access web page via QR code

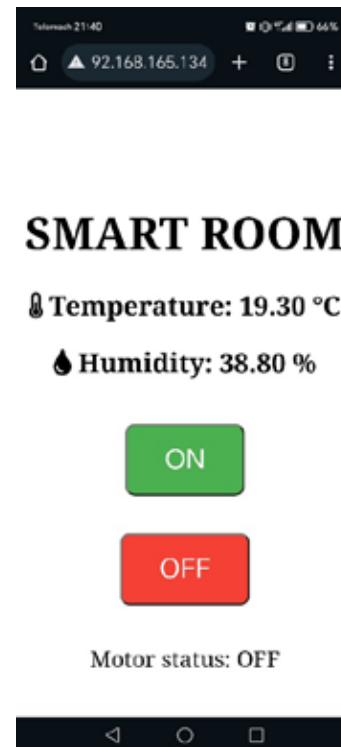
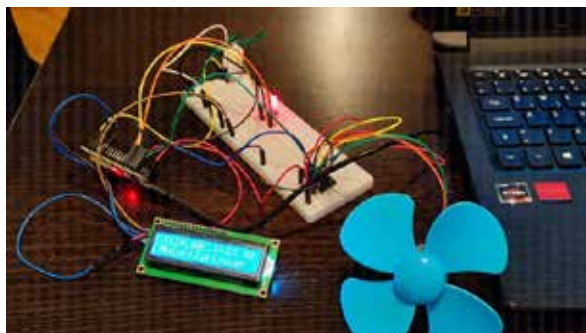
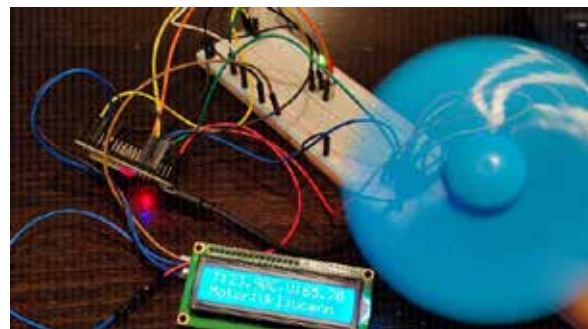


Figure 12 Web page



Motor status off



Motor status on

Figure 15 Status of motor

6. CONCLUSION

In this paper, the functionality of a motor control system via a web interface is demonstrated, utilizing the ESP32 microcontroller. This microcontroller facilitates the creation of a web server and seamless integration with various sensors and actuators responsible for motor control. Thorough testing was conducted to ensure the system's robustness, covering motor control capabilities, temperature monitoring via the web interface, and evaluation of response times and reliability across various scenarios.

Augmented reality technology was utilized to improve accessibility and user experience. With augmented reality, users can interactively access the web server. Remote motor control and environmental parameter monitoring, such as temperature, are enabled through a simple QR code scan.

The research lays a solid groundwork for future advancements. Its potential applications span across various domains, including smart homes, tourism, industrial settings, and the Internet of

Things. As technology progresses, systems like this hold limitless potential for automating tasks and fostering connectivity in our increasingly digital landscape.

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MEET CURRENT HARMONIC LIMITS – CHALLENGES AND SOLUTIONS

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Abstract. Distortion of mains current caused by non-linear loads creates harmonics that can significantly affect the overall system efficiency and particularly power factor. This paper explores several methods of higher harmonics mitigation according to the limits specified in standards IEC 61000-3-2 and IEC 5555-2 and in the equivalent European standard EN 61000-3-2. [4]. Passive power factor correction approach improves the power factor by filtering harmonics using passive filters comprising of inductors and capacitors on both AC and DC sides of the power supply. Active power factor correction includes use of Power Factor Correction circuit or use of dedicated circuits for injection of 3rd and 5th harmonic. Regarding the above-mentioned correction of the power factor, in this paper the emphasis will be given on the interleaved boost regulator usage for mitigation of the load current higher harmonics. Future work will include resonant converters for power factor correction purposes.

Key words: *passive and active power factor correction, interleaved boost regulator, non-linear load,*

1. Introduction

The ratio between true power used in a circuit to the apparent power delivered to the circuit is known as power factor. In ideal case, value of the power factor is one (1) while in real cases, when value of the power factor is less than one, an extra power is required to complete the actual work. Power factor below 0.95 is considered inefficient in many regions. With linear loads connected to the mains, power factor can easily be determined since voltage and current are both sinusoidal at any time, ratio between them is in accordance with the Ohm's law. On the other hand, current wave distortion caused by non-linear loads generates harmonics that can significantly impact power factor determination. This paper will discuss how to define and correct power factor in non-linear loads cases. Figure 1 represents case without power factor correction. Adequate equations are specified below the figures.

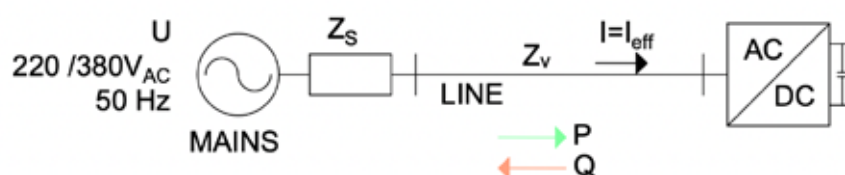


Figure 1 Case without Power Factor Correction.

$$S = \sqrt{P^2 + Q^2} \quad (1)$$

$$I_{eff} = \frac{\sqrt{P^2 + Q^2}}{U} \quad (2)$$

$$\Delta u = (Z_s + Z_v)I_{eff} \quad (3)$$

Power factor correction will increase mains efficiency, reduce losses on mains impedance and minimize voltage distortion. Figure 2 shows case with power factor correction. Adequate equations are specified below the figures.

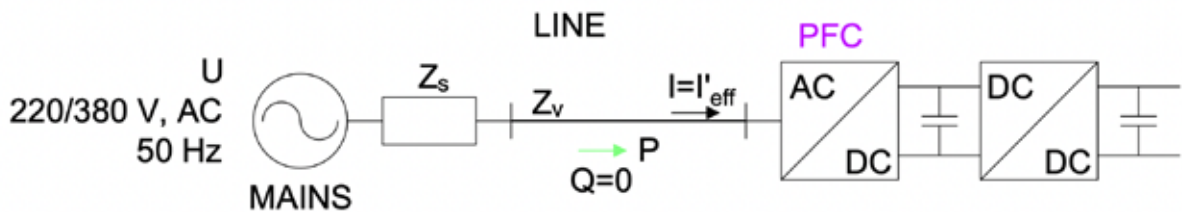


Figure 2 Case with Power Factor Correction.

$$S' = \sqrt{P^2} \quad (4)$$

$$I'_{eff} = \frac{\sqrt{P^2}}{U} \quad (5)$$

$$\Delta u' = (Z_s + Z_v)I'_{eff} < \Delta u \quad (6)$$

2. Non-linear loads

Personal computers represent low-power single-phase non-linear loads with a significant impact on overall distortion, which is caused by switching mode power supply. The impact on the mains is even higher if many of them are connected to the same bus. The input current of PCs consists of odd-order harmonics. In almost every type of personal computer, a large third-harmonic current (up to 87% of the fundamental) is present. These currents generate neutral currents as high as 1.7 times the line current. The Power Supply Unit (PSU) is a critical component of any desktop computer, including the front-end rectifying circuit that converts alternating 220V, 50Hz mains voltage to the 300V DC voltage for further high-frequency conversion to 5V DC and 3.3V DC output. The rectification is usually carried out by a full-wave bridge rectifier shown in Figure 3. To filter out the output waveform, a smoothing capacitor is installed in parallel with the load across the output of the full-wave bridge rectifier circuit, which represents a capacitive load. Figure 4 represents output current and voltage waveforms.

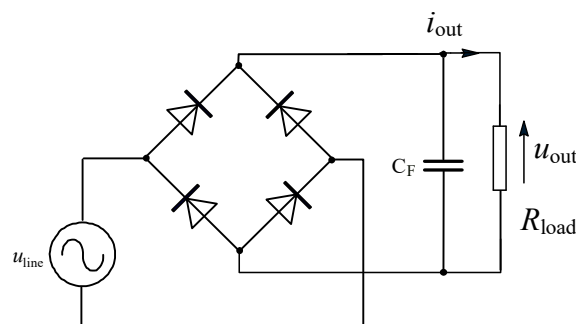


Figure 3 Full wave diode rectifier.

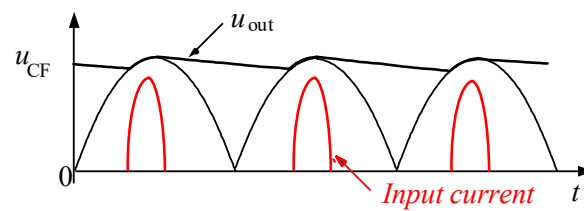


Figure 4 Current and voltage waveforms.

This combination increases the average DC output level as the capacitor acts like a storage device and at the same time reduces the AC variation of the rectified output. However, the large value of capacitor causes the odd harmonic presence in the input current waveform, along with first harmonic domination. Distorted supply current can be decomposed into the sum of the fundamental frequency and the harmonic components [4]. Figure 5 represents current and voltage waveforms without PFC. Input current spectrum is shown on Figure 6.

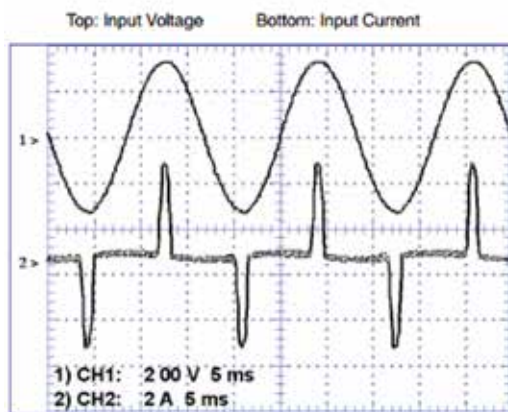


Figure 5 Full wave diode rectifier current and voltage waveforms without PFC

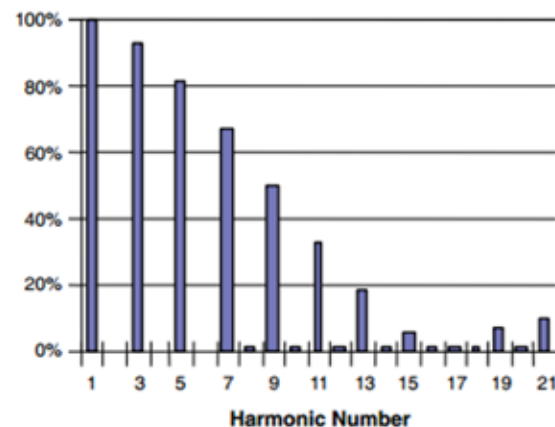


Figure 6 Input current spectrum without PFC

Power factor correction can be defined as the reduction of harmonic content. By making the current waveform look as sinusoidal as possible, as shown in Figure 7, the power drawn by the power supply from the line is maximized to real power. Assuming that the voltage is almost sinusoidal, the power factor depends primarily on the current waveform. Figure 8 represents the input current spectrum with PFC [4].

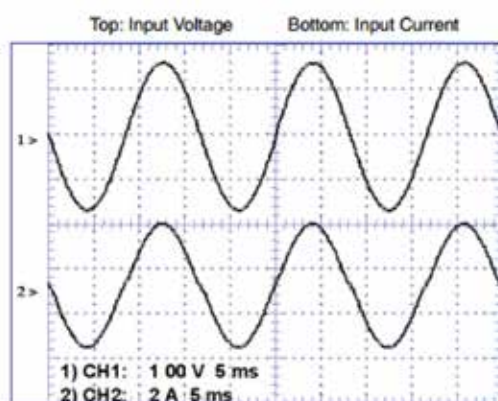


Figure 7 Full wave diode rectifier current and voltage waveforms with PFC

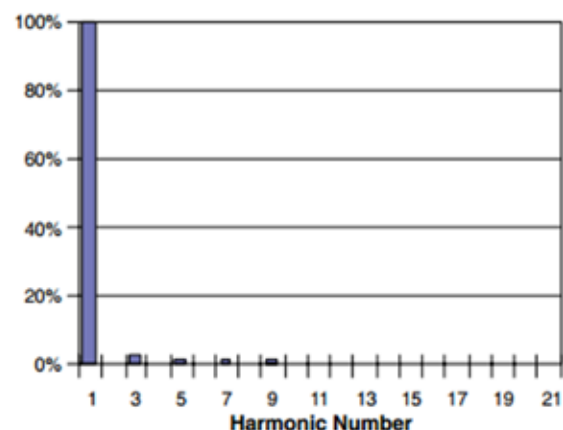


Figure 8 Input current spectrum with PFC

The presence of harmonics in both voltage and current causes distortion in power. Distorted power affects the power factor, as the power factor decreases in the presence of harmonics. The definition of power factor relates the primary harmonic current to the RMS current contained in all harmonics. The distortion of the voltage or current waveform compared to the pure sinusoid is defined by the total harmonic distortion (THD). THD is a global index that considers all present harmonics and is expressed as a percentage of the fundamental harmonic. It can be calculated for both voltage and current waveforms. High THD values indicate a high degree of distortion, which can negatively impact the operation of electrical devices and equipment. The total harmonic distortion and distortion factor (DF) are given in the equations below.

$$THD = \frac{\sqrt{\sum_{k=2}^{\infty} I_k^2}}{I_1} \quad (7)$$

$$DF = \frac{1}{\sqrt{1+THD^2}} \quad (8)$$

Non-sinusoidal current causes resultant active and reactive power to consist of harmonics of the same orders as both current and voltage; therefore, the influence of harmonics must be considered. The following equations define active and reactive power with harmonics included.

$$P = \sum_{n=0,1,2}^{n_{max}} (U_{(n)RMS} * I_{(n)RMS}) * \cos(\alpha_n - \beta_n) [W] \quad (9)$$

$$Q = \sum_{n=0,1,2}^{n_{max}} (U_{(n)RMS} * I_{(n)RMS}) * \sin(\alpha_n - \beta_n) [VAr] \quad (10)$$

The power appearing due to distorted voltage and current waveform is defined as distortion power D [1] and consists of unequal harmonics of voltage and current as noted in Eq (11).

$$D = \sum_{i=0}^{n_{max}-1} \sum_{j=i+1}^{n_{max}} (U_i^2 I_j^2 + U_j^2 I_i^2 - 2U_i U_j I_i I_j \cos(\vartheta_i - \vartheta_j)) [VA] \quad (11)$$

In this case, apparent power S is given by:

$$S = \sqrt{P^2 + Q^2 + D^2} [VA] \quad (12)$$

In the scenario of 200 personal computers connected to a single 220V, 50 Hz phase, an input current of 1A will be assumed. If the current impulse lasts 1ms and the half period is 10ms, the current peak value is 10A. This implies that with 200 PCs, the current peak value would reach 2kA, which is unacceptable due to voltage drops, harmonic generation, etc.

The main document dealing with requirements concerning the supplier's side is the EN 50160 standard, which defines voltage parameters of electrical energy in public distribution systems. For many consumers, meeting the requirements outlined in EN 50160 does not assure a satisfactory level of Power Quality (PQ). In such cases, the level of PQ required must be defined in a separate agreement between the supplier and the consumer. The requirements given in EN 50160 and EN 61000-2-2 are represented in Table 1 [6].

Table 1 EN 50160, EN 61000-2-2 Standard for harmonic limitations

		EN 50160	EN 61000-2-2			EN 50160	EN 61000-2-2
Even harmonics:				Odd harmonics:			
2	(100 Hz)	2.00%	2.00%	(multiples of 3)			
4	(200 Hz)	1.00%	1.00%	3	(150 Hz)	5.00%	5.00%
6	(300 Hz)	0.50%	0.50%	9	(450 Hz)	1.50%	1.50%
8	(400 Hz)	0.50%	0.50%	15	(750 Hz)	0.50%	0.40%
10	(500 Hz)	0.50%	2.50%	21	(1050 Hz)	0.50%	0.30%
12	(600 Hz)	0.50%	2.13%	27	(1350 Hz)	-	0.20%
14	(700 Hz)	0.50%	1.86%	33	(1650 Hz)	-	0.20%
16	(800 Hz)	0.50%	1.66%	39	(1950 Hz)	-	0.20%
18	(900 Hz)	0.50%	1.50%	45	(2250 Hz)	-	0.20%
20	(1000 Hz)	0.50%	1.38%	Odd harmonics:			
22	(1100 Hz)	0.50%	1.27%	(not multiples of 3)			
24	(1200 Hz)	0.50%	1.19%	5	(250 Hz)	6.00%	6.00%
26	(1300 Hz)	-	1.12%	7	(350 Hz)	5.00%	5.00%
28	(1400 Hz)	-	1.05%	11	(550 Hz)	3.50%	3.50%
30	(1500 Hz)	-	1.00%	13	(650 Hz)	3.00%	3.00%
32	(1600 Hz)	-	0.95%	17	(850 Hz)	2.00%	2.00%
34	(1700 Hz)	-	0.91%	19	(950 Hz)	1.50%	1.76%
36	(1800 Hz)	-	0.88%	23	(1150 Hz)	1.50%	1.41%
38	(1900 Hz)	-	0.84%	25	(1250 Hz)	1.50%	1.27%
40	(2000 Hz)	-	0.81%	29	(1450 Hz)	-	1.06%
42	(2100 Hz)	-	0.79%	31	(1550 Hz)	-	0.97%
44	(2200 Hz)	-	0.76%	35	(1750 Hz)	-	0.83%
46	(2300 Hz)	-	0.74%	37	(1850 Hz)	-	0.77%
48	(2400 Hz)	-	0.72%	41	(2050 Hz)	-	0.67%
50	(2500 Hz)	-	0.70%	43	(2150 Hz)	-	0.63%
The same for both standards:				47	(2350 Hz)	-	0.55%
Total harmonic voltage distortion THDv : max. 8%				49	(2450 Hz)	-	0.52%
Total harmonic current distortion THDi : max. 20%							

3. Methods for power factor correction

3.1. Passive PFC

The simplest form of power factor correction is a passive power factor correction, and it is the most common type of PFC for small power supply. A passive PFC uses a filter at the AC input to correct poor power factor. The passive PFC circuitry uses only passive components, inductors, and capacitors. Although simple and robust, a passive PFC rarely achieves low THD. Furthermore, since the circuit operates at the low line power frequency of 50 Hz, the passive elements are normally bulky and heavy. This type of power correction factor method corrects power factor in between 0.7 to 0.85. Passive power factor correction can be realized as follows:

1. inductor on AC (mains) side
2. inductor on DC side (rectifier output)
3. bandpass filter – series resonant LC circuit on AC side
4. bandstop filter – parallel resonant LC circuit on AC side
5. trap filters – harmonic filters on AC side
6. LC filters on DC side

3.2. Active PFC

3.2.1. Active power correction with PFC regulator

In power factor correction pre-regulators, the most popular topology used is a boost converter. Boost converters can have continuous input current that can be manipulated with average current mode control techniques to force input current to track changes in line voltage. Figure 9 shows a basic single stage boost converter.

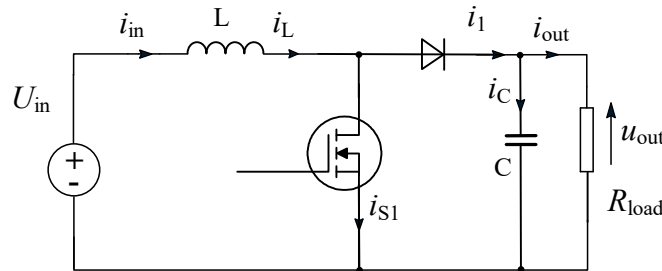


Figure 9 Single stage boost converter.

The output capacitor filters out the diode discontinuous output current (I_1). In this topology, the output capacitor current is very high, ripple and different than I_1 . Typical circuit waveforms are shown on Figure 10.

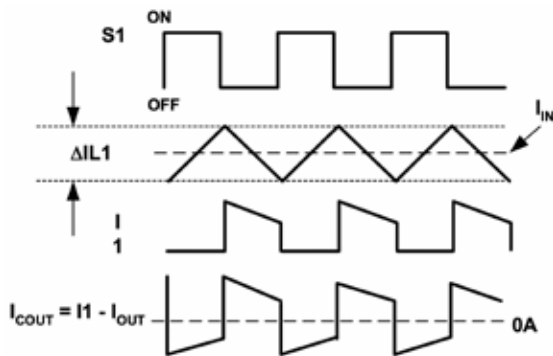


Figure 10 Single stage boost converter waveforms

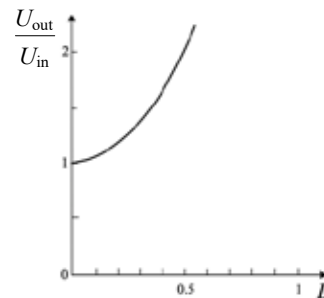


Figure 11 Boost converter DC voltage gain

Boost converters are used for generating high output voltages from low input voltages. However, the voltage gain has a natural limit. The voltage gain is the ratio of output voltage to input voltage. Figure 11 shows the voltage gain versus the duty cycle. Voltage gain can also be expressed in terms of the duty cycle.

$$D = 1 - \frac{U_{in}}{U_{out}} \quad (13)$$

The duty cycle indicates the amount of time that the switch, S1, is on in each cycle. The voltage gain describes the factor by which the output voltage exceeds the input voltage. To generate a high voltage, the duty cycle increases to values close to 1 but never reaches 1. The most widely used operation modes for the boost converter are continuous conduction mode (CCM) and boundary conduction mode (BCM). As the names indicate, the inductor current in CCM is continuous, while in BCM, the new switching period is initiated when the inductor current returns to zero, which is at the boundary of continuous conduction and discontinuous conduction operations. The fundamental idea of BCM PFC is that the inductor current starts from zero in each switching period. When the power transistor of the boost converter is turned on for a fixed time, the peak inductor current is proportional to the input voltage. Since the current waveform is triangular, the average value in each switching period is proportional to

the input voltage. In a sinusoidal input voltage, the input current of the converter follows the input voltage waveform with very high accuracy and draws a sinusoidal input current from the source. This behavior makes the boost converter in BCM operation an ideal candidate for power factor correction. A boost converter runs with variable switching frequency depending primarily on the selected output voltage, the instantaneous value of the input voltage, the boost inductor value and the output power delivered to the load. The operating frequency changes as the input current follows the sinusoidal input voltage waveform, as shown in Figure 12. The lowest frequency occurs at the peak of sinusoidal line voltage.

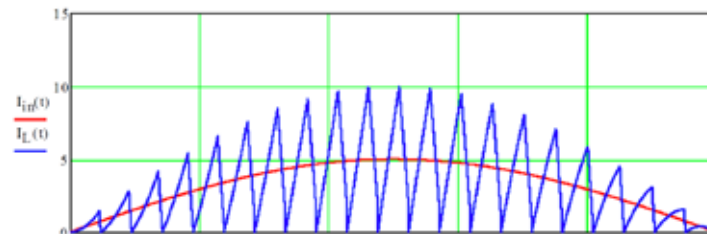


Figure 12 Current waveforms of BCM PFC

Continuous (CCM) operating mode usually suits power levels where the boost converter's switching device does not switch ON when the boost inductor is at zero current. Instead, the current in the energy transfer inductor never reaches zero during the switching cycle as shown in Figure 13. CCM boost is a better choice for high power applications.

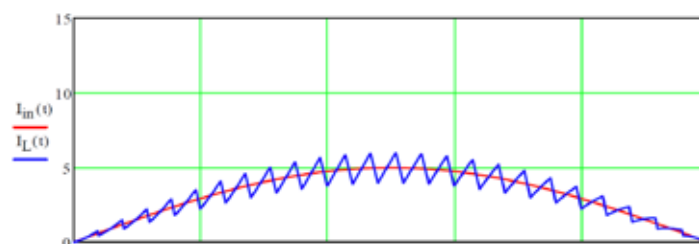


Figure 13 Current waveforms of CCM PFC

Discontinuous (DCM) operating mode occurs when the boost converter's switching device is turned ON when the boost inductor current reaches zero, and turned OFF when the inductor current meets the desired input reference voltage as shown in Figure 14

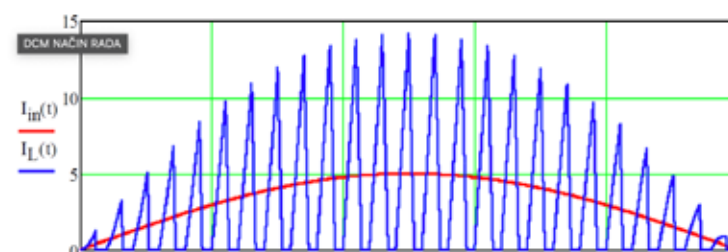


Figure 14 Current waveforms of DCM PFC

A typical PFC regulator is shown in Figure 15.

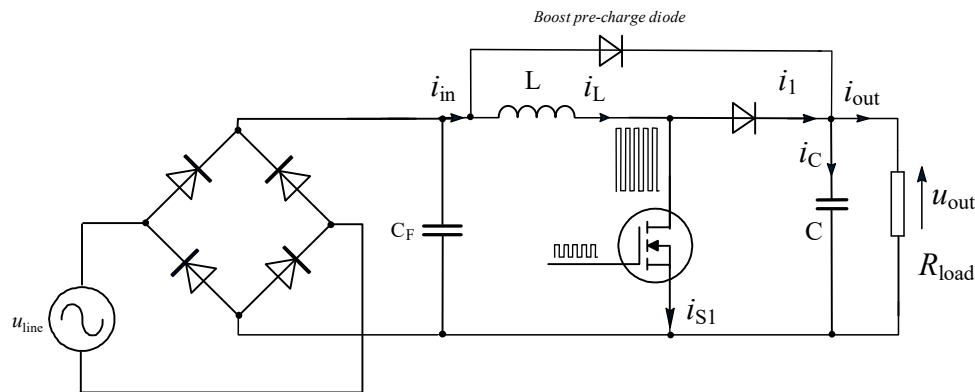


Figure 15 Typical single phase PFC regulator

A two-phase interleaved boost converter, shown in Figure 16, consists of two boost converters connected in parallel operating 180° out of phase. The input current is the sum of the two inductor currents I_{L1} and I_{L2} . Inductor's ripple currents are out of phase, they tend to cancel each other and reduce the input ripple current caused by the boost inductors [2].

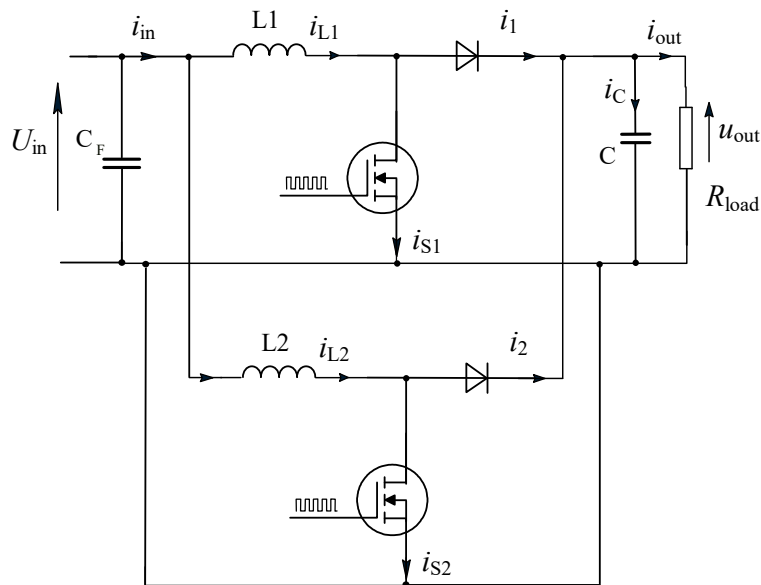


Figure 16 Two phase interleaved boost converter.

The best input inductor ripple current cancellation occurs at 50 percent duty cycle. The output capacitor current is the sum of the two diode currents ($I_1 + I_2$) less the dc output current. Interleaving reduces the output capacitor ripple current (I_{OUT}) as a function of duty cycle [2]. As the duty cycle approaches 0 %, 50 % and 100% duty cycle, the sum of the two diode currents approaches DC. Inductor ripple current is filtered out by output capacitor. Typical circuit waveforms of two-phase interleaved boost converter are shown in Figure 17.

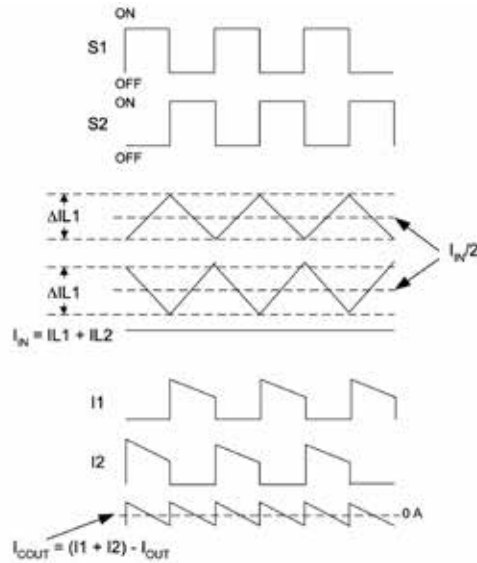


Figure 17 Two phase interleaved boost converter waveforms.

The ratio of input ripple current to the inductor ripple current ($K(D)$) varies with changes in duty cycle.

$$K(D) = \frac{\Delta I_{in}}{\Delta I_{L1}} \quad (14)$$

$$K(D) = \frac{1-2D}{1-D} \text{ for } D \leq 0.5 \quad (15)$$

$$K(D) = \frac{2D-1}{D} \text{ for } D > 0.5 \quad (16)$$

The duty cycle, D , is not constant and varies with changes in line phase angle and input voltage. The amount of duty cycle variation for universal applications can be quite large. Variation in duty cycle can be observed by evaluating a converter designed for a universal input of 85V to 265V RMS with a regulated 385V DC output. At low line, the duty cycle will vary from 100% to 69%, and at high line, it will vary from 100% down to 2%. The inductor ripple current cancellation will not be 100% throughout the line cycle. However, it is good enough to drastically reduce the input ripple current for a given inductance. The highest ripple current in this example would occur at the peak of low line with a duty cycle of 69%. The input ripple current at this duty cycle will be 55% of the individual inductor ripple current. When the converter is operating at 2% and 100% duty cycle, there is very poor inductor ripple current cancellation. At these duty cycles, the interleaved PFC pre-regulator has very small inductor ripple current. The input ripple current of the PFC boost will reach 55% of what it would have been in a single-phase PFC designed for the same power level and inductance. Below, adequate equations are specified.

$$U_{in}(\vartheta) = U_{IN(RMS)} * \sqrt{2} \sin \vartheta \quad (17)$$

$$D(\vartheta) = \frac{U_{out} - U_{in}(\vartheta)}{U_{out}} \quad (18)$$

Input ripple current reduction is represented in Figure 18.

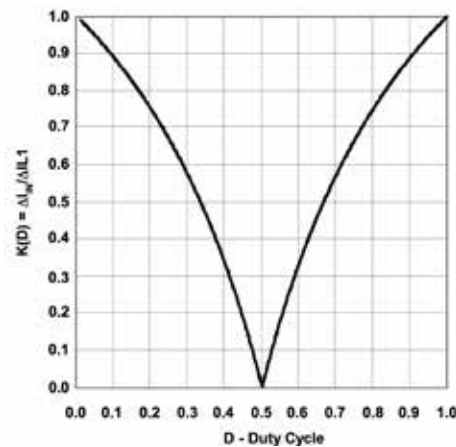


Figure 18 Input ripple current reduction.

Additional benefit with interleaving PFC regulator stages is output capacitor RMS current reduction. In Figure 11 capacitor RMS current as a function of duty cycle in a single boost and in a two stage boost interleaved boost converter is shown. Since the duty cycle in PFC application varies from 100% to 2%, interleaving will drastically reduce output capacitor RMS current which will result in electrical stress reduction in the output capacitor and converter's reliability improvement [3].

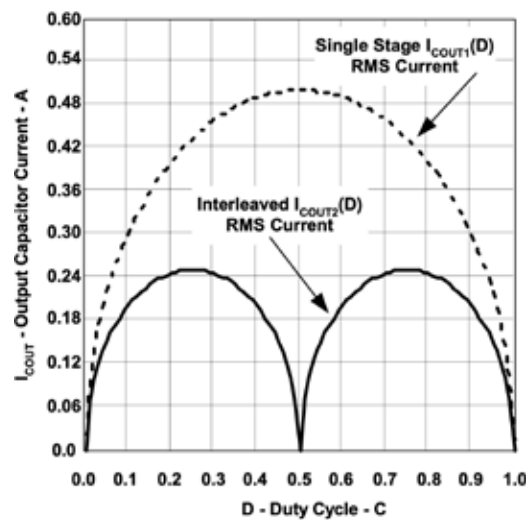


Figure 19 Normalized output capacitor RMS currents as a function of D.

Below adequate equations are specified.

$$I_{COUT1}(D) = \sqrt{(1 - D) * (1 - D)^2} \quad (19)$$

$$I_{COUT2}(D) = \frac{1}{2} \sqrt{(1 - 2D) * (1 - 2D)^2} \quad \text{if } D \leq 0.5 \quad (20)$$

$$I_{COUT12}(D) = \frac{1}{2} \sqrt{(2 - 2D) * (2 - 2D)^2} \quad \text{if } D > 0.5 \quad (21)$$

Converter's input current is shown in Figure 20.

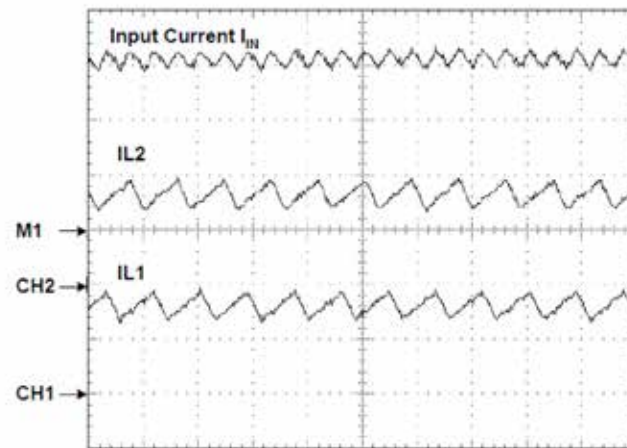


Figure 20 Converter's Input current.

Figure 21 shows input current and voltage with power factor of 0.99 [5]

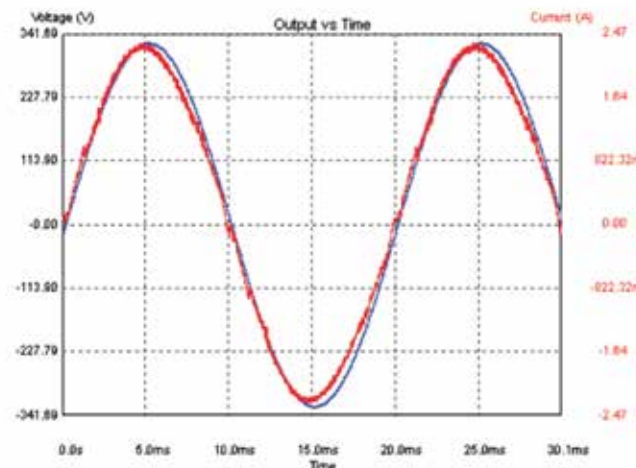


Figure 21 Input current and voltage with power factor of 0.99.

4. Conclusion

In this article, the fundamentals of power factor correction are presented. For lower power requirements, passive PFCs are simple, robust and reliable solution with bulkiness and lack of voltage regulation being potentially significant drawbacks. For any power supply design over 100W, the preferable type of PFC is Active Power Factor Correction (Active PFC) since it provides a lighter and more efficient power factor control. Active Power Factor Correction automatically corrects AC input voltage and has capability to handle a wide range of input voltages. Disadvantage of Active PFC is the extra cost resulting from the additional complexity required for its implementation. This method provides a more efficient power factor correction, is lighter and less bulky. A basic active PFC circuit consists of a control circuit that measures input voltage and current and then adjusts the switching time and duty cycle to ensure that the input voltage and current are in phase. This provides an automatic correction of the input AC voltage, resulting with a theoretical power factor of over 0.95. The most efficient topology that achieves almost optimal power factor correction is boost PFC pre-regulator with power factor of approximately 0.99.

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Innovative Teaching and
Learning Methodologies

LEARNING TO COMMUNICATE AUTHENTICALLY IN ENGLISH AND ITALIAN

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Abstract. This paper underlines the importance of a frequent introduction of authentic communication elements in the everyday language classroom. It has been acknowledged by contemporary methodological approaches that linguistic proficiency is a direct result of lexical, grammatical and cultural competence. These three aspects are not exclusive but create a meaningful whole, which is a pre-condition for the development of communication competence. It entails understanding of both verbal and non-verbal elements of communication. This important aspect of language learning, however, is insufficiently highlighted in language course books. Therefore, teachers should draw on their own resourcefulness by selecting challenging material from different authentic resources. In the light of English language teaching, Business English respectively, TED talks serve as an excellent example for creative presentations. Their content definitively gives birth to a wide range of activities that foster verbal communication, which is discussed in the first part of the paper. The second part of the paper revolves around the didactic role of gestures in the Italian language classroom. Gestures are integral part of Italian cultural non-verbal expression. Therefore, it is necessary to raise awareness of their significance for everyday communication. Since there are numerous communication functions that can be expressed by them, the most common gestural forms are listed with their meaning and examples of use. In addition, a variety of teaching activities that are specifically designed to facilitate their acquisition are presented. Reasons for creating the right conditions for the development of authentic communication skills are many: active interaction between teachers and students, promotion of critical thinking through discussions, familiarising with important cultural aspect of language, etc. Furthermore, all communication-related didactic activities are highly motivating and motivation is the key to both successful teaching and learning.

Key words: *language, communication, authentic materials, application, analysis*

1. Introduction – The meaning of authentic communication

Achieving proficiency in a foreign language is rather a complex process that is not necessarily linear. In other words, it is gradually developed through a series of activities that, as a matter of fact, allow students to use a language as a means of genuine communication in different situations rather than merely practice it through an indefinite number of contrived contexts. Students who embark on an adventure of a foreign language learning do so for one particular reason: they wish to become able to articulate their ideas correctly and effectively in everyday situations, drawing on their knowledge of appropriate and authentic expressions in the target language. Therefore, the focus of language teaching should be on creating the right classroom conditions to help students become authentic communicators.

What is precisely authentic communication? It is much more than a mere exchange of information: it is both the ability to convey ideas into words and understand emotions and intentions behind them. Skilled communicators are not only aware of the importance of using right words and expressions in different situations but are cognizant of the other two important aspects of effective communication, as well. These are active listening and the ability to observe non-verbal cues. They are aware that these skills play a significant part in not only giving and receiving different kinds of information but also in the development of human personality. "They become essential for personal growth through which communicating people will find themselves, develop self-confidence, and define the relationship with the surrounding environment. The failure in building good communication skills will happen when people do not want to understand other's opinions, thoughts, ideas, and feelings." (Abdikarimova, M. et al, 2021)

This paper focuses on the ways of the B2/C1-level Business English students' verbal skills improvement and on the importance of understanding and usage of non-verbal cultural aspect of the Italian language, gesticulation, which is practised with the B1-level Italian language students.

2. Fostering the development of communication skills in the Business English classroom

2.1. Briefly about the significance of communication in the business world

Communication is of the uttermost importance in the world of business. Skilful communicators are capable of articulating clear and strong messages about customer service, branding and strategy. They are also articulate in proposing and explaining different motions during business negotiations in order to reach agreements that will be advantageous to all the parties. Skilful communicators are thus the key to the reputation of their firm and, consequently, its profit margin, or, in other words, their skills highly contribute to the perceived success of their company in the realm of business. Profit margin and reputation aside, there are many different ways through which effective communication is reflected and that result in the two previously mentioned outcomes. The three most significant ones in the context of business are highlighted as follows:

a) setting up better teams – good communication creates a positive atmosphere that inspires team members to contribute to projects to the best of their abilities. They feel heard, supported and encouraged: should any tensions occur, they are promptly addressed by effective communicators who work towards finding the best possible solutions.

b) preventing communication failures – misunderstandings and conflicts – active listening is integral to good communication: it means listening to understand fully why a certain conflict happened and to respond promptly and appropriately in order to find a right solution without becoming defensive.

c) fostering creativity and innovation – employees who are skilled communicators are generally open to sharing ideas without judgement, thus building trust between team members. This, in turn, inspires them to generate ideas and share them with each other. When employees are enthusiastic about generating and sharing ideas, companies can easily transform their approaches and find unique ways to serve clients.

2.2. TED talks – a wealth of language and a showcase for presentation skills

TED (technology, entertainment and design) conferences began in 1984 and covered topics that revolved exclusively around these three fields. Today, however, TED covers a wide range of topics. Presenters from all walks of life are included in the event: philosophers, scientists, educators, musicians, business and religious leaders and many others.

In the realm of English language teaching, they have become an invaluable source for both teachers and students, since they provide an engaging and authentic content while also exposing students to different accents, vocabulary and cultural nuances of English. TED talks provide an excellent platform for creation of different types of exercises, such as listening comprehension, vocabulary expansion, writing activities, speaking practice et al.

In this paper, a TED talk is explored in the light of communication skills improvement through two different and yet similar exercises: structuring an effective argument, the so-called discussion point exercise and creating a brief power point presentation around assigned topics.

2.2.1. A TED talk: How to speak so that people want to listen by Julian Treasure

In his ten-minute talk, Julian Treasure, a British sound and communication expert, outlines the foundations of decent communication. It starts with conscious listening that opens the doors to understanding. It is indispensable to the survival of democracy and a civil society, which relies on enlightened disagreement - the notion that opposing ideas drive innovation and change, force critical thinking and reveal untapped solutions to pressing issues. In other words, enlightened disagreement means listening to people with whom we disagree and understanding and respecting their perspective. It also requires the skill of speaking – the elegant and skilful exposition of an argument, either in a debate to persuade an audience or to explain complex issues. Powerful speaking – speaking in a manner that drives change, is not always easy. It is precisely because of the most common obstacles in communication or, as Julian Treasure calls them, seven deadly sins of communication. These are gossiping, judging, being negative, complaining, blaming, exaggerating and using dogmatism. These “speaking sins” that are occasionally committed, make others less likely to listen truly to what individuals have to say. So, what is the secret to effective speaking, the one that allows us not only to be heard but to be listened to, particularly in a professional environment where a well-articulated view may definitely mean a difference between the success or failure of the company? The secret lies in the word HAIL, which is the acronym for four critical components that make an effective speech: honesty, authenticity, integrity, love. When individuals become aware of these four elements and, in turn, start applying them, they are definite to drive conversations in a more thoughtful and meaningful manner. In the context of challenging business situations, that means communicating messages with honesty and empathy. A CEO, for example, must deliver a speech about serious financial problems the firm has encountered. In a case such as this, a leader should speak honestly about the seriousness of the situation while, at the same time, be sensitive and mindful of employees’ concerns.

In addition to using the HAIL strategy, individuals should become aware of the power of their physical voices. If they put proper tone, emphasis and pace to their voices, their speech will be more credible and impactful.

This both captivating and revealing talk introduces students to the world of genuine communication and, at the same time, motivates them to correct their own mistakes. It also inspires many interesting didactic activities that promote linguistic fluency and critical thinking.

2.2.2. Discussion point exercise

Structuring an effective argument within limited time is a rather challenging activity for students, primarily since they have never done this type of exercise before. They have never thought about certain topics and now they are expected to form an opinion about them and structure them in English language. Moreover, the extent to which they succeed in meeting the requirements of the task will eventually be graded. This didactic activity mimics the second part of the IELTS Academic speaking test: candidates are given sixty seconds to prepare their arguments around assigned topics and then present them within the limited timeframe of 2 minutes. Within this two-minute interval, candidates do not only show their skill to maintain coherence in the argumentation but also have to prove linguistic proficiency in three other important aspects: knowledgeable use of vocabulary and grammar and correct pronunciation.

The rules in the Business English classroom are not as rigid as they should be in the IELTS exam environment for rather obvious reasons: candidates that apply for the exam take months to prepare and are ready for the challenge. Students, however, encounter this challenge for the first time. Therefore, to structure their arguments successfully they are given twenty minutes and are expected to present them within the two-minute timeframe. The assigned topics are reflective of Julian Treasure's talk, for example, traits of a decent communicator, secrets of successful business communication, the ways of eradicating dogmatism, etc. Students choose their topics.

Prior to the start of the activity, every assigned topic is explained and suggestions for organizing their views are provided. Students are encouraged to focus on one, two or three points that they would like to corroborate and to note down their thoughts and the order in which they are going to present them. In order to show coherence while presenting, they are strongly advised to use discourse markers and to avoid repetition of words and expressions. In this light, they should think about various ways of expressing their opinions using proper synonyms and paraphrasing. They are also reminded to speak at a normal speech rate and that it is perfectly alright to pause briefly between parts of their presentations.

The majority of students meet the requirements of the task rather successfully. However, suggestions for minor corrections in both the structure and vocabulary are usually provided, thus raising student awareness of linguistic complexity and subtlety.

2.2.3. Power point presentation exercise

Once students learn the secrets of structuring arguments, they find the task of creating power point presentations less difficult. Business presentations and discussion points have the same structure – introduction, main body and conclusion. They, however, differ in format. As it has been previously established, discussion points represent student point of view clearly explained within a coherent structure, whereas power point presentations are actually depictions of facts followed by explanations and references to various sources. Although their delivery is defined by specific structural rules, it does not mean that it should be dry. In other words, power point presentations are not just about clicking the next slide and recitation. They are about establishing and maintaining connection with the audience and responding to issues and ideas. The facts and ideas should be presented in such a manner that they spark an interest of the audience in a specific topic. Therefore, aside from presentation structure, a presenter should pay attention to voice, facial expressions, body movement and timing. Voice, as Julian Treasure states in his talk, plays a significant role: its volume, pacing and pitch define the emotional mood of a presentation. There is another important factor that must not be forgotten since it defines

the very success of a presentation. This is a focused and structured practice, or rather, hours of practice, which makes the delivery of facts and ideas spontaneous and natural rather than contrived. All of these important factors are carefully explained to students prior to preparation of their own presentations. The same topics that have been assigned for discussion points are assigned again and each student selects one and prepares a power point presentation during six classes of Business English. A lecturer monitors progress and provides suggestions for either linguistic or structural corrections where necessary. Once students complete their power point presentations, they are given one week to prepare for the delivery that should be done to the previously explained rules of “creative presentations”. The majority of students meet the requirements of the task rather successfully. Less successful students are provided instructions for corrections and their presentations are rescheduled for another time to be graded.

In conclusion, the relevance of these two communication exercises is apparent. Not only do students learn to structure facts and ideas within different yet similar formats but, by doing so, they also gain an insight into the richness of vocabulary and structures of the English language, which has a significant influence on raising the levels of their linguistic fluency.

3. Fostering authentic communication in Italian language classroom

3.1. Gestures - features and significance

Communication is the process of sending, transmitting and receiving messages, signals and/or information. In its basic form, it consists of a source of information, a communication channel and a destination. Human communication is divided into verbal and non-verbal communication. Verbal communication is that which an individual achieves through speech (or writing as a record of speech), while non-verbal communication is that which is achieved by non-verbal signs.

Gestures are the most studied and well-known part of non-verbal communication. They are used when verbal communication is not possible for various reasons; due to the distance of the interlocutor or the noise in the acoustic channel or to increase the power of the spoken message (Rot, 2004).

In Italy, gestures are a very important means of communication. The reasons for the emergence of gestural language are not entirely clear and, in this regard, there are two conflicting theories. According to the first, it is a phenomenon that developed in the period from the 14th to the 19th centuries, while the country was under foreign occupation, as an alternative form of communication, a secret language. The second theory advocates the point of view that it is an ancient phenomenon whose roots go back to ancient times. Namely, Andrea de Jorio, a 19th century-ethnologist and archaeologist, researched Neapolitan gestures and saw in them a clear link with elements of gesticulation from the ancient period. In other words, recognizable gestures were present on ancient Greek vases from the vicinity of Naples (Diadori, 1990). It is important to note that the presence of gestures in the language has changed over time under the influence of other cultures that once came into contact with local population. For example, thumbs up, which means OK, everything is fine/tutto a posto, was spread by the Americans during World War II. The successful introduction and acceptance of other American gestures, such as the fingers placed in the sign of victory and the high-five gesture - give me five/batti il cinque, was due to the specific sporting and cinematographic influence.

There is a wide spectrum of currently used and recognizable gestures by a large number of Italians, which are considered an integral part of their linguistic and cultural heritage.

They are characterized by the following features:

- conventionality (they have a universally accepted meaning within Italian culture);
- explicitness (they contain a message that the subject consciously conveys);
- topicality (they have been in use since the 1990s);
- distribution (they are present, at least at the level of understanding, on the entire territory of the Italian peninsula; national television, newspapers, literature).

The gesture itself can be represented by the following parameters:

- stylized presentation (photo);
- a short definition;
- expressive register to which it belongs (formal, informal, vulgar);
- linguistic expressions that follow and/or replace them.

3.2 Gestures - communication functions

Research into the rich world of gestures has shown that a truly wide spectrum of communication functions is expressed by the Italians (Diadori, 1990). These are, as follows:

3.2.1. Social conventions:

- greeting at the beginning of the communication act: shaking hands, kissing hands, lowering the hat, hugging, exchanging kisses on the cheek;
- greeting at the end of the communication act: shaking hands, waving, hugging, exchanging kisses on the cheek;
- congratulation: handshake, pat on the shoulder.

3.2.2. Feelings and emotional states:

- satisfaction: rubbing the hands, placing the fingers in the shape of the letter v;
- indifference: rubbing the chin with the hand;
- regret: biting the lip and/or nails, grabbing the head with the hands;
- approval: clapping the hands, raising the thumb, placing the thumb and index finger in the shape of a ring, drawing a straight line with the thumb and index finger placed in the shape of a ring, kissing the tips of the fingers together;
- disapproval: slow movement of the head from one shoulder to the other;
- boring: horizontally moves the hands along the forehead;
- fear: opening and closing the hand by moving the fingertips.

3.2.3. Actions:

- swearing: placing the hand on the heart, kissing crossed index fingers;
- call for silence: placing the index finger in front of the mouth;
- call for calmness: repeatedly lowering and raising the outstretched palm;
- invitation to reach an agreement: winking;

- call to attention: lowering the lower eyelid with the index finger;
- call for brevity: opening and closing the fingers of the hand placed in a bang;
- admonition: moving the outstretched index finger;
- wishing for evil: placing the index finger and little finger horizontally in the form of horns;
- providing comfort: patting on the shoulder;
- threat: joining the index fingers and thumbs of both hands in the shape of a circle;
- wishing for good: crossing the middle finger over the index finger;
- warding off evil: placing the fingers facing downwards in the shape of horns;
- uttering an insult: sticking out the tongue, raising the forearm with the help of the other hand.

3.2.4. Questions and answers:

- asking questions: moving forward and backward the hand with the fingertips placed together, folding the hands, moving the folded hands from the chest forward and backward;
- providing an affirmative answer: moving the head up and down;
- giving a negative answer: moving the head left-right, moving the outstretched index finger left-right;
- giving a response with elements of indifference: passing the hand under the chin, raising the shoulders.

3.2.5. Opinions:

- homosexuality: touching the ear;
- marital infidelity: vertical placement of fingers in the shape of horns;
- happiness: connecting the index finger and thumb of both hands in the shape of a circle;
- friendship: approaching and moving away with outstretched index fingers;
- cunning: placing the index finger on the forehead, lowering the lower eyelid with the index finger;
- stupidity: turning the fist near the temple, turning the hand with the fingertips placed together in front of someone's face, hitting the forehead with the hand in the bangs, tapping the temple with the tip of the index finger.

3.2.6. Descriptions:

- complete change: complete turning of the palm with outstretched fingers;
- lie: keeping hidden crossed fingers;
- agreement: winking;
- crowd: close the hand with the fingertips placed together;
- money: rubbing the index finger against the thumb.

3.3. Gestures - the most common forms in the Italian language

Many gestures, in the same or somewhat modified form, are known to our students and they are able to recognize and understand them. It is therefore strongly recommended to focus exclusively on gestural forms that are typically Italian, thus culturally defined and, as such, completely unknown or insufficiently understood by foreigners.

- In the rich tapestry of Italian gesturality, a special place belongs to the Italian gesture *per eccellenza*, the specific movement of the hand with the fingertips placed together (*muovere la mano a borsa/a pigna/a tulipano/a carciofo*). Introducing elements of surprise, indifference and/or irony, it mostly follows interrogative verbal statements that can be paraphrased with the sentences *But, what do you want/do/say? / Ma cosa vuoi/dici/fai?* This specific gesture from informal linguistic register represents an authentic movement that symbolizes the Italian gestural language in general.
- Another typical gesture is the one that expresses indifference and/or lack of interest; moving the palm several times under the neck (*passarsi la mano sotto il mento*).

It can be paraphrased as *It doesn't matter to me at all! I don't care at all! It is not important to me at all! / Non è mica importante per me! Non mi interessa affatto! Ma chi se ne frega!*

The other typical gestures that are highlighted and explained are, as follows:

- By repeatedly approaching and moving away the outstretched index fingers, it is indicated that two people are friends, their closeness and/or the beginning of a relationship: These two are together. These two understand each other. These two get along. / *Questi/e due stanno insieme. Questi/e due si capiscono bene. Questi/e due vanno proprio d'accordo;*
- Opening and closing the fingers of the hand clearly expresses fear, apprehension: What a shock! They are (very) afraid! I'm (very) afraid! / *Che paura! Ho proprio paura io! Hanno paura loro!* Equally, this movement of the interlocutor calls for brevity in the conversation: What is important? Get to the point! / *Di' velocemente quello che vuoi. Taglia la storia!;*
- By drawing an imaginary horizontal line with the thumb and forefinger joined, satisfaction is expressed unequivocally for something well done: Excellent!, Perfect! / *Benissimo! Perfetto!;*
- Moving the thumb left and right and the index finger pointing down replaces the verbal expression Nothing, not at all / *Non ce n'è più. È finito.* Most often it refers to money, but not necessarily;
- Moving back and forth with open palms facing the interlocutor is an invitation to calm down. (Just) take it easy! Calm down! / *Ma dai, calma! Tranquillo!;*
- Lowering the lower eyelid with the index finger is a gesture that indicates the lack of trust of the one who uses it, and conveys a message that can be paraphrased with the words: I don't believe you, I'm not stupid, you can't outwit/trick me! / *Non ti credo, non sono pazzo! Sono furbo io, non puoi ingannarmi, eh!;*
- The circular movement of the index finger resting on the cheek is a gesture with which one compliments the excellent taste of the food; It's delicious! / *È delizioso!*

3.4. Gestures - teaching activities

Aids in teaching foreign languages can play a powerful role if they are used in a planned and designed manner. The successful introduction of teaching aids presupposes the right selection

of the aid in relation to the specific teaching task, its correct use and skillful handling in terms of its incorporation within that particular task (Petrović, 1988). Motivation is a strong factor that contributes to the success of classes, and teaching aids have a strong motivational effect. The use of gestures in the teaching of foreign languages is didactically justified only if the content fully corresponds to the language competence, age and interests of those for whom it is intended, and if its introduction achieves the planned teaching goals.

At the very beginning of the lesson, it is desirable to completely free the students from nervousness and discomfort and to create a relaxed, pleasant atmosphere for work. It is possible to bring the desired content closer to the students with unambiguous, suggestive questions that make them the protagonists of the story they are about to embark on and instill in them the curiosity so necessary for learning new content. *Is it true, in your opinion, that Italians speak with their hands? Do you like this wealth of gestures or do you find it unnecessary? What are the most used gestures in your language? And in Italian? Do you know any typical Italian gesture? What does it mean?* The goal of this introductory part of the lesson is to warm up the students for the following teaching activity and to reduce their discomfort caused by the thought of encountering previously unknown content.

Then they should be invited to try to imitate any of the gestures they know, to state the communicative function it expresses and the expressive register to which it belongs and, finally, the linguistic expressions that follow and/or replace it. This individual activity is actually an incentive to reflect actively on the topic being discussed.

The activity in which the teacher lists certain communication functions and asks the students to connect them with the offered gestures has proved to be very well-received.

Furthermore, the teacher can imitate the desired gestures or bring their illustrated representation, and ask the students to list all those communication functions that can be expressed with the gesture in question (*lowering the eyelid with the index finger or moving the hand with the fingertips placed together*).

Communicative activities that are based on the imagined dialogue/conversation and carefully chosen authentic gestures have been extremely well-received. Regardless of the fact that they have been conducted in pairs or in groups, it is recommended to provide students with vocabulary and language structures that they will be able to use in speech. It is very important that the planned roles are adapted to the general knowledge and experience of the students. It is desirable that the dialogues are short and easy to dramatize. (*Whose book is this? Mine. No, I don't believe you. Do you want to trick me? / Di chi è questo libro? È il mio. Ma no, non ti credo, vuoi ingannarmi?*) This speech activity aims to motivate students to reach communicative goals. The linguistic accuracy of the statement is not that important. It is important to keep in mind that the success of this type of oral role-play task depends not only on the students' linguistic knowledge, but also on their character traits. Imaginative and eloquent students will surely intrigue many and often make people laugh with their answers, while the introverted, insecure ones, no matter how linguistically competent they are, will not express themselves well enough in improvising the role assigned to them.

The television programme in all its diversity, as an authentic audio-visual medium, offers truly endless possibilities of discovering a rich gestural language. Television presenters in various shows, actors in series and films and singers very often consciously or unconsciously mirror the non-verbal communication signs of contemporary Italy. While watching a selected television/video clip, students record the gestures they recognize with drawings, key words or short definitions. At the same time, it is very important that the selected contents are sufficiently inspiring and thematically close to the students. This type of exercise encourages students to be

independent in expressing their own assumptions, which creates the necessary conditions for the development of creative thinking, which is very important, but often neglected in classes.

Short, well-designed dialogues can contain words and/or expressions that can be accompanied by appropriate gestural forms. Students can be asked to spot these words and then indicate which gesture(s) they are referring to. It is very important that the vocabulary is adapted to the students' general and linguistic knowledge. In this way, the need for additional explanations that disrupts the continuity of work is reduced, and the non-verbal component of language is truly placed at the center of this dynamic teaching activity.

- *Please give me a cigarette. / Dai...per piacere, dammi una sigaretta, ti prego.*

Gesture: persistently asking for something or insisting on something; keeping (moving) folded hands.

- *No, it's the last one and I'll smoke it. / Eh no, mi dispiace, è l'ultima e me la fumo io.*

Gesture: negation; turning the head left-right, moving the outstretched index finger left-right.

For teaching purposes, it is possible to use illustrated displays with gestures (photos, pictures, comics) whose protagonists can be an excellent stimulus for designing a suitable text. This activity is recommended to be done in pairs, with the help of the teacher, who, by asking questions, encourages as much diversity as possible in providing answers (photos with a gesture expressing the deliciousness of the food/calling for silence). As dialogues are very common forms of expression in everyday life, students, by practicing them in class, become familiar with the real, authentic world and, consequently, strengthen their communication competence.

Newspaper and television advertisements are very inspiring, very often accompanied by a gesture/gestures and/or a catchy slogan, and the imaginative combination of text and image opens up numerous possibilities for teaching work. Advertising gestures are carefully chosen and mostly unambiguous, and the messages they convey are strong and impressive. The language of advertising, immediate and alive, can be enhanced with neologisms, collocations, stylistic figures, word games and expressions specific to young people, and students can become familiar with different language registers and the language of certain regions and areas of interest. Working on advertising text is extremely suitable for systematic expansion of vocabulary. Students can be asked to, relying on the linguistic context, state the communicative function expressed by the gesture in question. The teacher can invite the students to complete the thought inspired by the advertising content (*Per me guidare la macchina significa... per me essere belli significa...*) and, if possible, find the associated gesture together.

The flexibility of the lexical system is especially emphasized in those metaphorical expressions in which the Italian language abounds (*ce l'ho sullo stomaco, ne ho fin sopra i capelli*). Students, using a monolingual dictionary, can search for the corresponding non-metaphorical expression (*sono proprio stufo, non lo sopporto*) and/or collocations containing the given word (*stomaco, capelli*). Finally, they are challenged to find the corresponding gesture (drawing a straight line in front of their forehead with an outstretched hand or hitting their stomach with their hand).

The witty activity in which the teacher presents carefully selected nouns (*occhio, braccio*) to the students has proved to be very inspiring. In a separate table, various communication functions are listed (*intesa, rifiuto*), and students find those expressions that unequivocally express the given communication functions and describe/imitate the corresponding gesture.

- *Occhio; intesa*; Gesture description: *strizzare l'occhio/fare l'occhiolino/fare l'occhietto (to wink)*;

- *Braccio; rifiuto*; Gesture description: *incrociare le braccia* (to cross arms).

Questions that are designed to enable comparison of individual elements with the same/similar elements in one's own country have a rather ambitious goal: to make one aware of the features of one's own cultural and linguistic reality and to accept the diversity of another. (*Does the gesture shown here seem typically Italian to you? And what about your country?*)

Non-verbal communication elements are a welcome incentive to discuss the existence/non-existence of the same/similar elements in one's own culture. Ignorance about them, regardless of whether they occur with the corresponding verbal expression or completely independently, can lead to either a misunderstanding of the message or its misinterpretation. The famous *mano a borsa* gesture is typically Italian and, as such, unrecognizable in other cultures. A non-verbal expression is often characterized by polysemy, and the corresponding gesture gives it the appropriate meaning. The sentence *Stavo solo scherzando* spoken with folded hands represents asking for forgiveness, while accompanied by a wink, it takes on a completely different meaning. Learning about gestures that are significant part of Italian everyday life contributes to the development of cultural awareness: they also provide an excellent opportunity to introduce students to many other cultural aspects of Italy (music, sports, newspapers, politics, fashion).

The consequences of not knowing about a foreign culture can cause unnecessary inconvenience and misunderstanding. Just as it is necessary to point out the possibility of grammatical and lexical interference of the mother tongue, it is necessary, from the very beginning of language learning, to highlight the possibility of interference of one's own culture with mastering a foreign language.

The very observation of the differences between the two cultures has as a result the development of tolerance and respect for the culture of our neighbours – the Italians.

4. Conclusion

The teaching activities that are based on authentic communication elements, TED talks and gestures, are truly numerous and diverse, and the teachers' preferences for individual exercises are defined by the goals they want to achieve, the language competence of the students and the time at their disposal.

Poor selection of teaching materials and/or activities in relation to the specific teaching tasks and their incompatibility with the language knowledge of the students can cause discomfort and repulsion among those for whom they are intended, which ultimately leads to slowing down and/or misdirecting the learning process (Skrljarov, 1993).

The reasons that make activities based on authentic communication elements didactically justified and desirable are truly many:

- they bring the necessary freshness and dynamism to the somewhat contrived classroom atmosphere;
- they can be designed in advance and saved for repeated use;
- easy-to-understand content makes them usable at all levels of language knowledge;
- they attract the attention of students with their distinct suggestiveness and spark their curiosity: intellectual curiosity is an essential prerequisite for acquiring new knowledge;
- the illustrated representations of gestural language are thought-provoking and stimulate student imagination, while visual elements in combination with language signs promote data memorization;

- they promote development of four language skills;
- they are gladly accepted by students, regardless of their age, and the enthusiasm that awakens in them raises the level of motivation, which is an important element in foreign language acquisition;
- they are reflective of the specific cultural elements of a country whose language is being studied;
- they contribute to the improvement of cognitive processes and develop critical thinking
- the polysemantic nature of certain gestural forms can lead to misunderstanding of their individual parts and stimulate discussion about possible meanings;
- they promote the necessary interaction between teachers and students, which is the key to both successful foreign language teaching and learning;
- they raise awareness of the intercultural dimension of language teaching.

Communicative language teaching activities that are based on authentic resources are challenging, highly motivating and provide something that is not usually provided by standard teaching materials – a window into a different culture. Due to their multiple didactic functions, they should be incorporated into a foreign language syllabus.

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STUDENT LACK OF MOTIVATION IN ELT – AN ONGOING CHALLENGE OR A SIGNAL FOR CHANGE

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Abstract. Motivation is a major drive for achieving success in every aspect of life. Similarly, it plays a significant role in learning English as a foreign language. The more motivated students are, the easier it is to achieve learning outcomes that are reflected in an increased level of linguistic proficiency. However, students, who possess solid pre-knowledge of the language, do not always appear to be highly motivated for making progress. In other words, they seem unwilling to make an extra effort to enrich their knowledge with subtler vocabulary and idiomatic expressions that are reflective of higher levels of language. In order to establish the reasons for the apparent lack of interest for further linguistic improvement and define methods that could spark motivation, a short survey has been conducted on the sample of 75 first-year students of Tourism and Trade Management at University Department of Professional Studies. The findings are rather unexpected. They have shown that students are not as unmotivated as they find the syllabus not sufficiently challenging. In addition, the findings suggest that some changes should be made in the syllabus in terms of including more creative materials to encourage students to strive for higher levels of language, which is discussed in the paper in greater detail.

Key words: *motivation, linguistic proficiency, teaching challenges, learning outcomes*

1. Introduction

Motivation is the driving force behind human behaviour. It is most commonly described as the option through which people define their goals and aims and, at the same time, assess the level of effort they have to exert in order to reach them. Similarly, motivation plays an important role in English language teaching and learning. It is an essential factor in achieving many fundamental goals in a student academic life. Different schools of psychological thought define motivation through its either cognitive or behavioural aspects, which has resulted in the classification of the two principal types of motivation: intrinsic and extrinsic motivation and integrative and instrumental motivation.

Intrinsic motivation stems out of one's interests and desires. When you are intrinsically motivated, you enjoy either an activity or a skill development because the very process is the source of satisfaction. If your motivation, however, is reflective of a certain outcome rather than of the fun, development or learning provided within an experience, then you are extrinsically motivated. (Ryan & Deci, 2000)

Integrative motivation describes a desire for learning a target language well and acquiring knowledge of its people and culture since this eventually enables full integration in the society where this particular language is spoken. Instrumental motivation, however, is apparent in a variety of practical reasons that drive it, such as better career opportunities, chances for a raise in salary, the likelihood of bonuses, etc. (Gardner & Lambert, 1972)

In a foreign language learning, English language respectively, students' motivation level is an important predictor of success. Students who are motivated to learn perceive the very process as a positive and rewarding experience. They do their best to tackle all linguistic issues that are presented to them regardless of the level of difficulty and, eventually, succeed in reaching higher levels of a language. Those who are not interested in learning, however, do not invest much effort and the final success is ever-elusive. This lack of interest has been a source of frustration for lecturers whose teaching is reflective of the latest teaching methodologies that put students in the focus. Lessons have become interactive, the latest topics and trends in business are discussed in the selected materials through a variety of interesting texts that contain relevant and up-to-date vocabulary and expressions. There is little grammar and it is usually covered through communicative exercises that are created for revision purposes and clarification where it needs to be done. Yet, enthusiasm for learning is lacking and students do not seem to be motivated to reach higher levels of language, although their existing knowledge and solid communication skills would make it not only possible, but rather easy for them were they willing to put an extra effort into their learning.

Therefore, the authors of this paper have decided to create a rather simple questionnaire to establish the reasons for students' lack of motivation and discuss possible teaching solutions that might eventually prove successful and result in the increased motivation levels.

2. Survey of motivation for reaching higher levels of English language (C1, C2)

2.1. Reasons behind the survey

English that is taught at university level – English for Specific Purposes, in this particular case Business English, has been perceived as an important part of the educational system. Despite the general opinion that the good command of English has become an imperative for success in career, it has not simultaneously promoted student positive learning motivation for English courses. ESP students already possess relatively good knowledge of English that can be expanded further in order to communicate a set of professional skills and to perform particular job-related functions. It is important to emphasize that students have already learnt English as a second language for 12 years before entering university. Furthermore, a foreign language is a mandatory requirement for all the study programmes at our department. Although students are obligated to attend classes regularly, the level of participation is relatively low as is the level of effort in class assignments. A universally acknowledged fact is that participation in the ESL classroom is indispensable for them to improve their language skills.

Yet, they have little or no desire to raise the level of their linguistic competence and appear to be satisfied with current knowledge. This is rather surprising since Business English is represented in the curriculum with 4 hours a week, which suggests its significance for their future professional life. So, the aim of this brief survey is to establish the reasons for the absence of willingness on students' part to learn new vocabulary and subtler idiomatic structures that are not only typically used in different business situations, but are reflective of higher levels of language, as well. Survey questions and findings that the authors find rather surprising are discussed further in the paper.

2.2. Survey analysis

The survey was conducted in the winter term of 2023/2024 academic year on the sample of 75 first-year students of Trade and Tourism Management at the University Department of

Professional Studies in Split. The aim of the study described in this paper was to establish attitudes among first-year university students towards learning English and to understand to what extent they are motivated for the English course.

The instrument that the authors used was a questionnaire. It consisted of 3 multiple-choice items. In the first item students were asked why they learnt English. The great majority of students, 65% of them, said that they studied for better job opportunities and career advancement; 21% of students said that they learnt English for pleasure and 14 % said that they studied English just because they wanted to do well in their exam as it is shown in Figure 1. In the second item, students were asked what, in their opinion, English teachers should base their teaching on, in order to make it more motivating and effective. The results showed that 58% of students believed that teachers should be more creative (using additional resources apart from course books). On the other hand, 37% of students thought that teachers should focus on student linguistic needs, and by this they meant adapting the curriculum accordingly, while only 5% found that teachers should strictly follow the curriculum (using exclusively course books and workbooks), which is shown in Figure 2. In the third item students were asked if they were motivated to reach higher levels of English (C1, C2). It is important to stress that the third item consisted of two sub-items whose purpose was to establish students' reasons for reaching higher linguistic levels. So, 88% of them said that they were very motivated, of whom 75% said it was because of the possible career advancement, while 25% of students felt motivated because the very learning of English gave them the feeling of achievement and boosted their self-confidence. However, there was a small number of students, 12% of them, who felt not motivated to improve their knowledge of English: 35% of them believed that they did not need English in terms of career advancement or overall life situation and 65% of students said that they had no interest in learning English as they were satisfied with their current language proficiency. This can be seen in Figure 3.

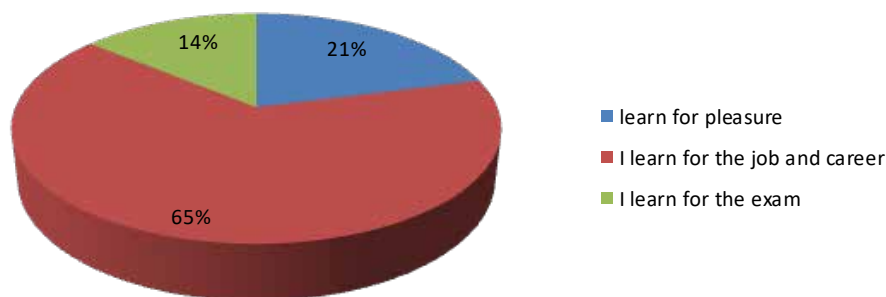


Figure 1: Reasons why students learn English

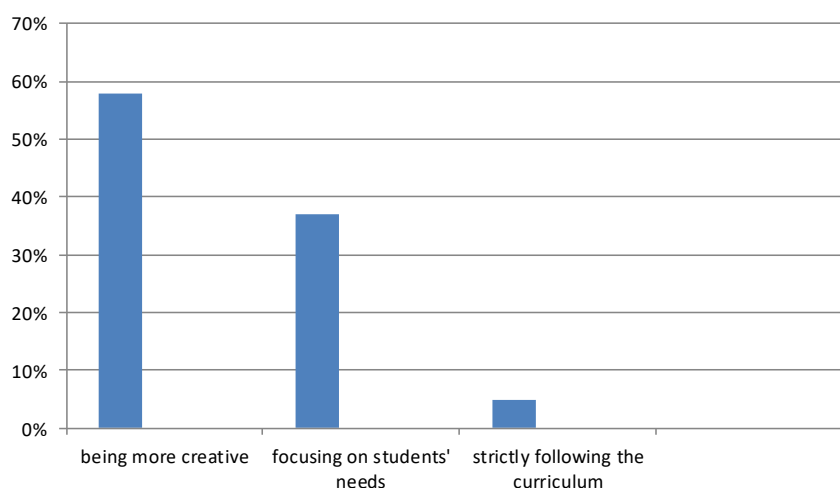


Figure 2 What teachers should base their teaching on

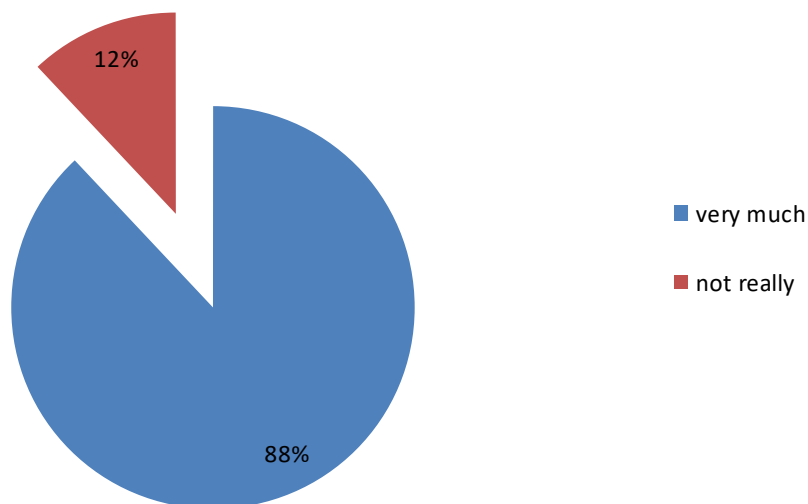


Figure 3 Students' motivation for reaching higher levels of English

3. Importance of learning English

As it is generally accepted and according to Rao (2019), English is a global language that is used as a medium of communication, a tool for academic and professional advancement, and, finally, as a means of cultural exchange. English is taught and learned as a second language or as a foreign language in educational institutions around the world (Zubkov, 2020). It provides students with the knowledge to communicate with people from different cultural backgrounds. It enables them to engage in conversations, express their opinions and ideas, and understand written texts. It is sometimes the language of instruction in higher education institutions. Proficiency in English allows students to use a wide range of teaching materials and resources and participate in international programs. According to the spread of the role of using English, Kachru (1992) points out that not all processes of learning the language work well, some challenges still exist along the process. According to this study, different factors affect these challenges, such as boredom, lack of interest in studying, fear of making mistakes or the activities that are considered as too challenging.

Students with an interest in learning English, however, are involved in the learning process and are eager to improve their language skills. They are looking for opportunities to practice English, such as reading books, watching movies or TV; they participate in class activities and ask questions. Effective English instruction enables students to use it effectively in real-life situations. Our students, although aware of the importance of learning English, seem to be uninterested to do so in the classroom setting.

4. How to make English classes more motivating?

EFL teachers, with all their knowledge and competences, face great challenges in terms of motivating learners who often lack interest and enthusiasm for English lessons.

Lasagabaster (2011) claims that one of the main objectives of many foreign language teachers in classrooms is to increase student motivation, so that pupils may acquire a good command of English. According to Lasagabaster (2011), motivation is the main important factor which is the drive that makes the learners use all their learning resources to reach learning goals. Cheng and Dörnyei (2007) state that in a foreign language learning, motivation plays the role of an

initial engine that brings about learning and later maintains the driving force in the process of learning a foreign language.

Although very high percentage of our students (88%) maintain that they are very motivated for expanding their knowledge and reaching higher levels of proficiency in English, many of them fail to demonstrate interest in classroom activities. In an attempt to identify the cause of students' lack of interest in expanding their knowledge of the English language, it has been established that the teaching materials and textbooks may be the one of the major obstacles to learners' interest and motivation for further learning as many students expressed in the survey the need for more creative classes with the use of additional materials. This clearly indicates students' dissatisfaction with the curriculum and classes based on textbooks only. Sometimes, it is difficult for lecturers to engage students in activities and content because they do not find it interesting or challenging enough. Daskalovska, N., Gudeva, L. K., Ivanovska, B. (2012) suggest that learner motivation is closely connected to classroom activities and those activities should be interesting and stimulate learners' curiosity. That is why including stimulating content that awakens learner interest in the lesson is recommended.

4.1. Choice of topics

Learning in a language classroom depends both on the learner and the materials used. It is useful for EFL teachers to become acquainted with learners' interests, since then they can add interesting topics to the material to be learned. It is also useful to provide a choice of topics and innovative ways to perform specific tasks.

The choice of topics plays an important role in students' attitude towards learning. Students are drawn to a certain category of topics and they may equally dislike some other topics. When selecting the range of ESP topics, which can generate students' interest in communicative activities, lecturers should include a variety of subjects, tasks and activities. From personal experience, we have noticed that students will engage into conversation more easily when the topic is entertaining and, in that case, they are also willing to express their opinions. It is possible to come up with entertaining material in ESP context which can make the learning more meaningful and relatable. Similarly, if the students find classes boring and monotonous, they will not be motivated either to participate or to study.

For that reason, interesting additional material should always be prepared before class. English should be presented in authentic contexts so that students become familiar with the ways in which the language is used. In order to stimulate and motivate students, materials must be challenging but not too difficult, they must offer new ideas and information, something that will give students a reason to communicate and engage. The ability to use the vocabulary and structures they learn in a meaningful context increases students' motivation. In terms of motivating students, language teachers should apply strategies and methods that provide opportunities for continuous enhancement of students' skills. The teacher has a very big role in the classroom. Harmer (2002) points out that one of the main tasks of the teacher is to arouse interest and involvement in the subject even when the students are not initially interested in it. With their choice of topic, activities and language content, they could effectively and successfully lead classes.

5. Conclusion

The survey has provided useful information about motivation and factors that affect the final learning outcome which is improved linguistic knowledge. Understanding and addressing

the motivational challenges that our students meet, taking into consideration their needs and interests and implementing interesting strategies is of crucial importance for achieving success in our students' language learning. The information gathered from the survey is of great value as it will definitely serve as guidelines in making English classes more creative and engaging, which should have as a result increased student motivation levels.

As motivation plays a significant role in developing linguistic competence, it is important to understand how it affects language learning, so that the students can achieve the best possible results.

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COMMUNICATION STRATEGIES AND THEIR EVERYDAY USE IN A FOREIGN LANGUAGE CLASSROOM

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Abstract. In our mutual communication, we encounter misunderstandings, misinterpretation, distortion of meaning, which leads to numerous communication conflicts. The communication skills, whether it is a native or a foreign language, are one of the linguistic phenomena that allow each of us to use the language, in this case another (foreign) language, in the best way and in different situations and contexts. When we encounter a problem in communication that is the result of our current language competence, there is a need to overcome it for communication to continue and to achieve all its stated goals. The use of communication strategies is one of the possible ways that will help us. We use words, facial expressions, gestures, and sometimes even descriptions with the purpose of clarifying the message, if the interlocutors agree in assigning meaning to certain objects or events.

In this paper, we will present the most important and most common communication strategies and their use by native Croatian speakers in the process of mastering a second foreign language, in this case English.

We conducted the research among first-year undergraduate students and first-year specialist students.

There is a slight variation in the selection of communication strategies between the two groups of students. Higher proficiency students employ reduction strategies less frequently than first-year students, they prefer strategies such as seeking help or paraphrasing. On the other hand, students with lower levels of oral proficiency most frequently employ avoidance strategies, retrieval strategies, and non-verbal strategies, while they use paraphrasing and strategies for seeking help less often.

Key words: *communication, strategies, students, English classroom*

1. Introduction

Communication in a foreign language requires communication skills, a linguistic phenomenon that allows us to use the language in the best possible way in different situations and contexts. When learners encounter a problem in communication, that is mainly due to their current competence that they demonstrate in that language and they need to overcome the problem to achieve the required communication goals so that the necessary communication can continue. Communication strategies represent one of the ways to overcome such problems. Activities that enhance language learning usually play a significant role in developing communicative competence and enabling communication skills.

In this paper, we will briefly present basic communication strategies and their use by Croatian students in the process of mastering a foreign language, which is the topic we decided to start with.

2. Second Language Acquisition

In the second half of the 20th century, with the expansion of communication beyond the local spoken language, there was an interest in the study of processes closely related to the learning of a non-native language. It marked the emergence of the Communicative Language Teaching Approach that recommends teaching English through communication or by using it. With the later trends in language teaching approaches and methodology, communicative competence has become the main aim for second and foreign language learning.

In English terminology, the term second language (L2) is used as an umbrella term for all the languages we learn, except for the acquired first language. There are three possible processes in the context of which the mastering of a language that is not an individual's mother tongue occurs: second language acquisition as spontaneous mastering of a language that is not the speaker's mother tongue, learning a foreign language as a process of formal mastering of a language in an institutionalized environment where that language is not widespread, and second language acquisition as a process that includes both spontaneous and formal processes (Medved Krajnović, 2010).

As an example of this last situation, we can mention an illustrative scenario. For instance, consider native Croatian speaker undertaking English language courses in their home country and subsequently embarking on a journey to Great Britain. This experience allows them to deepen their understanding of the language within an immersive setting where English serves as the official medium of communication. Ellis (1997) explains how important it is to describe and identify the external and internal factors that influence the way speakers acquire a second language. The status that a language has in society affects the attitudes that the speaker will develop towards that language. Internal factors that influence the process of language acquisition refer to various cognitive mechanisms that enable students to extract the information they need from the linguistic input for a successful acquisition process. It should be emphasized that those who want to master this language already possess several types of knowledge that can facilitate their acquisition process, starting with knowledge of the already acquired mother tongue to communication skills that facilitate the use of the knowledge needed for another language. In this paper, we focus precisely on communication skills, one of the important elements related to the process of acquiring a second language.

3. Theoretical frameworks of communication competence

Communication strategies can't be observed without reference to communication competence. The term communicative competence was first introduced in the late sixties, or early seventies of the 20th century in the work of the American linguist and anthropologist Dell Hymes. He believed that until then, all sociolinguistic factors were unfairly excluded, and competences were viewed only through the prism of language or linguistic competences Chomsky (1965). Hymes believed that linguistic competence is knowledge that the speaker is most often not aware of but is implicitly present in everything the speaker can say. According to Hymes (1972) the average member of a speech community possesses knowledge of all aspects of communication systems available to him. When Hymes discusses competence, he generally refers to a broad spectrum of capabilities and skills within a particular context. Since the end of 1960s Hymes has started to show interest in sociolinguistic factors in the study of language knowledge and use and the concept of communicative competence has begun to gain more and more importance and attracted more and more attention. During the seventies and eighties of the 20th century, Canale and Swain (1980) believed that grammatical competence should

be considered a component of communicative competence. Just as Hymes (1972) posited, there are rules of grammar that would be ineffectual without an understanding of the rules governing language use; likewise, there are rules of language use that would be futile without comprehension of grammar's principles. However, Canale and Swain (1980) claimed that in everyday speech, native speakers would focus more on language usage than on grammar. They refute assertions that communication competence is the broadest or most important level of language competence. On the contrary, they see communicative competence as a subcomponent of more general linguistic competence, just as communication performance which is considered a subcomponent of a more general language performance.

4. Communication strategies

The research interest in communication strategies (CS) emerged at the beginning of the seventies of the 20th century when the term communication strategy was used for the first time in 1972 by Selinker, who was the first to observe the strategies learners use when speaking a foreign language. These strategies occur in compensation for problems that arise when there is a discrepancy between the level of language skills and communicative intentions of the speaker.

Besides Canale, Swain and Hymes, we would like to mention Elaine Tarone, one of leading figures in sociolinguistics. Interactivity as a characteristic of her approach stems from the interactional nature of human communication and the observation of language not only as an object used in communication, but as that part of communication where is equally influenced by both the speaker and the listener (Tarone 1981). Tarone is primarily guided by the idea that strategies arise from situations in which speakers try to convey certain meaning-filled content despite the existence of certain deficiencies in their interlinguistic system. An important fact that communication strategies as a phenomenon indicate is that second language learners are capable to use the limited interlinguistic system in a way that will enable them to overcome these limitations (Tarone 1980). Within the conceptual theoretical framework that Tarone (1980, 1981) proposes, she defines two types of communication strategies: language learning strategies and language use strategies. Communication strategies belong to the latter type because Tarone considered that they are not part of the speaker's language knowledge, but the speaker simply uses them to show what he knows while trying to communicate with a speaker of the target language. CS can therefore be perceived as attempts to bridge the gap between the language knowledge of foreign language learners and the language knowledge of target language speakers in real communication situations. Tarone also believes that all kinds of strategies contribute to language acquisition because they help the student to learn the desired language unit or structure.

The psycholinguistic perspective of Faérch and Kasper (1983) and the interactional view of Tarone (1980) have been widely employed to investigate the application of communication strategies. They propose that speakers, when lacking adequate linguistic resources, rely on communication strategies to solve their communicative problems. By restructuring their utterances, they manage to compensate for the lack of linguistic knowledge. The strategies they described are classified into reduction strategies and achievement strategies. Reduction strategies, such as message abandonment and topic avoidance, are used for the purpose of giving up a fragment of the original communication goal. On the other hand, achievement strategies such as paraphrase, code-switching or borrowing, self-repair, general-meaning words, non-verbal strategies, and seeking assistance, are used to maintain the original goal of the language user. Since the number of different taxonomies is too large to mention them all in this paper, we chose and presented only those that we consider the most common and relevant. For a more detailed presentation of different taxonomies, see Bialystok (1990) and Dobao (2002).

4.1. Reduction strategies

4.1.1. Avoidance

Avoidance strategies include the speaker's avoidance of communication problems in two possible ways, by avoiding the topic or giving up on the message (message abandonment). When he/she avoids the topic, the student avoids talking about concepts they are not familiar with (it is not what the speaker initially had in mind), and when they give up on the message, students start to talk about the concept but cannot continue and decide to give up in the middle of the statement.

Avoidance or reduction strategies are usually more prominent among low proficiency learners as they have low level of mastery of the language.

4.2. Achievement strategies

4.2.1. Paraphrase

Paraphrase strategies are most often used for lexical units from another language that are not familiar to the student, and this includes approximation, word coinage and circumlocution. Approximation refers to the use of a lexical unit or structure from the target language for which the learner knows that it is not correct, but that it shares enough semantic features with the target unit that the speaker would be satisfied (e.g., chairs instead of stools, animals instead of dogs).

Word coinage is a situation when the student creates a new word to talk about the desired concept (e.g., hanging light instead of chandelier). Coinage is one of the many creative strategies performed by language learners in instances when they are not able to retrieve the accurate lexical item from their limited linguistic knowledge.

Circumlocution describes properties or parts of objects or actions instead of using a unit or structure from the target language (Bialystok, 1990) as shown in the following example: the speaker is missing a lexeme curtain so instead says *there is a cloth on the balcony door, most people have it, it serves as a protection from the sun.*

4.2.2. Code switching or borrowing

Borrowing strategies refer to the transfer of elements from the mother tongue and include literal translation and code switching.

In literal translation, the student translates from the native language (e.g., a native Croatian speaker says "I have 19 years" instead of "I am 19 years old"). Employing literal translation is a necessary strategy that should be regularly integrated into classroom communication, particularly in the initial stages. Over time, as students grow more confident in their target language skills, the reliance on literal translation as a communication strategy diminishes.

In code switching, a student uses a unit from the native language without translation (e.g., *I told the kids "nema" TV tonight* instead of *I told the kids no more TV tonight.*)

4.2.3. General words

This is the strategy when learners expand an empty lexical item to context where certain words are lacking. For example: the overuse of words "thing", "stuff", "make", "do", "what-do-you-call-it", "what-is-it".

4.2.4. Non-verbal strategies

These strategies include learners' use of nonverbal strategies instead of a lexical item (e.g., clapping hands to illustrate applause).

4.2.5. Seeking help

Help-seeking strategies refer to direct question that students can make about it which is the correct term (e.g., directly asking for help in the form of a question: "*I do not understand this word?*").

5. Research

5.1. The goal

This research was conducted with the aim of analyzing the use of communication strategies among first-year Management of Trade and Tourism students who attend Business English courses at the University Department of Professional Studies at the University of Split. The goal of the research was, primarily, to see how often students use communication strategies in communicating with professors and colleagues in English and whether there is a difference in the individual strategies they use. Moreover, an attempt was made to explore the distinction between students in their first-year of undergraduate studies and those in their first-year of specialist studies. There ought to be differences in their proficiency levels corresponding to their years of study, as it was hypothesized that, due to a longer exposure to language, the graduate students would demonstrate a higher level of language proficiency.

5.2. The sample

The research was conducted on a sample of 70 respondents, students at the Trade and Tourism Management department. The first group consists of 40 first-year undergraduate students. Their average age is 19.5 years, and the assumed level of knowledge of the English language is A2 or B1. In this group 25 are female students and 15 are male students. The second group consists of 35 first-year students of Business Trade specialist study. Their average age is 23.4 years, the assumed level of knowledge is between B2 and C1. In this group, 22 students are female and 13 are male students. All respondents voluntarily participated in the research.

5.3. The course of research

For the purposes of the research, we designed a questionnaire in which the respondents had to assess the extent to which they use certain strategies. The idea for the questionnaire was taken from Dornyei and Scott (1997) who studied different authors and designed their taxonomy.

The aim of this questionnaire was to obtain detailed information on the learners' self-awareness of the employment of CSs and their attitudes towards the use of each type of communicative strategies. The students were asked to rate the frequency of use for each strategy and its effectiveness. A sample of the questionnaire can be found at the end of the paper as an appendix. The list of communication strategies was taken from Dörnyei and Scott (1997). These strategies are divided into seven categories. The first group of questions contains the so-called reduction strategies, namely giving up the message, avoiding the topic and changing the

message. The second group contains examples of achievement strategies, such as paraphrase, approximation, and use of general words. The third group includes strategies such as: literal translation, use of the mother tongue and foreignizing. The fourth group represents a strategy called retrieval (a strategy that refers to the process of retrieving lexical items from memory by saying a series of incomplete or incorrect forms and structures before finding the optimal form) and correcting one's own speech. The fifth group includes indirect strategies that include the use of "fillers", various verbal means to fill pauses and procrastinate to keep the communication channel open, as well as repeating one's own and the interlocutor's words to gain some time until an appropriate form is found. The sixth group includes non-linguistic/paralinguistic strategies, such as facial expressions and gestures. The seventh group contains strategies for seeking help (whether direct or indirect, using mother tongue or other language). The respondents evaluated the use of the mentioned strategies on a Likert scale from 1 to 5, whereby number 1 meant "always" and number 5 "never". Rating scales included five points: (1) always, (2) often, (3) sometimes, (4) seldom, (5) never. So, for each individual communication strategy within a certain category, the respondents had to assess to what extent they use it, that is, to what extent such behaviour is characteristic for them. Table 1 shows the means of the students' answers.

6. Results and Discussion

The results of this research can be analysed in two ways: the frequency of use of communication strategies within each of these two groups of students and the differences in the use of individual strategies by each group. The results also showed that different levels of oral proficiency can affect the use of communication strategies.

6.1. Frequency

The analysis of the frequency of use of communication strategies at the level of two groups shows that the general frequency of use of strategies is not very high and that there are no great differences in the frequency of use between individual groups of strategies. It also shows that the most frequent strategies used in both groups are those based on the second language, while strategies based on the mother tongue are used less frequently, which can be explained by the fact that students in both groups have relatively good knowledge of the language. Furthermore, the number of communication strategies employed by the first-year students outnumbered the communication strategies employed by the fourth-year learners with higher level of oral proficiency (Table 1).

Table 1 Frequency of use of communication strategies

Communication strategies	Avoidance	Paraphrase	Literal translation	Retrieval	Fillers	Non-verbal strategies	Asking for assistance
First-year students	2.7	3.1	3.2	2.2	3.0	2.5	3.1
Fourth-year students	3.4	2.7	3.3	2.8	2.8	3.1	2.6

6.2. Selection of types of communication strategies.

There is a slight difference in the selection of the types of communication strategies by the two groups of students. The higher proficiency students use reduction strategies less

frequently than first-year students because they are willing to take risks and less often give up on communication, change the message or avoid the topic. It should be noted that reduction strategies are generally less frequently applied by high-proficiency students. Students with a lower level of oral proficiency showed that they most frequently use avoidance strategies, retrieval strategies and non-verbal strategies while they tend to use less frequently paraphrase or strategies for seeking help. On the other hand, fourth-year students with higher proficiency level prefer strategies like strategies for seeking help or paraphrase. The reason why students with higher language proficiency use strategies like paraphrasing more often is because they know from experience that using these strategies will help them achieve the communication goal more easily. As far as non-verbal strategies are concerned, it appears that first-year students use them more frequently than students with higher proficiency. This suggests that the need for this strategy decreases as students' knowledge increases.

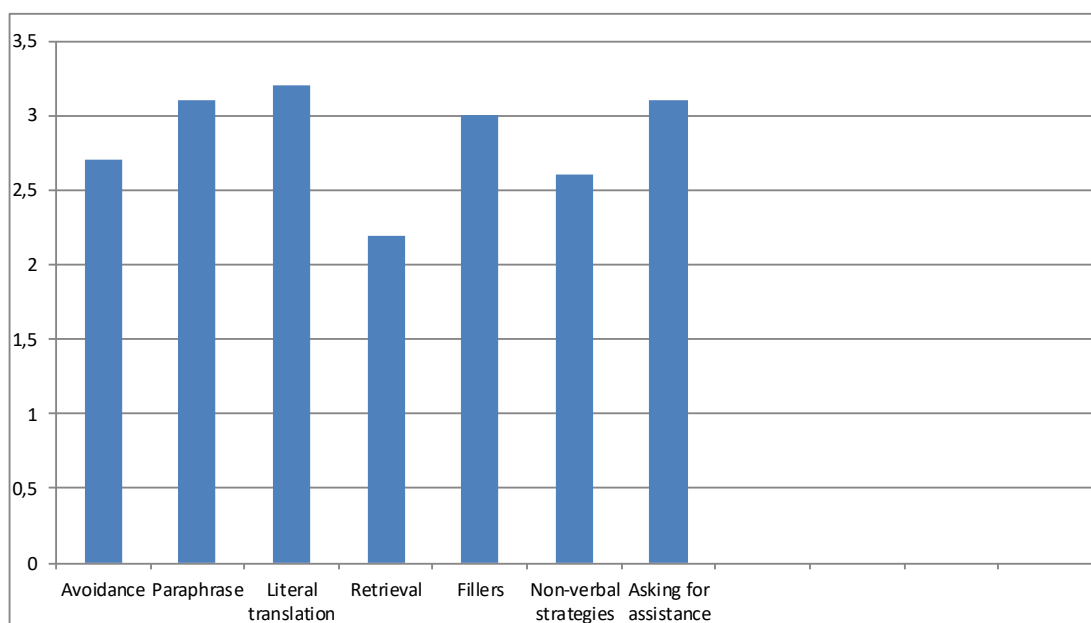


Figure 1 Frequency of use of communication strategies by first-year students

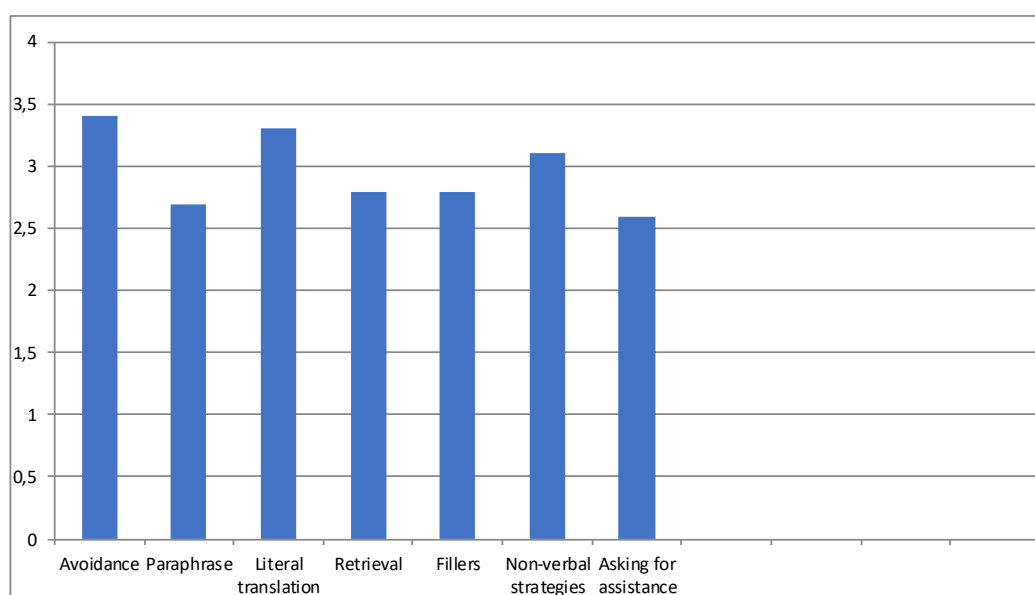


Figure 2 Frequency of use of communication strategies by fourth-year students

7. Conclusion

When L2 students encounter Communications problem as the result of their linguistic inadequacy, they frequently use several types of strategies in order to overcome communication challenges. The findings of the present study show that students' use of communication strategies is not a sign of their failure to communicate their message. Communication strategies manifest when learners recognize difficulties in expressing their intended message and seek assistance to address these challenges. The more strategies the students have, the more opportunities they have to solve communication problems. Therefore, efficient learning on the use of communication strategies is necessary to help the students communicate when their knowledge of the language is insufficient. The study of communication strategies is of great practical value because it suggests that strategies can and should be included in foreign language classes in order to teach students the techniques, they can use to improve their communication competence.

In the end, we can conclude that the selection of communication strategies differs slightly between the two groups of students. As hypothesized, fourth-year students showed higher language proficiency which led to less frequent use of reduction strategies than first-year students. They rather use strategies such as seeking help or paraphrasing which are more effective in achieving communication goals. On the other hand, students with lower levels of oral proficiency most frequently employ avoidance strategies, retrieval strategies, and non-verbal strategies, while they use paraphrasing and strategies for seeking help less often.

Appendix

Questionnaire

1) Always 2) Often 3) Sometimes 4) Seldom 5) Never

1.

a) When I notice that my language knowledge is not sufficient to express the desired message in English, I do not participate in classroom discussion. 1 2 3 4 5

b) If I realize I am missing a term in English, I do not finish the sentence I started. 1 2 3 4 5

c) If I believe I won't be able to express myself on a topic, I avoid it and try to talk about something else. 1 2 3 4 5

2.

a) I like to use paraphrase to help me communicate in English. 1 2 3 4 5

b) If I cannot remember the desired word in English or I do not know that word, I use the synonym. 1 2 3 4 5

c) When I communicate in English, I usually use general words and expressions (animals instead of specific type, things instead of specific term). 1 2 3 4 5

3.

a) If I cannot remember a word in English, I translate it from the mother tongue (literal translation). 1 2 3 4 5

b) When I cannot express myself in English well, I use words or expressions in my mother tongue (untranslated). 1 2 3 4 5

c) When communicating in English, I use words from my mother tongue but I adjust the pronunciation to English. 1 2 3 4 5

4.

a) When I cannot remember a certain form of a word in English I say different forms of that word out loud until I get to the one I need. 1 2 3 4 5

b) If I notice a mistake in my speech, I correct it. 1 2 3 4 5

5.

a) I try to fill the pause in speaking to gain some time - the communication will not be interrupted.

(First *things first*, *Well*, *Ok*, *So....*) 1 2 3 4 5

b) I repeat what other person said or I repeat my own words if I cannot remember the desired word immediately. 1 2 3 4 5

6.

a) I use gestures and movements during the communication in English, especially if I cannot describe the desired term. 1 2 3 4 5

b) My communication includes facial expressions when I cannot remember the desired word. 1 2 3 4 5

7.

a) When I have a problem communicating in English I ask my professor for help and I do it in English. 1 2 3 4 5

b) When I have a problem communicating in English I ask my professor for help and I do it in Croatian. 1 2 3 4 5

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AN EXPERIENTIAL LEARNING APPROACH IN BUSINESS PLANNING COURSE: CONNECTING STUDENTS TO THE REAL WORLD

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Abstract: Business education stands as a cornerstone in modern higher education, especially considering the substantial enrolment of students in business and economics programs worldwide. The main goal for educators is to enhance students' capacity to recognize business opportunities, assess feasibility, and conceptualize business models. Universities address this by offering courses in business planning and employing practical methodologies such as computer simulations and case studies to provide experiential learning. Consequently, experiential learning emerges as a pivotal mechanism for translating student experiences into effective learning outcomes, fostering knowledge acquisition grounded in real-world interactions. This pedagogical approach facilitates learners in exploring uncharted territories, embracing risk, and deriving lessons from setbacks, thereby nurturing confidence and self-efficacy. Integration of experiential learning demonstrates significant advantages for students preparing for the contemporary business landscape. An example of this transition was observed in a study conducted at the University department of professional studies at the University of Split, where a Business planning course was revamped from traditional lecture-based teaching to experiential and practical learning methodologies. The evaluation of this course reveals that students gained contemporary entrepreneurial knowledge and skills. The curriculum navigates students through a systematic journey of identifying business opportunities, analysing competitors, and articulating their proposals through written business plans tailored for actual entrepreneurs. The findings reveal that students who finished the course in 2022 and 2023 demonstrated improved proficiency in vital business areas, including management, marketing, risk assessment, and financial analysis. Moreover, the course emphasizes the development of entrepreneurial skills, covering networking, time management, communication, creativity, critical thinking, leadership, social awareness, and negotiation abilities. Finally, through the evaluation of a Business planning course that shifted from traditional lecturing to a student-oriented experiential learning approach, supplemented by exposure to real-world entrepreneurs, the results highlighted students' acquisition of relevant entrepreneurial knowledge.

Key words: *Experiential learning, Entrepreneurial knowledge, Transition, Business planning course, Higher education*

1. Introduction

Business planning education is a crucial element of the educational process in modern higher educational institutions. In this case, the activities of mentors and teachers should be aimed at developing the student's ability to identify entrepreneurial opportunities, describe entrepreneurial ideas, and evaluate the economic and financial sides of a particular business model. Thus, experiential learning is an important mechanism to transform the experience of students into effective learning outcomes, contributing to the advent of knowledge that is based on real experience.

This paper seeks to illustrate the innovative learning approach that will be exemplified through the Business planning course, where students work on the business plans of real entrepreneurs. It enables students to step into unfamiliar regions where they lack expertise and encounter uncertainty. They face challenges and learn valuable lessons from them, enhancing their level of self-assurance and available knowledge assets. The study additionally gives the findings of the survey regarding the students' attitudes towards that method of learning.

2. Experiential learning

There is an increasing interest on the part of governments, businesses, and individuals to develop managerial and entrepreneurial abilities due to the value of business education. Moreover, this results in an increase in spending on postsecondary education in general and business education in particular. Furthermore, many countries have expressed concern about increasing not just the number of students who enrol in postsecondary education but also the level of its relevance and quality. This implies that specialized practical entrepreneurial skills through experiential learning will help to develop the appropriate human capital (Karia et. al., 2015).

Plenty of concepts related to learning have been correlated with different philosophical viewpoints on the essence of knowledge. Experiential learning theories elucidate the process by which individuals acquire expertise and abilities through their unique interpretations and responses to personal events throughout the course of their lives. Education, viewed in this manner, is a process of personal metamorphosis, implying that there is no existence of absolute knowledge separate from the individual possessing it. The intellectual theory that forms the foundation of experiential learning is known as 'constructivism'. Constructivism recognizes the possibility of several conflicting truths. The research conducted in this discipline seeks to comprehend the process by which individuals construct various interpretations of reality (Yardley et. al., 2012). This is not to say that it is a better (or worse) philosophical viewpoint than others. In fact, it is to say that various viewpoints can help shed light on various issues and queries.

The process of learning by doing or applying what has been learned in life is known as experiential learning (Clemenson and Bradford, 1996). Experiential learning approaches encompass a wide range of activities that offer practical experience and education, both within and beyond the confines of a traditional classroom environment (Van Wart et. al., 2020). The American social psychologist David Kolb is responsible for the development of the theory of experiential learning, who in the late 1970s emphasized in his theory that every individual can easily learn all concepts and theories through lectures and books but cannot fully understand what has been learned until this very knowledge he did not apply first hand that is, that his understanding of the material does not result from a combination of understanding and application of knowledge (Sternberg and Zhang, 2001). Kolb emphasized that a series of actions

results in significant learning, and he believed that knowledge acquired through experience will have better results than knowledge that a person has only based on theoretical learning (Kolb, 1984) Kolb's theories are easily applied to every subject area, and they can be implemented in a particular lesson, session, or extended learning course and utilized by individuals, groups, or entire organizations (Bruton and Bradley, 1992).

This form of learning can best be described as applying knowledge and skills from books in the real business world and presenting one's own views and thoughts on certain topics (Sunčić, 2023.). Korban Črnjavič and Hus (2009) state that in this way the intellectual capacities of individuals are developed and strengthened, and at the same time the level of motivation to explore new things is raised and they are encouraged to learn. By actively participating in the teaching process, students can gain knowledge and skills rather than just being passive recipients of information. This method of learning allows students to become lifelong learners (Gross and Rutland, 2017).

Through experiential learning in business classrooms, students have a greater chance to develop their communication and interpersonal skills, understand course material, encourage teamwork, and team building, sharpen their critical thinking and problem-solving skills, and improve their listening comprehension (Krbec and Currie, 2010). The only way to enable students to comprehend the material more profoundly, to think critically, to widen their worldview, and to create positive professional behaviours and skill sets that will be put into practice in the future is through the practical experience. Engaging students in practical tasks is a successful method for enhancing student skills (Pamungkas et. al., 2019). This will give students self-assertion, responsibility, and leadership abilities as an adult in every role.

With the help of professors, who play the role of trainers and leaders, individuals can apply the acquired knowledge and skills in different situations and environments, whether private or business. Mentors should pay attention to how students deal with difficulties and advise them on how to find a solution in a particular part of the tasks instead of offering them final solutions for a particular problem. It is very important that students are given freedom and that they work hard on certain tasks, as they will do in real life. Professors who engage in experiential learning take pride in imparting concepts rather than irrelevant facts, and they frequently assert that learning and problem-solving abilities are more effectively transferred than they would be in a regular classroom (Kraft, 1990).

To understand university processes to support student entrepreneurship, scholars are focusing increasing attention on entrepreneurship education and the methods used in teaching entrepreneurship (Wright et al. 2017). Several studies in the literature have shown the dominant effectiveness of practically oriented models in relation to theoretical models. Rae and Carswell (2000) argue that entrepreneurial work-based learning programs have a stronger effect on the development of students' entrepreneurial skills. The criterion for research success is generally recognized to be the students' academic performance, and in several works, researchers argued that assessing the students' final grades and test scores relative to direct entrepreneurship coursework can serve as an appropriate indicator.

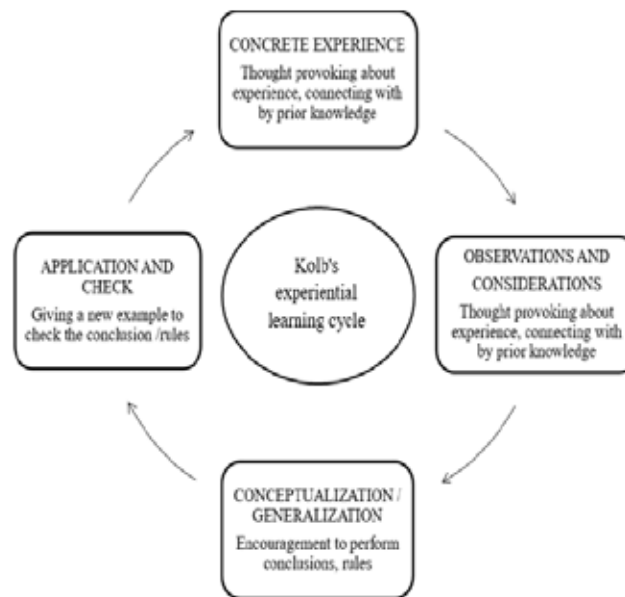


Figure 1 Kolb's cycle of experiential learning

The basis of Kolb's cycle of experiential learning in figure 1 is the idea that everyone possesses unique learning tendencies, which make them dominant during certain stages of the learning process. For example, some students will be better at reflective observation and concrete learning, while others will be better at abstract conceptualization and active experimentation.

According to Kolb's theory (1984), experiential learning takes place in four stages:

- Concrete learning includes the acquisition of new knowledge and experience by the student and refers to the ability of the student to interpret new knowledge in his own way through a certain process, facing various problems.
- Reflective observation refers to students' reflections on a new experience to which they try to give a new meaning and connect their prior knowledge to encourage them to think about a certain problem.
- Abstract conceptualization is the process by which students correct their ideas and arrive at new experiences.
- Active experimentation refers to a long-term process in which students apply their own ideas to real situations to see if their ideas will survive even though they face certain problems that may stand in their way.

According to Kolb, there are also four styles that differentiate the preferences of individuals and their ways of learning, namely:

- Active or divergent students - they give in to the moment, they are fully committed to their tasks, but they easily lose interest in some things and very quickly switch to other activities. Also, such people often act without thinking about the consequences of their decisions. Their learning is enhanced when the tasks they perform are challenging, have a clear and concise format, and excite them. It is difficult for them to learn when it comes to long-term projects in which they must passively participate, when they must analyze information or do work independently.
- Reflective students or assimilators – they observe the situation and collect information and thoroughly analyze it before making their decision. This type of student learns better if he has time to analyze all the necessary information, and they mostly want to go unnoticed. This type of learning will not achieve good learning results if they lack time for analysis or if they are forced to act without prior analysis.

- Theoretical or convergent students - this is the type of student who transforms information into theories based on logic, and when making decisions, they go through numerous steps to reach a conclusion at the very end. For them to focus on learning more easily, it is necessary that these activities represent a certain challenge for them, that they have realistic concepts and that they can independently research all the necessary facts. Learning is more challenging for them if they must work within the research without a theoretical basis, if there is an emotional activity and if there are inaccurate and confusing activities.
- Pragmatic students or servers - students who gladly accept the application of new knowledge in practice, have a high ability to solve problems and, when performing work, try to perform the work in the best possible way. They learn the easiest if they can apply the theory in practice, and it is difficult for them to learn if the activities they learn do not have a specific purpose or if they cannot be applied in practice.

Numerous advantages of experiential learning influence the educational process. Students develop first-hand experiences through active participation in practical tasks, which encourage better understanding and better memory of acquired knowledge. Their thinking about information stimulates their creativity, i.e., their innovative problem-solving techniques and creative thinking that they apply to solve real-world difficulties. Furthermore, since the application of learned concepts in practice has a lasting effect on decision-making and problem-solving skills, experiential learning enables faster acquisition of information by giving students the opportunity to apply their academic knowledge in practical settings. Through experiential learning, students create strategies for solving problems, and in this way, they come to new knowledge through mistakes. At the same time, this way also promotes the recognition of the importance of failure as an additional learning opportunity. By bringing together theory, knowledge gained through academic study from textbooks and books, and real-world experience, the career emphasis helps students prepare for their future careers. Another advantage is encouraging cooperation and teamwork and developing strong communication skills. All things considered, experiential learning offers a comprehensive teaching method that encourages student effort, development of basic abilities, and readiness for new challenges in later life.

Although there are numerous advantages of experiential learning for students, there are also certain disadvantages that should be considered. One of these shortcomings is precisely the constant supervision of students when experimenting with different strategies when solving problems. The reason for this is the passage of time, which can be a problem for mentors and students to reach the desired solution. Also, the problem can be decentralization, i.e., constant online communication and assignment of tasks in such a way that it also represents the mentor's limitations in relation to the traditional way they are used to when approaching students.

3. About the course

The Business Planning course is conducted in the first year of the Specialist professional graduate study programme: Trade and tourism management at the University of Split, University Department of Professional Studies. Below, the learning outcomes and objectives of the course will be explained. It is important to emphasize that for the past eight years, the practical part of the exam, namely the development of a business plan, is carried out for real small entrepreneurs. The project itself is called Plan start. Students are divided into teams of 4 to 5 students, and through the allocation of individual tasks over three months, they develop a business plan. In this process, constant communication with the entrepreneur for whom the project is being developed is of paramount importance. Throughout the process, the Croatian Chamber of

Economy plays a significant role as an intermediary in the communication project with the students. For the purposes of this study, a survey was conducted to examine students' attitudes towards various elements of this teaching method, the results of which will be presented in the following chapters of the paper.

3.1. Learning outcomes

Students who successfully complete the Business planning course will receive training in several key skills and abilities that will help them effectively manage entrepreneurial projects. First, students will be able to understand the essential components that make up the structure and goal of an entrepreneurial project and see it as an extension of a new business idea. These include market analysis, target group identification, competitor analysis, and strategy development. In addition, students will be able to distinguish between static and dynamic project evaluation techniques after this process. As a result, they will be able to make well-considered judgements on the profitability of investments when considering time value of money considerations. Cash flows of investment projects and permanent working capital will become possible target calculates for students. Thus, the students will have the ability to determine financial feasibility of the project and the volume of resources required for its implementation. A projection of the investment project's profit and loss account as well as a projection of economic and financial flow will allow students to predict the project's future performance and identify potential threats and opportunities. In addition to quantitative research, students will acquire the skills of critical thinking and analytical approach to economic and financial facts, which will enable them to argue the acceptability of the project based on in-depth examination. Finally, to facilitate the creation of economic and financial analyzes of entrepreneurial ventures, students will learn how to use computer tools. This will allow them to conduct accurate and efficient analyzes and simplify their decision-making. All the competencies listed above will contribute to both personal and professional growth in the areas of project management and entrepreneurship, allowing them to ethically lead entrepreneurial projects and make rational strategic decisions in a business aspect.

3.2. Course objectives

During their academic career, students will acquire a wide range of competencies and skills, many of which are included in the objectives of the Business planning course. With a focus on real projects in a corporate environment, students will first be able to understand the intricate process of making financial decisions about the allocation of funds and other resources to different initiatives. They will be able to recognize potential investment opportunities and risks, as well as make educated choices about asset allocation if they understand this process. In addition, by applying methods of planning, organizing, evaluating, and monitoring investment projects, students will acquire the skills necessary to use their newly acquired information in real-world scenarios. This includes the ability to organize and oversee investment initiatives from inception to execution and impact assessment. Students will additionally develop their analytical-mathematical abilities by using computer tools to create economic and financial analyzes of entrepreneurial initiatives. This will help in decision-making and reveal important indicators of project success. Each of the competencies from this list will help students to advance professionally in the field of business project management and enable them to successfully navigate challenging business situations.

4. Research findings

The research was conducted among students who participated in the Plan start project as part of the Business planning course. Sixteen students who took the Business planning course in 2022 and 2023 participated in the survey. The survey questionnaire contained a total of 10 questions, 8 of which the students were asked to assign grades on Likert scale from 1 to 5, where grade 1 refers to strong disagreement, while grade 5 refers to strong agreement. One question asked students to choose one or more statements that they agree with, that is, the skills they have acquired or improved, while the last question refers to students' comments or recommendations on how to improve and advance the performance of the Business planning course. The results concerning each question are presented below.

When asked how useful creating a business plan for a real small business was in their academic development, not a single student rated the experience as a 1 or 2. Four students (25%) rated the experience a 3, while three students (18.8%) rated it a 4. The largest share of surveyed students, nine of them (56.3%), rated this experience as the highest, and they believe that it was extremely useful for their academic development. The overall mean score is 4.31, suggesting that students have determined that the process of creating a business plan for an actual small business was highly advantageous for them. Results are shown in figure 2.

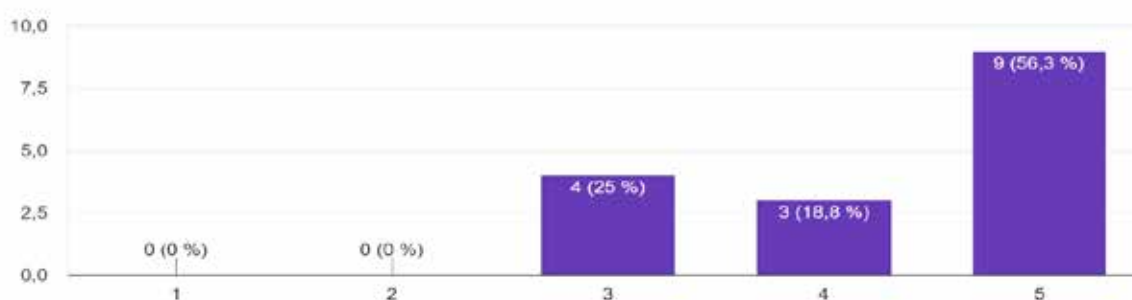


Figure 2 The usefulness of the experience of creating a business plan for a real small business

When asked how they would evaluate the level of complexity of the task of creating a business plan for a real small business compared to other academic tasks they had, not a single student rated it as 1. As can be seen in figure 3, three students (18.8%) rated it as 2, while most students (8 of them, or 50%), assessed the complexity of the task of creating a business plan with a grade of 3. Three students (18.8%) assigned grade 4, while only two students (12.5%) awarded grade 5. Taken together, the average mark of students' task complexity to develop a business plan for a real small business is 3.25. It may be concluded that the activity is of moderate complexity for the students, as it is between the easier and harder activities they carry out.

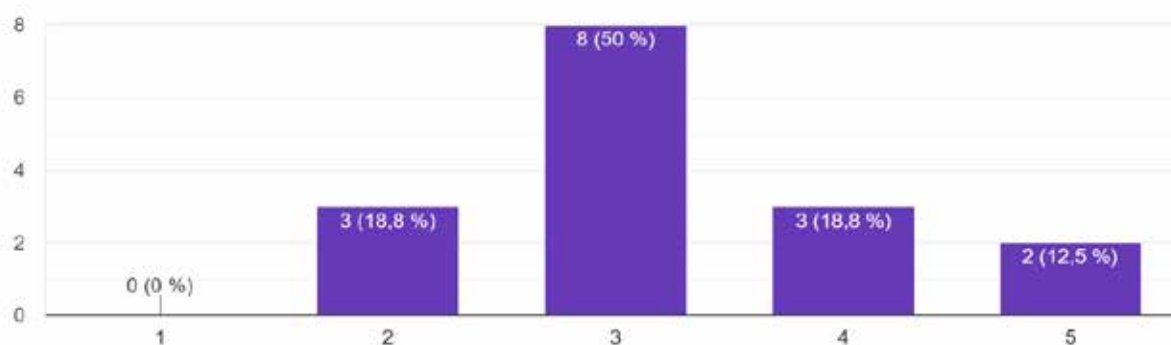


Figure 3 The level of complexity of the task of creating a business plan for a real small business compared to other academic tasks

When asked how much self-confidence the students received from the opportunity to create a business plan for a real small business, as seen in figure 4, not a single respondent gave a score of 1 or 2. Three students (18.8%) rated their level of confidence as a score of 3, while two students (12.5%) gave it a grade of 4. The largest number of students, eleven (68.8%), gave it a grade of 5, which shows that the majority of students gained a lot of self-confidence when creating a business plan. The students' average grade of 4.50 reflects a significant level of self-confidence gained from the experience of developing a business plan for an actual small firm. The students' average grade of 4.50 reflects a significant level of self-confidence gained from the experience of developing a business plan for an actual small firm.

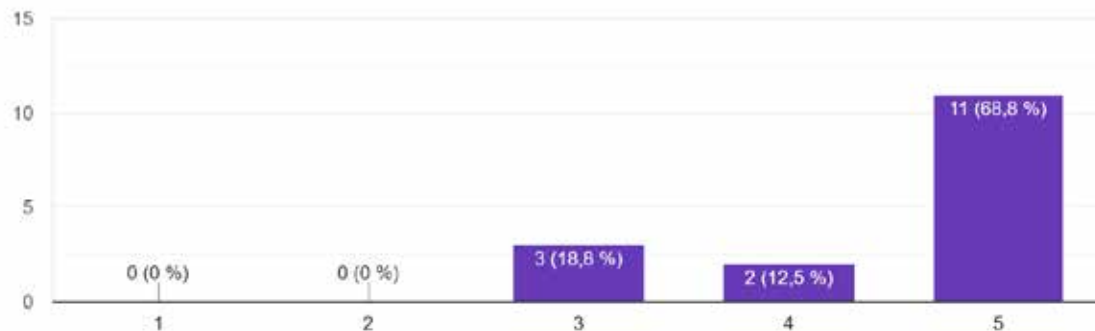


Figure 4 The level of acquired self-confidence from the opportunity to create a business plan for a real small business as part of the exam

When asked how they would rate the support they received from the teacher during the process of creating a business plan for a real small business, only one student rated the support received from the teacher with 4. The remaining fifteen students indicated by score 5 the excellent support of the teacher, as shown in figure 5. Consequently, the teacher's support during the process of creating a business plan for a real small business was excellent quality, which is confirmed by a group average rating of 4.94.

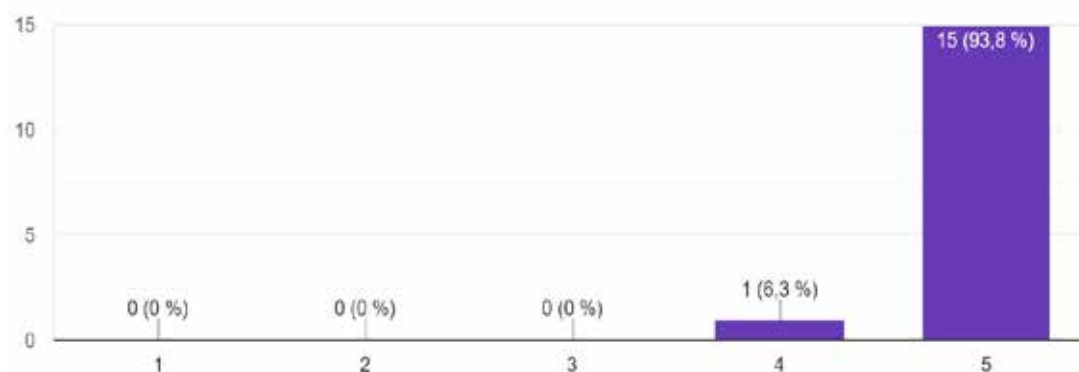


Figure 5 Received support from the teacher during the process of creating a business plan for a real small business

When asked how they would rate the support they received from entrepreneurs during the process of creating a business plan, as shown in figure 6, the students gave different ratings. Only one student (6.3%) assigned grade 1, while two students (12.5%) assigned grade 2. Two students (12.5%) also assigned grade 3, while a quarter of the students, or 25%, assigned grade 4. Seven students, accounting for 43.8% of the total, rated the support from entrepreneurs when creating a business plan as the highest. The overall mean score of 3.88 suggests that the level of support students received from entrepreneurs while developing a business plan may benefit from a more consistent and interactive engagement.

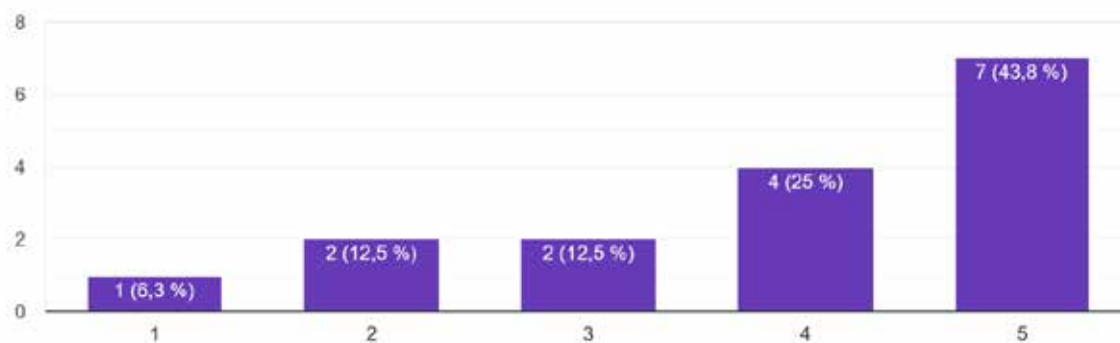


Figure 6 Received support from entrepreneurs during the process of creating a business plan for a real small business

In the sixth question students were asked about the key skills they gained or improved through the process of creating a business plan for a real small business. Students had the option to select more different skills that they believed they had enhanced or acquired. At the end twelve students answered that they gained and/or improved analytical skills. Eleven students agreed that they acquired and/or improved their creative thinking skills. Regarding the acquisition and improvement of communication skills, nine students indicated how they improved their communication skills in terms of acquisition and improvement. Thirteen students believe that they have acquired and/or improved their financial literacy. Eleven students identified cooperation and teamwork skills as competencies they acquired and/or improved through this project.

When asked how they would rate the usefulness of the actual experience of creating a business plan compared to the theoretical approach they may have had through lectures and literature, as seen in figure 7, not a single student gave a score of 1 or 2. Only two students (12.5%) assigned a score of 3, while six students (37.5%) assigned a rating of 4. Eight students (50%) gave this experience the highest rating, describing it as extremely useful. The average grade of 4.38 indicates that students found the practical experience of preparing a business plan is additionally valuable as the theoretical approach they learned from lectures and literature.

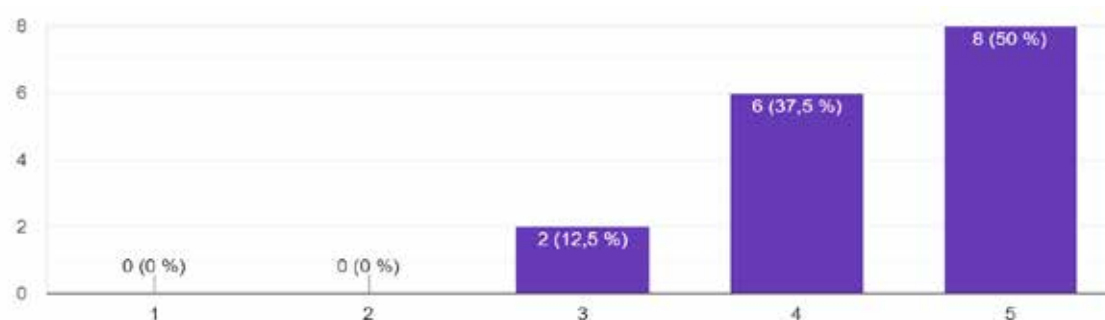


Figure 7 The usefulness of the experience of creating a business plan compared to the theoretical approach given through lectures and literature

When asked how much creating a business plan for a real small business stimulated their interest in entrepreneurship or their understanding of the business environment, students offered very different answers, as seen in figure 8. Only one student (6.3%) assigned a grade of 1, while two students (12.5%) assigned a grade of 2. One student (6.3%) assigned this with a grade of 3, while five students (31.3%) assigned a grade of 4. Most students, seven of them (43.8%), rated the usefulness of collaborating with colleagues during the creation of a business plan as a 5. The mean score of 3.94 indicates that the creation of a business plan has moderately

sparked students' interest in entrepreneurship and comprehension of the business surroundings. However, there is still potential for these projects to further excite students' enthusiasm for entrepreneurship.

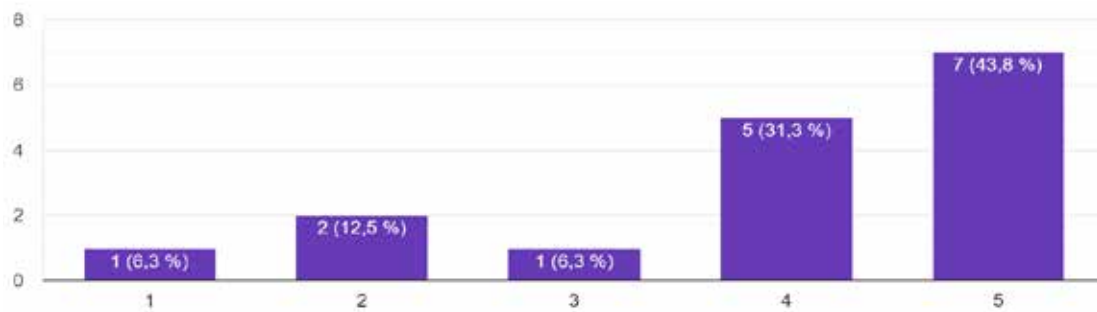


Figure 8 Sparked interest in entrepreneurship or understanding of the business environment

Finally, when asked how useful it was for students to collaborate with their colleagues during the process of creating a business plan, not a single student gave a grade of 1 or 2, as can be seen in figure 9. Three students (18.8%) awarded grade 3, while six students (37.5%) awarded grade 4. Most students, 7 of them (43.8%), rated the usefulness of collaborating with colleagues during the creation of a business plan as a 5. An average value of 4.25 indicates that that the level of collaboration with fellow college students in the development of the business plan was quite good.

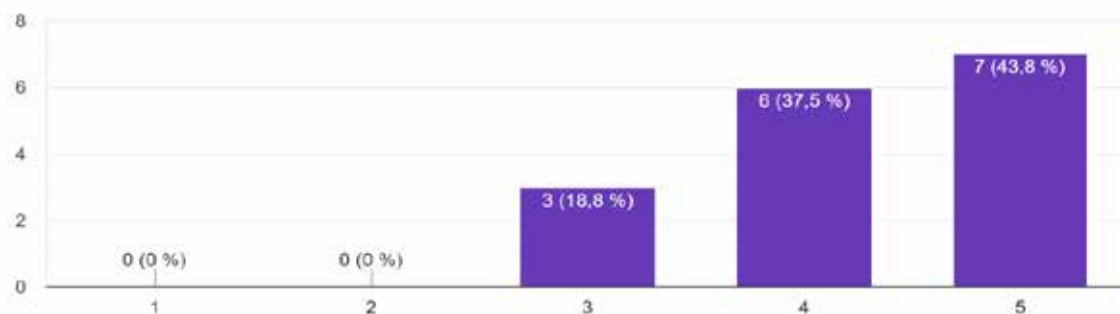


Figure 9 The usefulness of collaboration with other students during the process of creating a business plan for a real small business

Last part of research was asking students to propose modifications or enhancements for the structure and execution of the Business planning course's business plan creation task. For the purpose of this paper the proposed answers are shown exactly as written by students in the table below.

Table 1.. Proposed modifications or enhancements for the Business planning course

COMMENTS	
1.	<i>I am satisfied with everything.</i>
2.	<i>I believe that it would be necessary to organize more field classes by companies, because I believe that this is the best way for students to adapt and gain insight into reality. Theory always remains theory, and everything requires practice.</i>
3.	<i>This project enabled us to gain insight into the challenges that entrepreneurs face when planning an entrepreneurial venture and to change all the theoretical knowledge that we gained during our studies.</i>

4.	<i>I wouldn't improve anything. I believe that the course is well developed, just like Plan start itself, in order for students to improve their communication and analytical skills.</i>
5.	<i>In order to improve the creation of a business plan, it would be good to examine the specific needs of a real small business through more detailed questions in order to present the financial part of the plan as well as possible.</i>
6.	<i>I rate it as a 3.</i>
7.	<i>Find more small entrepreneurs or start-ups in a variety of industries.</i>
8.	<i>There is no need for any changes; it was a nice experience.</i>
9.	<i>In a nutshell, it's excellent. Plan start is something that I will remember as one of the most useful and instructive experiences during my studies.</i>
10.	<i>I believe that in addition to the formal opening and presentation of the plan, a meeting would be useful in which we would physically present the plan to the entrepreneurs with whom we cooperated and, in that way, verbally clarify all doubts and raise the vision of the plan to a higher level.</i>
11.	<i>The plan of cooperation with real entrepreneurs is an extremely good idea because the course is not based exclusively on theory but also on practice, which I believe will help many people in their later dealings with business plans.</i>
12.	<i>Very positive experience.</i>
14.	<i>I believe the mentor has very well coordinated everything.</i>

One could conclude that the course on business planning has had a great impact on the students, as it resolved the issue of combining the application of theoretical knowledge with practical experience. In addition, working in a structured fashion with businessmen aided the students to develop practical knowledge. Working on a real project within the course helped them to apply the obtained data and the skills described to make useful recommendations for reality. And therefore, they were able to see how businesses were actually working. The result of success within the course project allowed the students to apply their knowledge to reality, and the practicality of education understanding was developed. A well-organized approach to education aimed at developing analytical and adherent abilities allowed the students to form personally and professionally.

5. Conclusion

The main goal for educators in modern higher business education is to enhance students' capacity to recognize business opportunities, assess feasibility, and conceptualize business models. Universities address this by offering courses in business planning and employing practical methodologies such as computer simulations and case studies to provide experiential learning. Consequently, experiential learning emerges as a pivotal mechanism for translating student experiences into effective learning outcomes, fostering knowledge acquisition grounded in real-world interactions. Integration of experiential learning demonstrates significant advantages for students preparing for the contemporary business landscape.

An example of this transition was observed in a study conducted at the University department of professional studies at the University of Split, where a Business planning course was revamped from traditional lecture-based teaching to experiential and practical learning methodologies. The Business planning course has significantly impacted the students by helping them reconcile the application of theoretical knowledge with practical experience.

Furthermore, the students were able to improve their practical proficiency by engaging in a methodical approach while collaborating with entrepreneurs. Consequently, students acquired a comprehension of the operational concepts of businesses. After successfully completing the course project, the students were able to effectively utilize their knowledge in real-life scenarios, enhancing their understanding of the practical aspects of education. Students were also able to enhance their personal and professional growth by participating in a well-structured education plan that emphasized the development of analytical and practical skills.

Work in the application of experiential learning needs to be constantly improved, and new models and ways of transferring knowledge to new generations of students must be sought. Last but not least, mutual cooperation and open knowledge among educators is extremely important in this process.

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ANALYSIS OF STUDENTS' VIEWS ON THE USE OF DIGITAL TECHNOLOGY AND CONTENT IN HIGHER EDUCATION INSTITUTIONS

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Abstract. With the goal of finding information about the current use of digital technologies and content in higher education institutions, a survey was conducted among students of the University of Split titled “The Use of Digital Technology in Higher Education”. The initial focus was on the analysis of responses from students in technical fields, humanities and social sciences so a comparison could be made, but responses from students in other fields were included in the overall analysis as well. The first part of the survey dealt with the current situation (which digital technologies and content are used and how often). In the second part of the survey students were asked if they found the digital technologies and content used by the teachers useful in their education. The main part of the survey asked if students think digital technology and content improve the quality of their education or not and why they think so. At the end students were also asked which way of holding lectures they would prefer. This article presents their responses, which were mostly positive towards the current amount of digital technology and content used, so the teachers could have an insight into students’ opinions on how lectures should be held.

Key words: *digital technology, digital content, higher education*

1. Introduction

In the last few decades various forms of digital technologies penetrated nearly all segments of people’s lives, including education. It is generally considered that introducing technology leads to better organisation of education and better transfer of knowledge. Furthermore, teachers are expected to not only base their lectures on content in classrooms, but also enrich them with digital content.

The authors conducted a survey titled “The Use of Digital Technologies and Content in Higher Education”, the goal of which was to get information from the students’ point of view about the use of digital technologies at their institutions and their opinion on the amount and usefulness of such content. The research had the aim to compare the responses from students in humanities and social sciences with the responses of students in technical fields which was primarily collected at the University of Split, but it reached students at other universities in Croatia. The survey consisted of three parts. A total of 220 students responded, from that 132 are in technical fields and 72 in humanities and social sciences. This paper encompasses all of the responses given.

In the first part students were asked about their course of study, faculty and their current year of study. In the second part the emphasis was on the analysis of digital content used in education and the frequency of their use. The third part addressed students' opinions on what they think about the use of digital technologies and content in education, as well as how they would prefer lectures were organised. The results of the second part of the research were discussed in paper [1], while this paper analyses in detail the responses collected in the third part of the research in which the main emphasis was on the students' opinions about how digital technologies and content improve education. Students were asked if they think digital technologies and content are represented enough at their faculty which was presented in the paper [1] as well.

The vast majority of students currently enrolled in a university program had mandatory lectures online due to the COVID-19 pandemic, either during high school or during first university years. Because of this, students were asked how they coped with the situation, as it gave them invaluable experience needed to decide how they would want lectures to be organised today and which technologies and content they find useful.

Their responses could help as guidelines for teachers in organisation of education and in presenting the course content in a way that would be most suitable for students.

2. Analysis of students' opinions on the quality of education with the use of digital technologies and content

The first question students were asked was about their opinion on the use of digital technologies and content, "Do you think the use of digital technologies and content improves the quality of lectures?". 83% of students responded positively and 13% of students were unsure. More detailed percentages are shown in Figure 1.

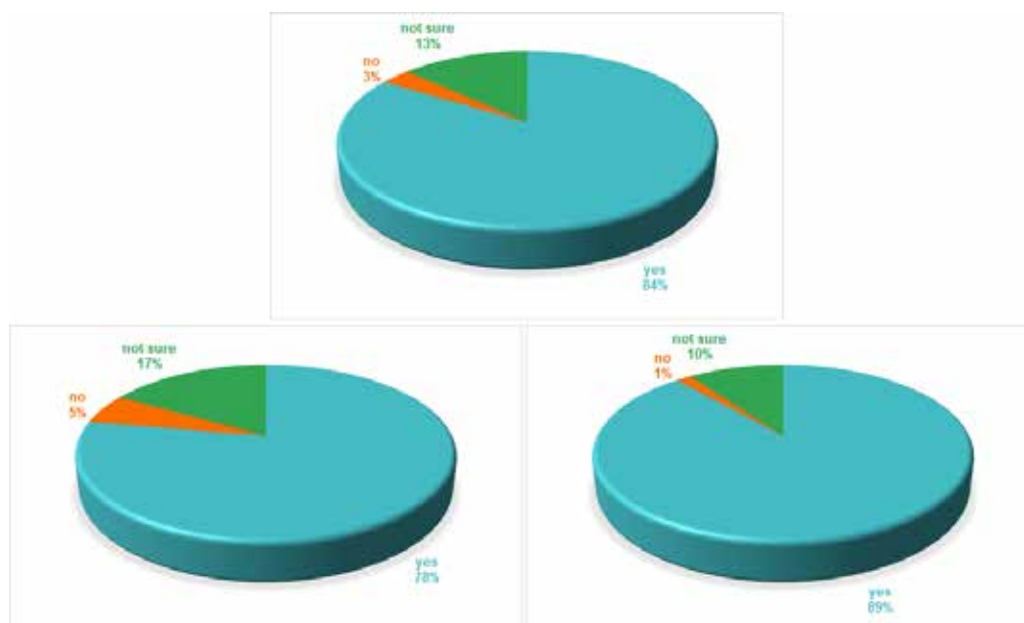


Figure 1 Use of digital technology improves education
a) all surveyed, b) humanities and social sciences students, c) students in technical fields

Next, students were asked to write their opinions on how they think digital technologies and content improve or don't improve the quality of education. The analysis of their responses is shown in the following section.

2.1. The use of digital technologies and content improves education

The students' commentary on the digital technologies and content incorporated in their higher education was mostly positive. They overwhelmingly consider PowerPoint presentations as a useful tool for professors and students alike. Students emphasised how PowerPoint presentations make the lectures more efficient. They are neater than writing on a blackboard and are a faster way for teachers to relay information to their students. If the presentations are shared with the students, they can later revise from them. That way they don't have to focus solely on writing down everything the teacher says, but can focus on the lecture better, while only writing down the main ideas. Presentations also emphasise the main points of the lecture so students know which parts they should focus on. Many pointed out that they find it easier to concentrate on lectures that utilise PowerPoint presentations precisely because of the key points written. As today's generations are used to digital technologies in most, if not all areas of their lives, they find this way of teaching more interesting as well.

Students in all fields that were focused on in the research emphasised the importance of visual representation, (e.g. in art history, with being able to see the buildings on presentations which they can't see in person). Students in technical fields pointed out that with visual aid and presentations, many complex concepts can be explained more easily. By showing concrete examples, instead of just describing them, students learn more easily and larger parts of the curriculum can be explained and learned faster. Presentations also make the lectures more systematic, better organised and more interesting to students.

Another important area of digital technologies students appreciate are learning platforms, such as Moodle and Google Classroom. They provide a virtual space where students can have all their assignments and materials needed for studying in one place. According to students, the provided materials are generally better organised and if they miss out on a lecture it is easier to make up what they missed. Some of the assignments can be done on the learning platforms, and if the presentations from the lecture are then uploaded to the site, the students can immediately catch up on the curriculum. They can access the learning platforms over any of their devices, which means they can access the materials whenever necessary.

Overall, students praised the professors who use various digital content that make lectures more interesting, diverse and interactive, such as YouTube videos that simplify certain topics or show them from a different perspective and can make visualising certain concepts easier. Students found pre-recorded lectures useful as well. Although they aren't a common practice now, some professors recorded their lectures during the COVID-19 pandemic and made them available to students even after returning to in-person lectures. Students claimed they found them useful as they could pause as necessary or watch certain parts multiple times until they understood the topic, allowing them to study at their own pace. Since students have different ways of learning they find useful, as will be discussed later on, having diverse content and technologies available can make studying more adaptable to a wider range of students. Some have pointed out that they prefer revising for exams with succinct PowerPoint presentations, while others prefer finding videos on the topic that can remind them of the most important parts.

Various digital archives and publicly available materials have enabled faster and easier access to the resources needed for studying and writing papers. If the required source isn't available online, students can at least find where they can access it. Digital technologies and content also encourage more active learning as they can elaborate on the topic in different ways and make finding relevant and up to date information easier.

Although most professors don't often use them, students found positives in short tests at the end of lectures which can give them an idea of how much they understood the material. When

short online tests or online exams are used, they make correcting the exams faster, so students can oftentimes immediately know their results.

Although it is rare since the quarantine due to the COVID-19 pandemic ended, some students have the option of participating in lectures online if they aren't able to participate in person, which makes keeping up with the curriculum easier.

2.2. The use of digital technologies and content does not improve education

Very few students commented on the negative aspects of digital technologies and content. Some had issues with lectures that were only held online as they couldn't concentrate as well as they could in a classroom, especially when those lectures weren't recorded in any way so they couldn't watch them again. There is also the issue of professors who have PowerPoint presentations, but instead of using them as guidelines they simply read from them and don't expand or further explain the material in any way. Some use digital content, such as educational videos on YouTube, as the main part of their lectures, without presenting the material themselves. Some students also noticed an overreliance on digital technologies which, in their case, made in-person lectures redundant, leading to them having to do far more work at home than they would otherwise have to. There are also the negative side effects of looking at screens for prolonged periods of time which can be tiring and for some leads to worse concentration than studying from physical materials would.

3. Different ways of giving lectures

Most students who are currently enrolled in higher education institutions at some point in their education, had to follow online lectures due to the COVID-19 pandemic. Some of them were in high school during that period, while others were already at higher education institutions. Such a sudden leap into an environment they weren't familiar with didn't have an equal impact on all of them. Some adjusted to the new situation with ease, while others had more difficulties. The results of the Matura exams showed some shortcomings in online education. That could be ascribed to how quickly the transition was done, but also to the students' ability to adapt to the new situation.

This is why the survey posed the question "How did you adapt to online lectures during the COVID-19 pandemic?". The responses are shown in Figure 2. The first graph (a) shows the responses of all participants, graph (b) shows responses from students in humanities and social sciences, while graph (c) shows responses from students in technical fields.

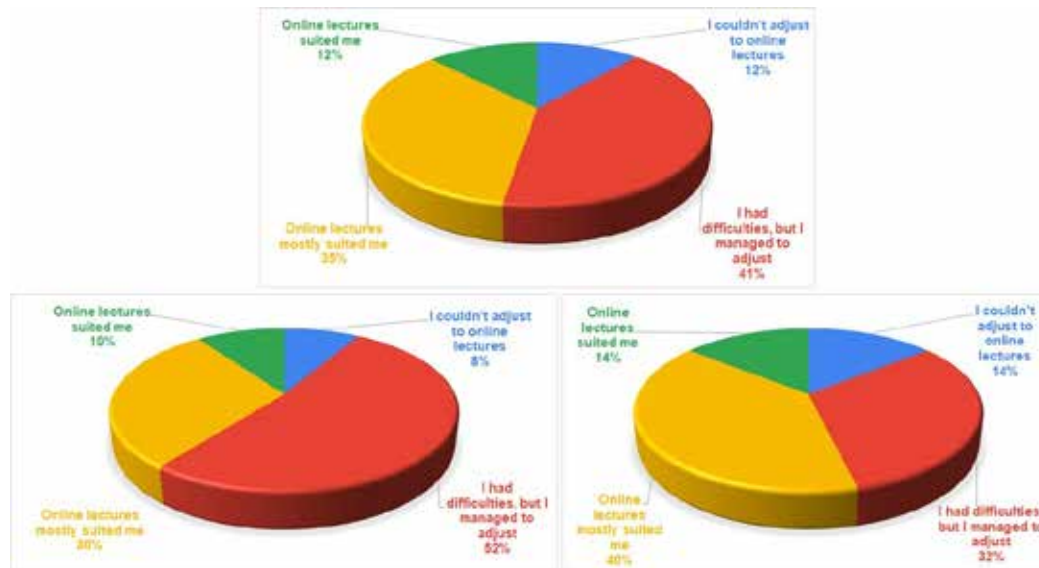


Figure 2 Adapting to online lectures during the Covid19 pandemic
a) all surveyed, b) humanities and social sciences students, c) students in technical fields

The question which could give guidelines to teachers on how to organise lectures so they suit the most students was “Which way of holding lectures would suit you the most?”. The suggested responses were “exclusively in the classroom with a teacher”, “exclusively online lectures with a teacher”, “individual studying of pre-prepared digital content followed by a discussion with a teacher in a classroom”, “attending a lecture, followed by broadening the materials with pre-prepared digital content”, and “exclusively individual studying of pre-prepared digital content”. The exact percentages of the responses are shown in Figure 3.

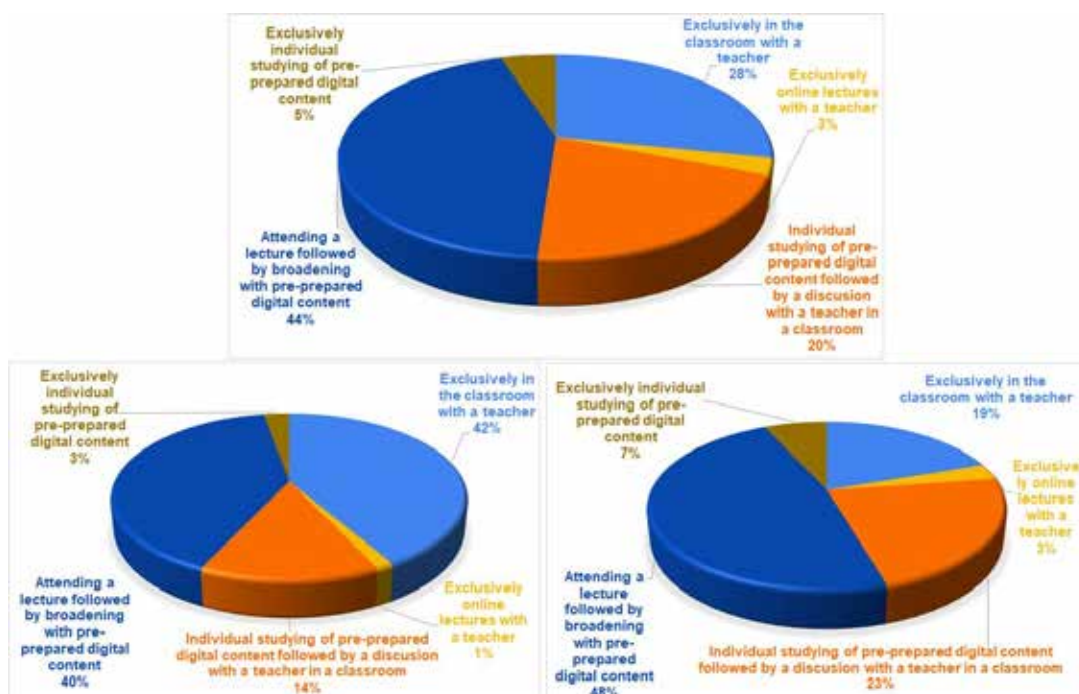


Figure 3 Ways of holding lectures students prefer
a) all surveyed, b) humanities and social sciences students, c) students in technical fields

In graph (a), which shows all the responses, more than 40% of students would prefer in-person lectures after which they could study from pre-prepared digital content. Almost 30% of students would prefer exclusively in-person lectures, while 20% of students would prefer to

study on their own first, and follow that up with a discussion in person. In technical fields, the results stay relatively similar, with slightly fewer students wanting only in-person lectures, and more students wanting in-person lectures followed by studying from digital content. When it comes to humanities and social sciences, about the same amount of students want exclusively in-person lectures and in-person lectures followed by studying at home. It is apparent that students still prefer the current kind of education, in the classroom followed by broadening the materials with some pre-prepared digital content. It is also notable that practically none of the students prefer exclusively online lectures. These results show that there is no need for substantial changes in the way lectures are delivered.

The final question of the survey asked for students' opinions on the usefulness of certain digital technologies and content in education and how often they would want them incorporated in their education. The results are shown in Figure 4.

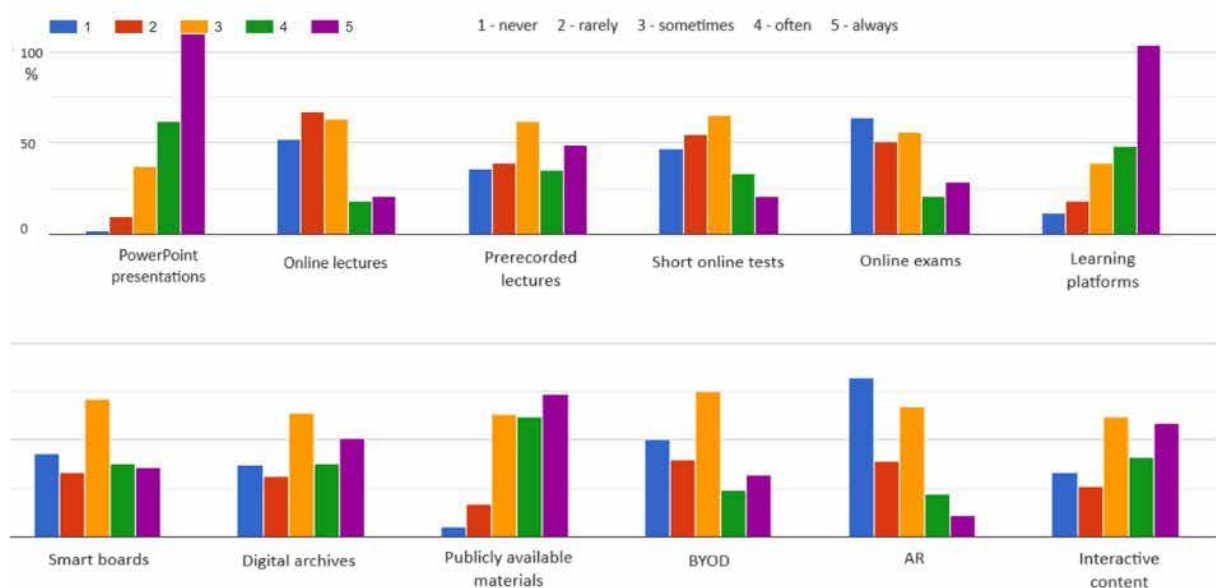


Figure 4 How often would the students like for digital technologies and content to be incorporated in their lectures

The digital technologies most people said they want incorporated in their education were PowerPoint presentations and learning platforms, which could also be seen from their comments, as many students commented on their usefulness. A lot of students want publicly available materials incorporated in their education, with a less interactive content. The opinions on prerecorded lectures, smart boards and digital archives were more or less equally divided, with some students still finding them useful. Most students don't find using their own devices and short online tests useful so they rarely want them incorporated. As for online lectures, online exams and AR most students said that they don't want them in their education for the most part.

4. Conclusion

The research held at the University of Split had the goal of analysing the amount of digital technologies and content used during lectures at higher education institutions. It also meant to compare the responses from students of humanities and social sciences with the responses from students in technical fields. The first part of the research, presented in the previous work [1], analysed how often specific technologies and content are used. The second part of the research,

which was the topic of this paper, analysed students' opinions on the use of digital technologies and content in education and whether or not it improves the education process and why. Special attention was given to the analysis of responses on how well students adjusted to online lectures during the COVID-19 pandemic and if they want that kind of lecturing incorporated more often.

Overall, students have shown they are mostly satisfied with the amount of digital technologies and content in their education, mostly expressing how useful they find PowerPoint presentations and learning platforms.

Although it might seem that today students want less and less direct contact with their teachers in their education, as the present technology allows them to research topics they find interesting on their own through various content on the internet (first and foremost through YouTube videos, but through different online courses as well), this paper has shown different results. Virtually no students at higher education institutions want exclusively online lectures. Based on their responses it is apparent they prefer in-person lectures that can be broadened with additional materials, such as various digital content.

Overall, from their responses, it can be concluded that students don't want any major changes in the educational system both in regard to the digital technologies and content incorporated, and how often they are used. This information can be useful to teachers while preparing future lectures and materials.

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PHYSICS IN THE SOUND OF THE VIOLIN

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Abstract. *The beauty of a violin's sound, apart from the skill of the musician, depends on many other factors. the characteristics of the wood from which it is built, the shape and size of its body, i.e. the resonant box, the length of the neck or strings, the varnish it is varnished with...As for the material, elasticity is a key property that enables vibration and propagation of disturbances in the form of progressive waves. Longitudinal disorder in a solid body is caused by the action of an external force, for example by the friction of a bow against a violin string. Depending on the frequency of the tone being played, the violin's sound box oscillates in different patterns. In this paper, we examined how plates made of different materials vibrate at different frequencies. Relatively thin violin-shaped panels made of aluminum, wood and Plexiglas. The plates are set to vibrate with the help of a frequency generator. When we cover the board with fine sand, the formation of standing waves on the board creates interesting shapes known as Chladni figures. Nodal lines form in areas of the board that do not oscillate. Small sand particles are collected in these places so that when the plate is vibrated, these nodal lines are easily visualized. In this way, we found out whether it really matters what material the violin's soundboard is made of, or what effect the material has on the formation of standing waves. In addition to the experiment, a computer simulation was made using MATLAB with the aim of comparing the obtained samples by physical means and simulation.*

Ključne riječi: *standing waves, Chladni figures, Matlab, violin, frequencies*

1. Introduction

Over time, music became a subject of interest for physicists as well. Physicists have studied how sound is created and which laws apply to the propagation of sound through space.

The reason for the creation of this work is the love for physics and music and a better understanding of the violin as an instrument of endless beauty of melodies.

The goal of our research is to determine how changing the frequency changes the wavelength on fixed violin strings of different thickness. We will use a thicker wire (D wire) and a thinner wire (E wire). We want to determine whether and how the speed of wave propagation depends on to change the force of wire tension. Finally, we want to see how changing the vibration frequency changes the shapes sand figures on plates of different shapes and materials.

Standing waves on a two-dimensional board create fascinating patterns, especially beautifully visible if we cover the board with sand. The shapes we get are called Chladni figures, after the physicist who first described them, Ernst Chladni.

Another reason for writing this paper is to motivate students to learn, and to understand new physical terms as well as possible. Often lessons with waves are abstract for students, it is difficult to understand all new concepts. Examples from everyday life and experiments we do ourselves help us learn new concepts better. Research has shown that the visual learning style brings much better results than any other style. We learn better by watching or doing some kind of experiment than by hearing about it. A visual learning style is known to activate different parts of the brain leading to a fuller understanding of concepts. In this case, with little equipment, an experiment can be done to help students understand new concepts.

2. Sounds, violin, music

The violin is a wooden string musical instrument with four strings. In addition to violins, the symphony orchestra contains other wooden string instruments, violas, cellos and double basses. They all have four strings, but the size of the violin is the smallest. Of course, the strings of violin and double bass are not the same. The strings of the double bass are much longer and thicker, due to which the double bass has a deeper tone. The deeper tone of the double bass also corresponds to a larger body or resonant box. Unlike double bass, the violin produces sounds of the highest frequency of all string instruments in the orchestra. In all string instruments, including the violin, sound is produced by friction between the bow and the string. The pitch changes by changing the length of the string, which is achieved by pressing the strings on the fingerboard of the violin. The hollow body of the violin is the largest surface area of the instrument and it has unique shape. The body of the violin is made up of three pieces: the front plate and the backplate with these two pieces being connected by the sides or 'ribs' of the violin. The hollow interior creates amplification and resonance when the violin is played. The bridge of the violin is a small, arch-shaped piece of wood. It is located in the middle of the body and supports the strings. When the violin strings are played the bridge carries the vibrations into the hollow body of the violin, enabling sound to resonate out. The f - shaped sound holes that have been cut into the body of the violin either side of the bridge has got function to release and project the sound oscillations out. The Sound Post is the small post which connects the front and back plates and additionally supports the structure of the instrument. It assists in carrying vibrations to the back of the violin. The Bow is a crucial tool for producing the sound on the instrument. Violinists can produce sound without the bow which is known as playing pizzicato and is achieved by plucking the strings with the fingertips. However, it's more common to play with the bow. The bow consists of a long piece of wood attached to either horse or synthetic hair. At the base of the bow is the frog, which is where violinists grip the bow and the hair is attached. The friction caused by the bow gliding over the string is what produces the vibrations that create the sound of the violin.

3. Waves and sound

In this paper, we will observe a wave spreading through the wire. In the wire, the displacement $s(x, t)$ is a function of two variables, distance x and time t . Suppose that in the source of the wave at $x = 0$ particle harmonic vibrates by law:

$$s(0,t) = A \sin \omega t = A \sin \frac{2\pi}{T} t$$

A is the amplitude of the oscillation, ω is the circular frequency, and T is the oscillation period. The wave will spread from the origin to distance x in time:

$$t = \frac{x}{v}$$

v is the velocity of the wave. When the wave reaches the position x, the wire particle will begin to oscillate at the same frequency ω , but with a phase difference relative to the oscillation of the particle in the wave source. Then displacement is:

$$s(x, t) = A \sin \omega \left(t - \frac{x}{v} \right) = A \sin 2\pi \left(\frac{t}{T} - \frac{x}{\lambda} \right)$$

By introducing the wave number k, we get the following equation:

$$s(x, t) = A \sin(\omega t - kx)$$

Where's k:

$$k = \frac{2\pi}{\lambda} = \frac{2\pi}{vT} = \frac{\omega}{v}$$

Standing waves are formed by the interference of two or more waves of equal amplitude and equal frequency, and thus of equal wavelength traveling in the same direction opposite each other. The standing wave can be easily obtained by reflecting the progressive wave on the wire at one end, going back and adding up with the intrusion wave. So, let's look at the taut wire of length L attached to both ends. When we flicker one end of the tightened wire, a wave is formed that spreads through the wire, reflects at the end, and then reflects again at the beginning and thus we get waves traveling along the wire in both directions. Next equation represents a wave that travels in the direction of the +x axis in the wire:

$$s(x, t) = A_1 \sin(\omega t - kx)$$

and a wave traveling in the opposite direction:

$$s(x, t) = A_2 \sin(\omega t + kx + \varphi)$$

According to the principle of superposition, the resulting wave motion is the sum of the above two waves:

$$s(x, t) = A_1 \sin(\omega t - kx) + A_2 \sin(\omega t + kx + \varphi)$$

If we assume that there is no phase shift, $\varphi = 0$, then the boundary conditions are:

$$s(0, t) = 0 \quad s(L, t) = 0$$

The first condition applied to the above equation gives:

$$s(0, t) = A_1 \sin(\omega t) + A_2 \sin(\omega t) = 0$$

and this can be fulfilled if $A_1 = -A_2$ So, it follows:

$$\begin{aligned} s(x, t) &= A \sin(\omega t - kx) - A \sin(\omega t + kx) \\ s(x, t) &= -2A \sin kx \cos \omega t \end{aligned}$$

$$s(x, t) = 2A \sin kx \sin \left(\omega t - \frac{\pi}{2} \right)$$

Wire harmonic vibrates, and the amplitude of oscillation depends on the position of x on the wire. At the beginning ($x=0$), as well as at the end, ($x = L$), the wire is fixed and there are nodes of the standing wave.

By applying the second marginal condition we get:

$$\sin kL = 0$$

$$kL = n\pi$$

$$k_n = \frac{n\pi}{L}$$

$$\frac{2\pi}{\lambda_n} L = n\pi \Rightarrow L = n \frac{\lambda_n}{2}$$

respectively:

$$\lambda_n = \frac{2L}{n}$$

Where n is the natural number $n = 1, 2, 3, \dots$

This means that only those standing waves will be aroused on the wire for which the length of the wire is equal to the entire number of halves of the wavelength. The frequencies of the tensioned wire, the so-called own frequencies, are determined by the velocity of wave propagation:

$$f_n = \frac{v}{\lambda_n} = n \frac{v}{2L}$$

Since the velocity of the wave in the wire depends only on the force F with which the wire is stretched and on the linear density of the wire μ :

$$v = \sqrt{\frac{F}{\mu}}$$

we can write:

$$f_n = \frac{n}{2L} \sqrt{\frac{F}{\mu}}$$

The lowest frequency ($n=1$) of wire oscillations is then:

$$f_1 = \frac{v}{2L}$$

The wire can also vibrate at other frequencies, the so-called higher harmonics. As can be seen, the thin, light and heavily tightened wire gives a high base frequency and the heavier, thick and poorly tightened wire gives a low base frequency, that is, a deep base tone.

4. Measurement

The goal of our research is to determine how changing the frequency changes the wavelength on fixed violin strings. We want to check whether and how the speed of wave propagation depends on the change in the tension force of the wire. We will also show how changing the vibration frequency changes the shapes of sand figures on plates of different shapes and materials.

In the first measurement, we will fix the violin string (model RS 1000) on one side to the electromagnetic vibrator (PASCO - vibration frequency: 10Hz to 10kHz), and on the other side to a plate with weights whose value we will not change (Picture). By changing the frequency on the frequency generator (Frederiksen - student - frequency range: 0.05Hz to 50kHz), we will observe a change in the number of half-wavelengths and nodes. We will determine the frequencies for whole values of half-wavelengths.

At the fundamental frequency of the string, only one half-wavelength appears. At resonant frequencies, we counted the half-wavelengths of the standing wave. The distance between adjacent nodes is one half of a wavelength.

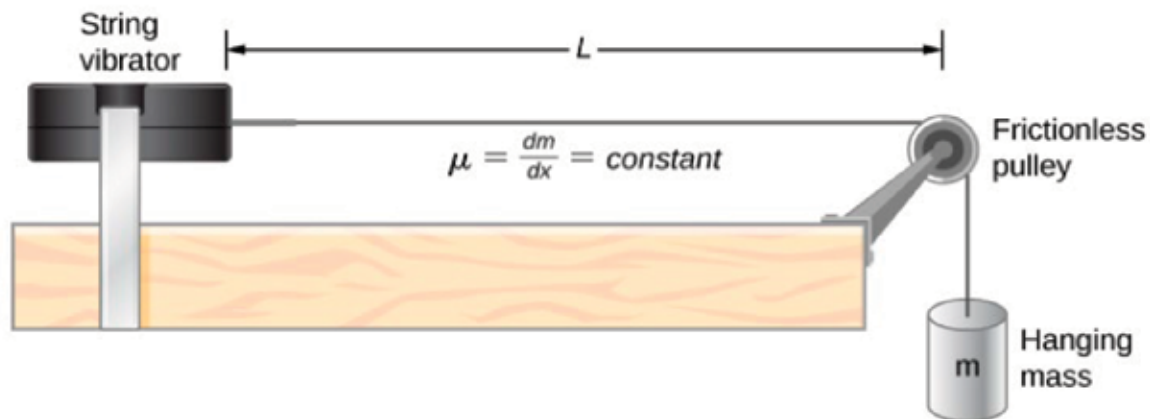


Figure 1 A lab setup for creating standing waves on a string. The string has a node on each end and a constant linear density. The length between the fixed boundary conditions is L .

If L is the length of the wire, the modes of vibration of the wire will be determined by

$$L = n \frac{\lambda}{2}, n = 1, 2, 3, \dots$$

i.e. we will calculate the wavelength λ using the relation

$$\lambda = \frac{2L}{n}$$

We weighed the wires on an analytical balance and calculated the line density μ

$$\mu = \frac{m}{L}$$

In the second part of the measurement, we will change the tension force of the wire by increasing the weight of the weights on the plate. The frequency will be constant, 60 Hz. We will record the force of tension for whole values of wavelengths. For each force of tension value, we will calculate the propagation speed, v as well as the square of its value, v^2 .

For each value force of tension, we calculated the speed of sound on the wire v

$$v = \sqrt{\frac{F}{\mu}}$$

In the third part, we will examine how figures made of fine sand on violin-shaped bases change when we change the frequency.

If we cover a flat plate with sand and direct sound waves at it, resonances occur on it. Depending on the frequency and characteristics of the material, the board segments vibrate in different directions. Nodal lines are formed in places that do not vibrate. Small sand particles will be

collected on these lines and the appearance of nodal lines will be visualized when the plate is vibrated.

We will determine whether the same figures will be formed for the same frequencies, given that the substrates are of the same shape but of different materials.

The resulting sand shapes are called Chladni figures. We will repeat the measurements several times for each material and sketch the figures.

On the electromagnetic vibrator, we fixed a flat aluminum base in the shape of a violin, 4mm thick, and sprinkled it with grains of fine sand. We changed the frequencies and observed different shapes that formed on the substrate. We took photos of the shapes, recording the vibration frequency. After that, we fixed the wood base in the shape of a violin, 4 mm wide and sprinkled it with sand and repeated the process.

5. Results

5.1. Results of measurement of resonance frequency and wavelength of vibration of violin strings

Using an electromagnetic vibrator, a frequency generator, and different types of violin strings, we examined changes in wavelengths, frequencies, and vibration speeds of the strings.

Violin strings are tuned in fifths, from the deepest to the highest – g, d¹, a¹, e² (Table 1)...

The range of tones on the violin is from G minor to some tone on the E string, which depends on the length of the neck. The longer the neck, the higher the tone. We will look at Wires E and D.

Table 1 Tones and frequencies of a tuned violin

Žica	Ton	Frekvencija
1	e ²	660 Hz
2	a ¹	440 Hz
3	d ¹	294 Hz
4	g	196 Hz

We analyzed the data for wire E, length $L = 0.5\text{m}$, from Table 2 and the graphic representation from Figure 2, we notice that the number of half-wavelengths increases with increasing frequency increases. Initial frequency for $n = 1$ is $f = 62.22\text{Hz}$, and we observed the largest number of half-wavelengths, $n = 6$ already at the frequency $f = 522.7\text{Hz}$.

Table 2 Dependence of the number of half-wavelengths on frequency for wire E0

Number of measurements	Wires	Length of the Wires; L / m	Mass of the Wires; m / kg	Mass of the vessel; m_1 / kg	Mass of cargo; m_2 / kg	Force of tension F / N	Mass per unit length of wire; $\mu / kg/m$	Number of half-wavelengths; n	λ / m	f / Hz	The mean value of the resonant frequency; f / Hz
1	D	0,5	0,00116	0,064	0,2	2,58984	0,00232	1	1,00	41,08	38,49
2										39,73	
3										38,44	
4										37,88	
5										35,31	
1								2	0,50	83,1	76,06
2										82,18	
3										80,3	
4										72,15	
5										62,55	
1								3	0,33	123,5	118,84
2										122,6	
3										120,2	
4										115,5	
5										112,4	
1								4	0,25	162,7	155,44
2										162,5	
3										152,4	
4										150,5	
5										149,1	
1								5	0,20	207,4	202,34
2										204,1	
3										202,5	
4										200,5	
5										197,2	
1								6	0,17	253,8	246,98
2										250,3	
3										245,7	
4										244,8	
5										240,3	

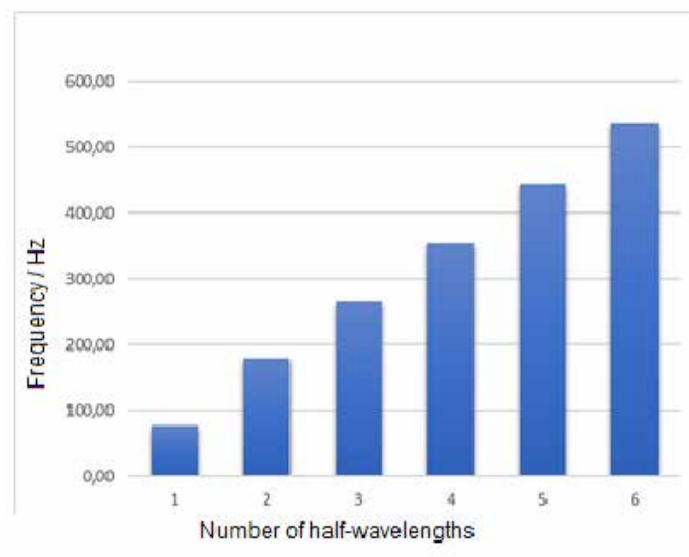


Figure 2 Graph of dependence of frequency and number of half-lengths for wire E

We analyzed the data for wire D, length $L = 0.5\text{m}$, from Table 3 and the graphic representation from Figure 3, we notice that the number of half-wavelengths increases with increasing frequency increases. Initial frequency for $n = 1$ is $f = 35.31\text{Hz}$, and we observed the largest number of half-wavelengths, $n = 6$ already at the frequency $f = 240.3\text{Hz}$.

Table 3 Dependence of the number of half-wavelengths on frequency for wire D

Number of measurements	Wires	Length of the Wires; L / m	Mass of the Wires; m / kg	Mass of the vessel; m_1 / kg	Mass of cargo; m_2 / kg	Force of tension;	Mass per unit length of wire;	Number of half-wavelengths;	λ / m	f / Hz	The mean value of the resonant frequency; f / Hz
1	E	0,5	0,000 41	0,064	0,2	2,58 984	0,000 82	1	1,00	86,4	77,51
2										81,6	
3										79,6	
4										77,73	
5										62,22	
1								2	0,50	189,5	178,70
2										188,1	
3										175,02	
4										172,5	
5										168,4	
1								3	0,33	270,3	265,04
2										269,6	
3										263,7	
4										261,2	
5										260,4	
1								4	0,25	356,8	353,88
2										356,4	
3										353,6	
4										352	
5										350,6	
1								5	0,20	448,8	443,82
2										446,9	
3										443,8	
4										442,8	
5										436,8	
1								6	0,17	547,2	535,92
2										543,9	
3										538,5	
4										527,3	
5										522,7	

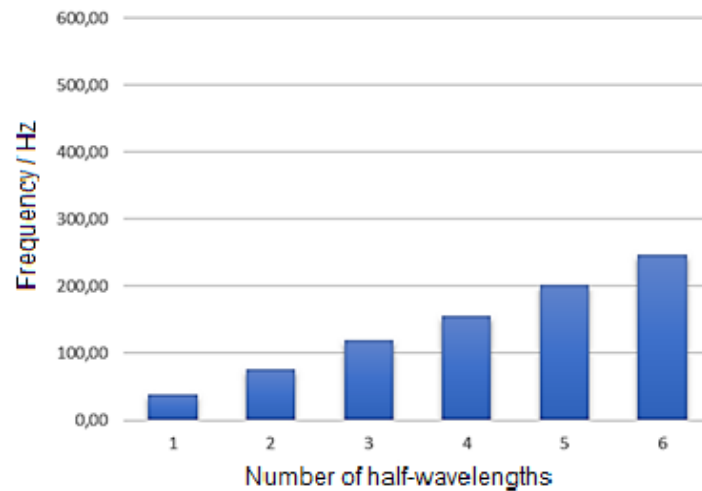


Figure 3 Graph of dependence of frequency and number of half-lengths for wire D

5.2. The results of measuring the speed of wave propagation on violin strings

We analyzed the data for wire E from Table 4 and the graphic representation from Figure 4. We observe that for an arbitrarily chosen frequency $f = 60\text{Hz}$, by increasing the mass of the weights in the container, i.e. by increasing the force of tension, the vibration speed of the wire also increases. By increasing the mass of the weights in the pelvis, i.e. by increasing the force of tension of the wire, the number of half-wavelengths decreases, which means that the wavelength increases.

The lowest speed $v = 27.89$ was for $n = 2$, at force of tension $F = 0.64\text{N}$, and the highest speed $v = 60.31$, for $n = 1$, at force of tension $F = 2.98\text{N}$.

Table 4 Dependence of the wave speed on wire E on the force of the tension of the wire

Number of measurements	Wires	Length of the Wires : L / m	Mass of the Wires; m / kg	Mass of the vessel; m_1 / kg	Mass per unit length of wire; $\mu / kg/m$	Number of half wavelength; n	λ / m	f / Hz	Mass of cargo; m_2 / kg	Force of tension; F / N	Speed; $v / m/s$	Square of speed; $v^2 / (m/s)^2$	The mean value of the force of tension; F / N	The mean value of square of speed; $v^2 / (m/s)^2$
1	E	0,5	0,00041	0,064	0,00082	1	1	60	0,22	2,79	58,29	3397,61	2,82	3438,29
2									0,225	2,84	58,80	3457,43		
3									0,232	2,90	59,51	3541,17		
4									0,24	2,98	60,31	3636,88		
5									0,2	2,59	56,20	3158,34		
1						2	0,5		0,005	0,68	28,73	825,48	0,65	791,98
2									0,002	0,65	28,10	789,59		
3									0,001	0,64	27,89	777,62		
4									0,001	0,64	27,89	777,62		
5									0,002	0,65	28,10	789,59		

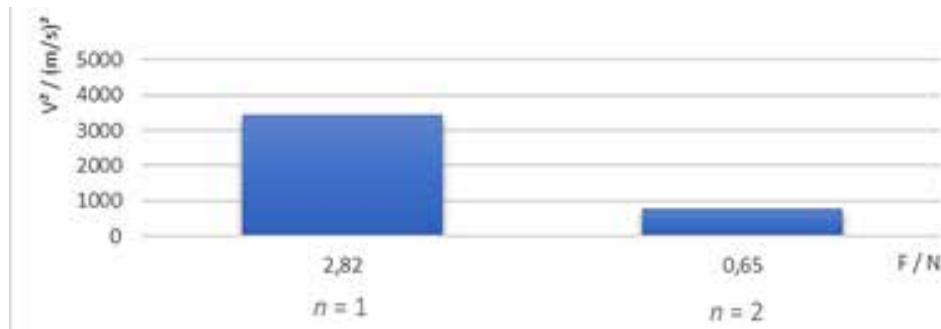


Figure 4 Graphic representation of the dependence of the square of the speed on the force of tension for wire E

We analyzed the data for wire D from Table 5 and the graphic representation from Figure 5, we observe that for an arbitrarily chosen frequency $f = 60\text{Hz}$, increasing the mass of the weights in the pelvis, i.e. increasing the force of tension, also increases the vibration speed of the wire. By increasing the mass of the weights in the pelvis, i.e. by increasing the force of tension of the wire, the number of half-wavelengths decreases, which means that the wavelength increases. The lowest speed $v = 18.28$ was for $n = 3$, at tension force $F = 0.77\text{N}$, and the highest speed $v = 59.03$, for $n = 1$, at force of tension $F = 8.08\text{N}$.

Table 5 Dependence of the wave speed on wire D on the force of the tension of the wire

Number of measurements	Wires	Length of the Wires ; L / m	Mass of the Wires; m / kg	Mass of the vessel; m _v / kg	Mass per unit length of wire; μ / kg/m	Number of half-wavelength; n	λ / m	f / Hz	Mass of cargo; m _c / kg	Force of tension; F / N	Speed; v / m/s	Square of speed; v ² / (m/s) ²	The mean value of the force of tension; F / N	The mean value of square of speed; v ² / (m/s) ²
1	D	0,5	0,00116	0,064	0,00232	1	1	60	0,75	7,99	58,67	3441,96	8,03	3463,10
2									0,755	8,03	58,85	3463,10		
3									0,76	8,08	59,03	3484,24		
4									0,75	7,99	58,67	3441,96		
5									0,76	8,08	59,03	3484,24		
1						2	0,5		0,15	2,10	30,08	904,89	2,01	866,83
2									0,14	2,00	29,37	862,60		
3									0,16	2,20	30,78	947,17		
4									0,125	1,85	28,27	799,18		
5									0,13	1,90	28,64	820,32		
1						3	0,333		0,015	0,77	18,28	334,05	0,81	350,12
2									0,02	0,82	18,85	355,19		
3									0,022	0,84	19,07	363,65		
4									0,017	0,79	18,51	342,50		
5									0,02	0,82	18,85	355,19		

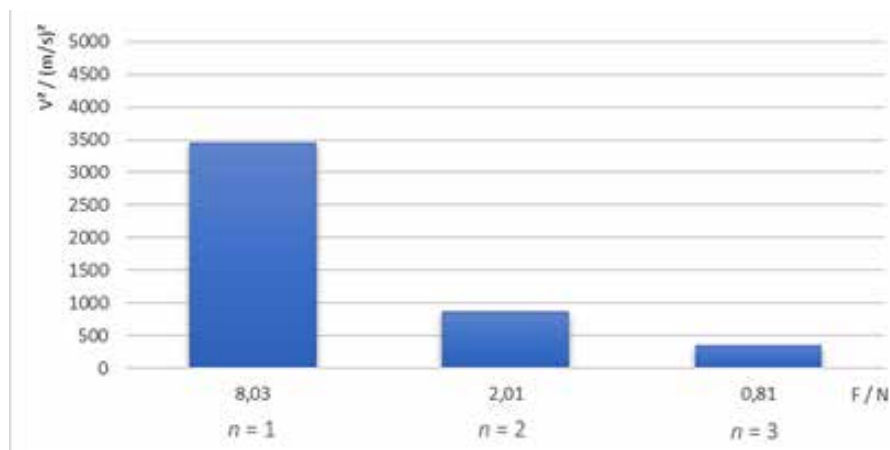


Figure 5 Graphic representation of the dependence of the square of the speed on the force of tension for wire D

5.3. Figures made of sand on bases made of different materials in the shape of a violin

We used wooden and aluminum bases. We noticed that by increasing the frequencies, figures with more fine details are created.

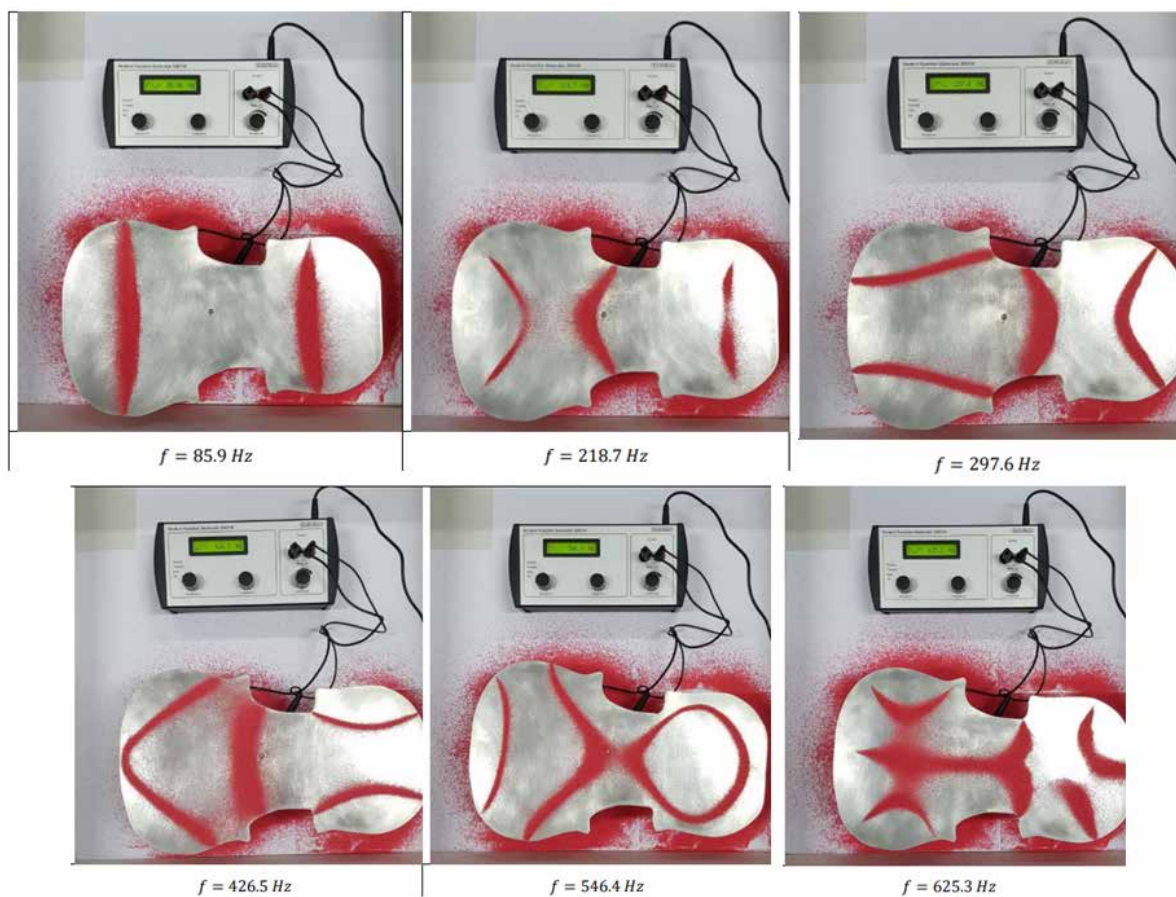


Figure 6 Figures made of sand on aluminum base in the shape of a violin for different frequencies

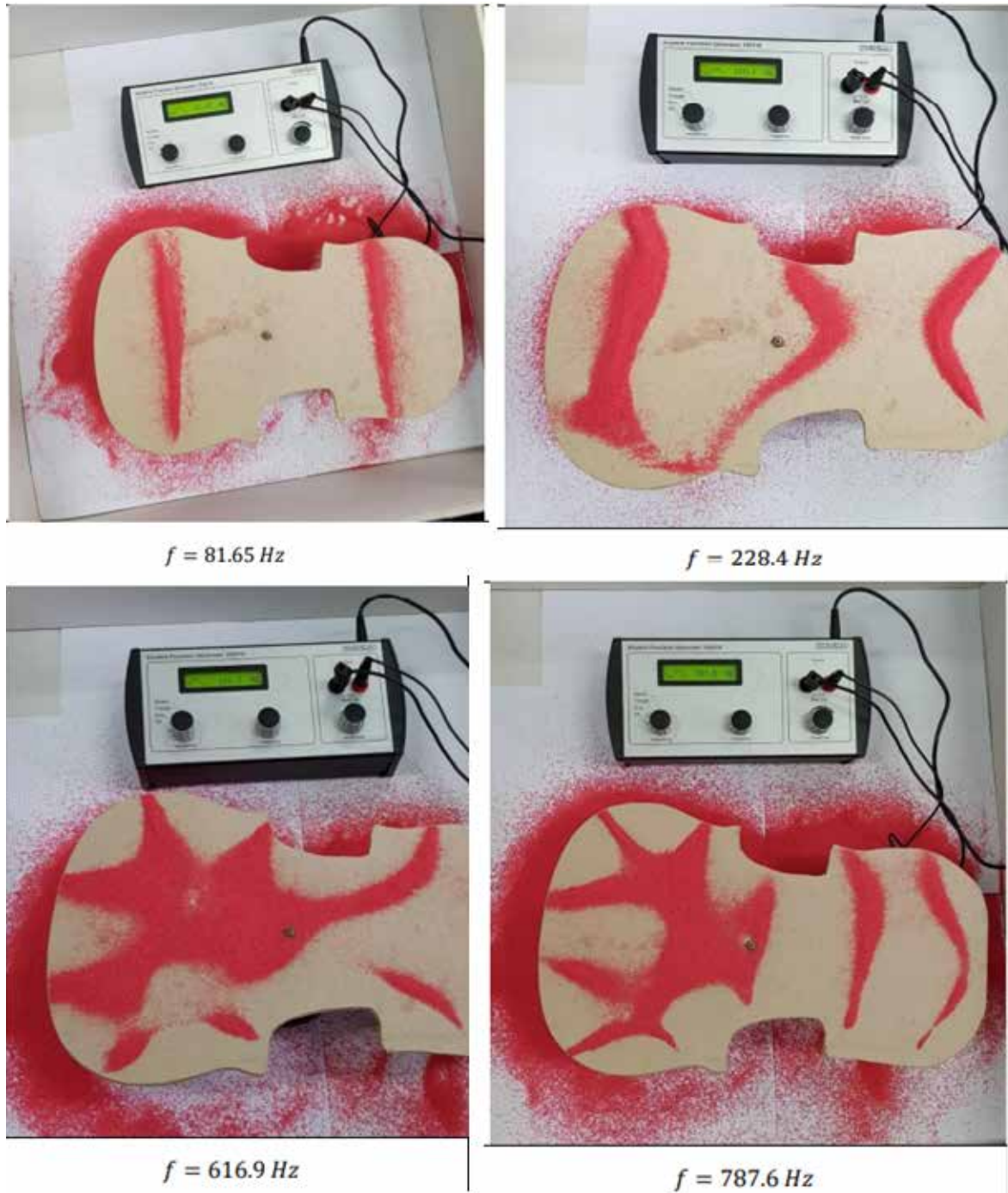


Figure 7 Figures made of sand on wooden base in the shape of a violin for different frequencies

6. Conclusion

In this paper, using simple equipment, we examined the behavior of two violin string at different frequencies. By changing the frequencies, the number of half-wavelengths also changed, i.e. by increasing the frequency, the number of half-wavelengths increased. We have shown that increasing the frequency decreases the wavelength.

Also, at a constant frequency, the vibration speed of the wire changed by changing the tension force. A higher tension in the string caused a higher rate of oscillation. Thicker wires (wire D) have a lower frequency, and thinner wires (wire E) have a higher frequency. Because thicker wires have a higher line density, the speed of the wave on the wire decreases for a certain tension, and the result is a lower frequency.

We observed the creation of different forms, which are called Chladni figures. Emphasis is placed on the experiment and the analysis of the thus obtained samples on two violin-shaped plates. One panel was wooden and the other aluminum.

A simulation was also made in the MATLAB program, using existing functions for solving partial differential equations. The results obtained in this way did not match our experiment. The program in Matlab was not precisely created. Maybe it could be modeled in other ways that would potentially yield better results.

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FROM ASHES TO TREES: A MATHEMATICAL MODEL OF FOREST RESTORATION IN MEDITERRANEAN LANDSCAPES

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Abstract. This paper presents how mathematical methods and techniques familiar to the students of Electrical engineering, Mechanical engineering and Computing at the University Department of Professional Studies, University of Split can effectively address environmental challenges. Demonstrating to students the application of their knowledge acquired during their studies is important in fostering their awareness about the significance of sustainable development. Utilizing mathematical modelling in real-world ecological dynamics, the paper delves into the concept of sustainable development in the context of post-wildfire forest regeneration in Dalmatia and Mediterranean. The motivation stems from the recurring forest fires that devastate these regions, attributed to a combination of global warming and local factors. The focus lies on the gradual recovery of pine forests across the slopes of Mosor, Kozjak, and Poljička planina, prompting inquiries into the time frame and potential extent of regeneration, particularly concerning the challenges posed by eroded and degraded karst soil. To address these questions, the study employs the well-established Chapman-Richards model, a tool widely used in forestry to forecast forest growth trajectories. The parameters of Chapman-Richards' model are determined using the least squares method, a numerical technique taught to the students. Additionally, two improvements of the model are implemented. The model is tested on empirical data collected from field measurements of young Aleppo pine heights on locations previously affected by forest fires to enhance its practical relevance. Using data regarding young Aleppo pine underscores the role of pine species, particularly the Aleppo pine, in the reforestation and sustainable development of the karst region of Dalmatia. Furthermore, it fosters critical examination of the true factors behind wildfires, which are frequently misattributed to the Aleppo pine in the media, contrary to the opinion of forestry experts.

Key words: *sustainable development, mathematical modelling, Chapman-Richards model, forest growth*

1. Introduction

Summer after summer, series of wildfires sweep the coast of Croatia, most often in Dalmatia. Citizens and visitors of Split were particularly alarmed in the summer of 2017, when the flames started near Tugare village, lasted several days, and reached the outskirts of Split, burning 4500 ha and leaving the hillsides of surrounding mountains charred and barren (Zečić, 2017). Considering the poor maintenance of forests, the overgrown agricultural areas in Dalmatia, and the general neglect of homesteads and the surroundings of settlements, such a fire burns mostly

everything on its way to the very border of roads and houses. The only tree species that can inhabit a stone-barren fire-ravaged area of eroded karst are the pines, especially Aleppo pine (*Pinus halepensis* Mill). The fortunate circumstance is that it spreads very quickly, so in a few years the young trees may abundantly green the black slopes, at least until the next wildfire.

Being a pyrophyte species, the Aleppo pine regenerates and spreads with the help of fire. When the old stand is destroyed by the fire, young trees sprout very quickly at the fire site from the seeds, whose cones can scatter on large distance. Thus, the pine swiftly regrows the burnt area and the forest starts to recover very quickly. If the Aleppo pine forest was destroyed by fire together with a neighbouring site of some other regional vegetation, for example, a holm oak forest, or a garigue, the pines will spread to that site too (Trinajstić, 1993).

But just for the same reason, due to large amount of resin, dead lower branches and needles, Aleppo pine stands are very flammable, their canopies, when caught by fire are said to be shooting burning cones 60 meters away, thus spreading the flames further. In recent years there have been several media attacks on Aleppo pines, treating them as invasive species, responsible for increasingly frequent fires in Dalmatia, e.g. Šarac (2017). Also, in Juras-Slamić (2022), a retired agronomist was quoted, saying that: „In 1960, Dalmatia had a million sheep. And then when a fire broke out, 2.7 ha would burn. In 1998, Dalmatia had only 200000 sheep, but then 47 ha burned in one fire... And it will continue to be like that because there is no real prevention... There is no grazing, and no maintenance of neglected agricultural surfaces, infested by Aleppo pine... The cause of frequent and annual fires in Dalmatia is the Aleppo pine.“

Forestry experts have a very different opinion. Vidulić (2019) in his article elaborates on the long-term damage caused by the recent unprofessional cutting of Aleppo pines in Marjan park forest.

2. A brief history of Croatia's coastal karst

Dinaric karst is the term used for the southern side of the Dinaric Mountains, sloping towards the Adriatic Sea, built mostly from the limestone rocks, with very little surface water. Karst features of bare white rocks and rare vegetation are a familiar sight in Dalmatia, although it wasn't always like that. Researches show the region has been densely vegetated some 3500 years ago, when the first human settlers arrived. Building of houses and fortifications, war campaigns and constant migrations, farming, stock breeding, ore smelting, ship building, together with increase in population and rising industrial demands with no attitude to sustainability at all have reduced the heavily wooded landscape to a bare rocky desert, especially in 18th and 19th century. Although available biological data suggest that originally 90% of the coastal karst of Croatia was covered by forests, Austrian sources from 1876. categorize 93% of it as bare, unproductive land, with the prospect of further forest diminishment of 1% every year. Kranjc (2009) gives a brief history of deforestation and desertification of Dinaric karst and he bitterly concludes that “man is the main factor both at destroying his natural environment and at restoring it. The man is capable of both.”

Some attempts have been made by Austrian authorities in late 19th century to start the reforestation of the karst by pines, mostly the hinterland of Trieste and Rijeka. But, it was not earlier than 1929. that the newly formed Kingdom of Yugoslavia issued the State's Act on Forest, with the essential prescription: “...all deforested lands especially on karst have to be classified in the period of 10 years with the aim to be afforested as soon as possible.” Matić et al. (2011) estimate that 14808 ha of Croatian karst were afforested in the Kingdom of Yugoslavia, of which about 15% were successful. As forestry profession gained knowledge and experience, systematic reforestation slowly spread over the entire Dinaric karst and continued into the

1950s. Socialist Yugoslavia saw massive actions of reforestation immediately after the end of the World War II: between 1946 and 1956, 11150 ha of Croatian karst were afforested, with 62% success. From these times on, reforestation was mainly the duty of the forestry organization and of the forest owners. Sustainable management of the forests and decline in agricultural activity in the Dinaric karst helped some of the formerly devastated terrain start to slowly recover on its own with the growth of shrubs and thickets, thus being slowly transformed into forests (Kranjc, 2009).

In afforestation of bare karst Matić et al. (2011) view the pines as the pioneering tree species, especially Aleppo pine and black pine (*Pinus nigra*). Under the pines the soil is gradually formed, taking on characteristics that lead to the appearance of elements of autochthonous vegetation as an understory. The pine gradually disappears and the autochthonous trees, mostly oaks, prevail. This happens over a period of 60 to 80 years or more, depending on the scale of former devastation.

As more and more suburban and rural areas in Republic of Croatia become construction, business or tourist zones, slovenly planned and often with inadequate infrastructure, the sensitive karst ecosystem is threatened again. Matić et al. (2011) complain that about 1000 ha of forest land afforested annually in Croatia, is shockingly symbolic, compared to an average of 10000 ha of forest cultures and different degraded stages of autochthonous forest vegetation which perish in fires every year on our coast. Years of neglecting forest maintenance, along with global warming only add to the problem.

3. Mathematical modelling of forest recovery in coastal Croatia

The vast majority of the present-day forests in coastal Croatia exists for less than 100 years. Good part of them are pine forests, either planted to pioneer, or spread by natural means. Foresters agree that Aleppo pine is the first-class species to create forest on degraded Mediterranean karst on altitudes under 500 m, on the higher altitudes black pine is preferred.

Prgin (2005) praises Aleppo pine for its flexibility, ability to spread fast and regenerate quickly upon burnt areas. Opposing the media incitement, he states that well-tended Aleppo pine forest is a natural barrier to the spreading of forest fire. Regretfully, without that treatment Aleppo pines often tend to perish in fires without previously creating conditions for the return of the autochthonous vegetation. The soil then degrades further, and the process starts again with the new generation of the pine sprouts.

Trinajstić (1993) asserts: “On the basis of previous research on the surface of the Aleppo pine forest that perished in the fire, we can conclude that forests regenerate themselves with seeds from fertile old trees that were consumed by the fire. But if a new fire engulfs such a young forest (less than 10 years old), pine is eliminated from the site for a long time, and the distinct kind of maquis sets in as a stable and long-term development stage. In terms of further succession in the direction of the development of forest vegetation, the very occurrence of Aleppo pine, as well as holm oak is unlikely, so if reforestation is needed, such surfaces need human intervention.”

The question arises: When observing the recovery of a fully burned, fertile Aleppo pine stand several years after the fire, and tracking the growth dynamics of young pines, how long will it take them to grow again, and to what height?

In this study, the least squares method will be utilized to seek answers to the aforementioned question. This method falls under the Applied and numerical mathematics course, which is attended by students of Electrical engineering, Mechanical engineering and Computing at the

University Department of Professional Studies, University of Split. The application of the least squares method demonstrates to students how environmental challenges such as post-wildfire forest regeneration in Dalmatia and Mediterranean regions can be effectively addressed by integrating mathematical modelling with real-world ecological dynamics and using mathematical methods and techniques familiar to them.

3.1. Mathematical model of forest growth

The Chapman-Richards growth model has been in use in biology for the past five decades. Coble and Young (2006) testify to its remarkable reliability for predicting the growth of not only individual organisms but also entire populations like plants, fish, and bacteria. In forestry, it is usually used to predict the average growth of the dominant trees in the forest to monitor the quality of the forest community (Pommerening, 2017). In the context of this paper, the tallest trees are considered to be the dominant ones.

Chapman – Richards equation for the average height $f(x)$ of the Aleppo pines x years after the fire is

$$f(x) = A(1 - Be^{-Cx})^D. \quad (1)$$

The constant $A > 0$ is the limit value of the tree height and the constant $B = 1 - \left[\frac{f(0)}{A} \right]^{\frac{1}{D}}$ depends on the initial height of the tree $f(0)$ at the moment $x = 0$. The moment $x = 0$ is the moment when the previous fire has been put out, when the forest area is burnt to the ground, that is $f(0) = 0$, $B = 1$. The constants C and D depend on the tree species and on the habitat quality.

The recovery time of the forest, as well as the parameters corresponding to the new forest in the given habitat should be estimated based on the heights of the Aleppo pine saplings in the first years after the fire. As the graph of the function $f(x)$ somewhat resembles the Greek letter sigma it is usually called the sigmoid curve.

The heights of the tallest, presumably the oldest, saplings of the Aleppo pine are measured on burned areas of approximate altitude, similar properties and orientation, and points $(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$ are obtained. The first coordinate represents the age of the sapling, i.e. the time elapsed since the fire expressed in years, and the second its height in meters.

The deviation of the points $(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$ from the graph of the function $f(x)$ can be described as the sum of the squares of the deviations of the function values $f(x_k)$ from the ordinate of the points y_k ,

$$S(A, C, D) = \sum_{k=1}^n [f(x_k) - y_k]^2 = \sum_{k=1}^n \left[A(1 - e^{-Cx_k})^D - y_k \right]^2. \quad (2)$$

According to the least squares method, $S(A, C, D)$ should be minimized in order to determine the most favourable approximation of the given shape for the points, that is the global minimum of the function of three variables $S(A, C, D)$ for $(A, C, D) \in \langle 0, +\infty \rangle^3$ should be determined.

Given that the set $\langle 0, +\infty \rangle^3$ is open, the problem is reduced to searching for the “most optimal” local minimum. According to the necessary conditions of the local extrema, partial derivatives of the sum of the squares of the deviations (2) must be equated with zero. Partial derivatives of

$S(A, C, D)$ are

$$\begin{aligned}\frac{\partial S}{\partial A}(A, C, D) &= 2 \sum_{k=1}^n \left[A(1 - e^{-Cx_k})^D - y_k \right] (1 - e^{-Cx_k})^D \\ \frac{\partial S}{\partial C}(A, C, D) &= 2AD \sum_{k=1}^n \left[A(1 - e^{-Cx_k})^D - y_k \right] (1 - e^{-Cx_k})^{D-1} x_k e^{-Cx_k} \\ \frac{\partial S}{\partial D}(A, C, D) &= 2A \sum_{k=1}^n \left[A(1 - e^{-Cx_k})^D - y_k \right] (1 - e^{-Cx_k})^D \ln(1 - e^{-Cx_k}).\end{aligned}\quad (3)$$

Partial derivatives (3) are equated with zero and the following system of equations is obtained

$$\begin{aligned}\sum_{k=1}^n \left[A(1 - e^{-Cx_k})^D - y_k \right] (1 - e^{-Cx_k})^D &= 0 \\ \sum_{k=1}^n \left[A(1 - e^{-Cx_k})^D - y_k \right] (1 - e^{-Cx_k})^{D-1} x_k e^{-Cx_k} &= 0 \\ \sum_{k=1}^n \left[A(1 - e^{-Cx_k})^D - y_k \right] (1 - e^{-Cx_k})^D \ln(1 - e^{-Cx_k}) &= 0\end{aligned}\quad (4)$$

Since (4) is system of three nonlinear equations with three unknowns it can be solved numerically, using Newton's method, similar to the one-dimensional case. If following notation is used

$$\begin{aligned}g_1(A, C, D) &= \sum_{k=1}^n \left[A(1 - e^{-Cx_k})^D - y_k \right] (1 - e^{-Cx_k})^D \\ g_2(A, C, D) &= \sum_{k=1}^n \left[A(1 - e^{-Cx_k})^D - y_k \right] (1 - e^{-Cx_k})^{D-1} x_k e^{-Cx_k} \\ g_3(A, C, D) &= \sum_{k=1}^n \left[A(1 - e^{-Cx_k})^D - y_k \right] (1 - e^{-Cx_k})^D \ln(1 - e^{-Cx_k})\end{aligned}\quad (5)$$

the Jacobi matrix of system (4) is

$$J(A, C, D) = \begin{bmatrix} \frac{\partial g_1}{\partial A}(A, C, D) & \frac{\partial g_1}{\partial C}(A, C, D) & \frac{\partial g_1}{\partial D}(A, C, D) \\ \frac{\partial g_2}{\partial A}(A, C, D) & \frac{\partial g_2}{\partial C}(A, C, D) & \frac{\partial g_2}{\partial D}(A, C, D) \\ \frac{\partial g_3}{\partial A}(A, C, D) & \frac{\partial g_3}{\partial C}(A, C, D) & \frac{\partial g_3}{\partial D}(A, C, D) \end{bmatrix}.\quad (6)$$

Newton method starts with an initial approximation $v_0 = \begin{bmatrix} A_0 \\ C_0 \\ D_0 \end{bmatrix}$ and creates a sequence of approximations $v_k = \begin{bmatrix} A_k \\ C_k \\ D_k \end{bmatrix}$ using the iteration formula

$$v_{k+1} = v_k - J^{-1}(A_k, C_k, D_k) \cdot \begin{bmatrix} g_1(A_k, C_k, D_k) \\ g_2(A_k, C_k, D_k) \\ g_3(A_k, C_k, D_k) \end{bmatrix}, k \in \mathbb{N}_0. \quad (7)$$

For the convergence of that sequence it is necessary but not sufficient that the Jacobi matrix is regular in each step. A detailed analysis of sufficient convergence conditions is not the subject of this paper, but it can be said that the procedure is more likely to converge for the initial approximation in the vicinity of the minimum. In addition, the data $(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$ may contain errors, so careful consideration of initial approximation may be needed in order for Newton's method to converge.

In choosing the initial approximation $v_0 = \begin{bmatrix} A_0 \\ C_0 \\ D_0 \end{bmatrix}$, following procedure may be useful. If the

approximation $f(x)$ is good enough, for every $i \in \{1, 2, \dots, n-2\}$ the following should hold

$$\begin{aligned} y_i &\approx f(x_i) = A(1 - e^{-Cx_i})^D \\ y_{i+1} &\approx f(x_{i+1}) = A(1 - e^{-Cx_{i+1}})^D \\ y_{i+2} &\approx f(x_{i+2}) = A(1 - e^{-Cx_{i+2}})^D. \end{aligned} \quad (8)$$

From (8) follows

$$A \approx \frac{y_i}{(1 - e^{-Cx_i})^D} \quad (9)$$

$$\ln\left(\frac{y_{i+1}}{y_i}\right) \approx D \ln\left(\frac{1 - e^{-Cx_{i+1}}}{1 - e^{-Cx_i}}\right) \quad (10)$$

$$\ln\left(\frac{y_{i+2}}{y_{i+1}}\right) \approx D \ln\left(\frac{1 - e^{-Cx_{i+2}}}{1 - e^{-Cx_{i+1}}}\right). \quad (11)$$

Expressing D from (10),

$$D \approx \frac{\ln\left(\frac{y_{i+1}}{y_i}\right)}{\ln\left(\frac{1 - e^{-Cx_{i+1}}}{1 - e^{-Cx_i}}\right)}, \quad (12)$$

and substituting it in (11),

$$\ln\left(\frac{y_{i+2}}{y_{i+1}}\right) \ln\left(\frac{1 - e^{-Cx_{i+1}}}{1 - e^{-Cx_i}}\right) \approx \ln\left(\frac{y_{i+1}}{y_i}\right) \ln\left(\frac{1 - e^{-Cx_{i+2}}}{1 - e^{-Cx_{i+1}}}\right), \quad (13)$$

equation

$$\ln\left(\frac{y_{i+2}}{y_{i+1}}\right)\ln\left(\frac{1-e^{-Cx_{i+1}}}{1-e^{-Cx_i}}\right)=\ln\left(\frac{y_{i+1}}{y_i}\right)\ln\left(\frac{1-e^{-Cx_{i+2}}}{1-e^{-Cx_{i+1}}}\right) \quad (14)$$

is obtained.

Equation (14) may be solved graphically or numerically, for instance using the one-dimensional bisection method, and its solution may be used as the initial value C_0 of the parameter C .

After that, initial approximation of the parameter D is obtained by substituting C_0 in (12),

$$D_0 = \frac{\ln\left(\frac{y_{i+1}}{y_i}\right)}{\ln\left(\frac{1-e^{-C_0x_{i+1}}}{1-e^{-C_0x_i}}\right)}, \text{ and finally initial values of the parameter } A \text{ substituting } C_0 \text{ and } D_0$$

$$\text{in (9), } A_0 = \frac{y_i}{(1-e^{-C_0x_i})^{D_0}}.$$

The initial approximation may also be chosen by experience, or by studying the literature. For example, when trying to establish an initial approximation of the maximum height of the Aleppo pine, the information available on the internet is that the Aleppo pines with heights of up to 30 m have been recorded and that could help. On the other side, an analysis of the Aleppo pines from 80 to 100 years old on the northern side of the Marjan park forest in Split shows that few exceed 20 m in height which may be a consequence of the scarcity and dryness of the soil and insufficient insolation. On the Adriatic islands, the average height of adult pine trees by the sea is approximately about 18 meters.

However, arguments based on botany and experience are no guarantee that Newton's method will converge for specific data.

3.2. Two improvements of the model

In order to refine the model under consideration, two improvements are suggested. Those two improvements are related to the Jacobi matrix implemented in the Newton method.

To start with, since computing the inverse matrix at each iteration step is slow, expensive, and numerically unstable, it is replaced by solving the system, so instead of computing

$$w_k = J^{-1}(A_k, C_k, D_k) \cdot \begin{bmatrix} g_1(A_k, C_k, D_k) \\ g_2(A_k, C_k, D_k) \\ g_3(A_k, C_k, D_k) \end{bmatrix} \quad (15)$$

it is recommended to solve the linear system

$$J(A_k, C_k, D_k)w_k = \begin{bmatrix} g_1(A_k, C_k, D_k) \\ g_2(A_k, C_k, D_k) \\ g_3(A_k, C_k, D_k) \end{bmatrix} \quad (16)$$

and after that $v_{k+1} = v_k - w'_k$.

Secondly, as it is expected that the calculation of the partial derivatives of the functions $g_i(A, C, D)$ needed for the Jacobi matrix would be a sluggish and tedious job, the definition of the partial derivative is used. Instead of the actual Jacobi matrix its approximate value is calculated as

$$J_\varepsilon(A, C, D) = \frac{1}{\varepsilon} \begin{bmatrix} g_1(A + \varepsilon, C, D) - g_1(A, C, D) & g_1(A, C + \varepsilon, D) - g_1(A, C, D) & g_1(A, C, D + \varepsilon) - g_1(A, C, D) \\ g_2(A + \varepsilon, C, D) - g_2(A, C, D) & g_2(A, C + \varepsilon, D) - g_2(A, C, D) & g_2(A, C, D + \varepsilon) - g_2(A, C, D) \\ g_3(A + \varepsilon, C, D) - g_3(A, C, D) & g_3(A, C + \varepsilon, D) - g_3(A, C, D) & g_3(A, C, D + \varepsilon) - g_3(A, C, D) \end{bmatrix} \quad (17)$$

for sufficiently small $\varepsilon > 0$.

Hence, in the iteration of Newton's method, the linear system

$$J_\varepsilon(A_k, C_k, D_k) w'_k = \begin{bmatrix} g_1(A_k, C_k, D_k) \\ g_2(A_k, C_k, D_k) \\ g_3(A_k, C_k, D_k) \end{bmatrix} \text{ is solved for some } \varepsilon > 0 \text{ and after that } v_{k+1} = v_k - w'_k.$$

4. First example

In this example of Chapman – Richards model, the emphasis is on testing of the numerical method and it is by no means a thorough investigation. The data for model testing are randomly collected by authors, due to the limited data availability. The numerical data presented in Table 1 are based on observations of young Aleppo pines on the previously burnt southern slopes of Kozjak, Mosor and Poljička planina in the vicinity of Split at elevations between 150 and 300 meters. Each of five sites of former wildfires have been visited in two consecutive years: near Podstrana (burnt in 2021), Kaštel Sućurac (burnt in 2020), Žrnovnica (burnt in 2017), Rupotina (burnt in 2015) and Kaštel Stari (burnt in 2014). The sites were selected for similarities in the terrain and the exposure to the sun. Each year, the height of the tallest tree was recorded.

Table 1 Tallest Aleppo pines height depending on their age

Age [years]	1	2	3	4	5	6	7	8	9	10
Site	Podstrana		Kaštel Sućurac		Žrnovnica		Rupotina		Kaštel Stari	
Height [m]	0.01	0.02	0.08	0.21	0.42	0.74	1.15	1.58	2.30	2.82

Note: Data are collected by authors.

For the empirically plausible initial approximation are chosen $A_0 = 18$, $C_0 = 0.25$ and $D_0 = 5$. Analysis and calculations are performed using the MATLAB software package and the Newton method iterations are presented in Table 2. It is obvious that the Newton method diverges for the selected initial data and after a few more steps the Jacobi matrix becomes singular. In accordance with the note earlier in the text, the data were analysed more closely. Given that the first few points refer to the period when the growth of pine saplings has just begun, the points from the middle of the period were selected and the initial approximation C_0 is obtained as a solution to the equation

$$\ln\left(\frac{y_5}{y_4}\right) \ln\left(\frac{1 - e^{-Cx_4}}{1 - e^{-Cx_3}}\right) = \ln\left(\frac{y_4}{y_3}\right) \ln\left(\frac{1 - e^{-Cx_5}}{1 - e^{-Cx_4}}\right) \quad (18)$$

Table 2 Approximate values obtained by Newton method for $A_0 = 18$, $C_0 = 0.25$, $D_0 = 5$ using $\varepsilon = 10^{-6}$ to calculate the approximation of the Jacobi matrix

k	A_k	C_k	D_k
0	18	0.25	5
1	4.72802937473372	0.250169163923438	5.2360612408584
2	4.60028060515426	0.252752765444066	6.31782366952954
10	1.03067950952828	5.31871403247903	550.078273189804
20	1.03472378250948	10.3183295637191	61394.8065918124
30	0.964634759462139	20.266985721358	61261099.3267505

Figure 1. shows the graph of the function $C \mapsto \ln\left(\frac{y_5}{y_4}\right) \ln\left(\frac{1-e^{-Cx_4}}{1-e^{-Cx_3}}\right) - \ln\left(\frac{y_4}{y_3}\right) \ln\left(\frac{1-e^{-Cx_5}}{1-e^{-Cx_4}}\right)$ localized on the segment $[0.01, 0.2]$ where it contains its only zero point. Therefore, the obvious choice for the initial approximation is $C_0 = 0.14$.

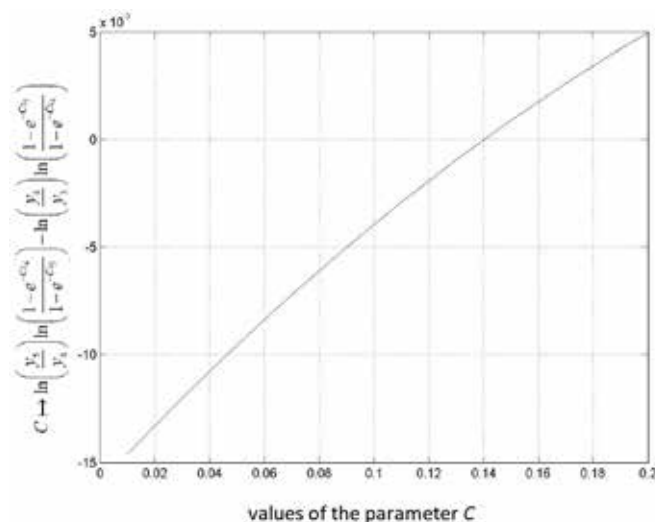


Figure 1 Choosing the initial approximation C_0 of the parameter C

If better accuracy is needed, employing bisection on the segment $[0.1, 0.2]$ in 45 steps leads to even better initial approximation $C_0 = 0.140109586904113$.

Opting for $C_0 = 0.14$ leads to $D_0 = \frac{\ln\left(\frac{y_5}{y_4}\right)}{\ln\left(\frac{1-e^{-C_0x_5}}{1-e^{-C_0x_4}}\right)} = 4.3201597170942$ and consequently $A_0 = \frac{y_5}{(1-e^{-C_0x_5})^{D_0}} = 8.14661240339005$. Newton iterations are outlined in Table 3 and Figure 2 and Figure 3 show the approximation for the first ten and fifty years, respectively.

Table 3 Approximate values obtained by Newton method for $A_0 = 8.14661240339005$, $C_0 = 0.14$ and $D_0 = 4.3201597170942$ with $\varepsilon = 10^{-6}$ for the approximation of the Jacobi matrix

k	A_k	C_k	D_k
0	8.14661240339005	0.14	4.3201597170942
1	10.4857313537112	0.13984923954557	4.77735493603663
2	11.0778979923485	0.139579125620496	4.79166513256083
10	14.8652185459948	0.113586456856009	4.26549168931732
20	14.8715561109273	0.113553845730834	4.26487810377773
21	14.8715561109274	0.113553845730833	4.26487810377772
22	14.8715561109274	0.113553845730833	4.26487810377772

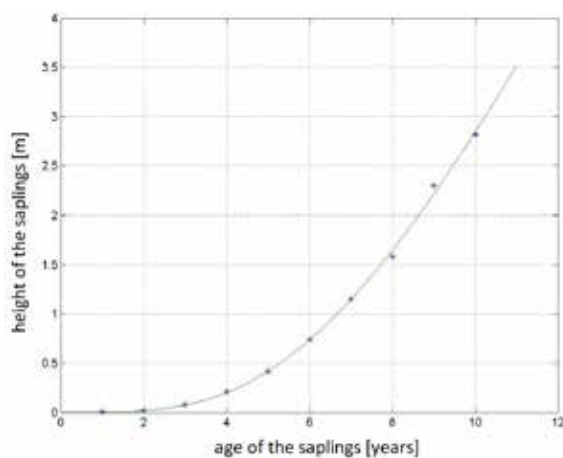


Figure 2 Approximation, first 10 years.

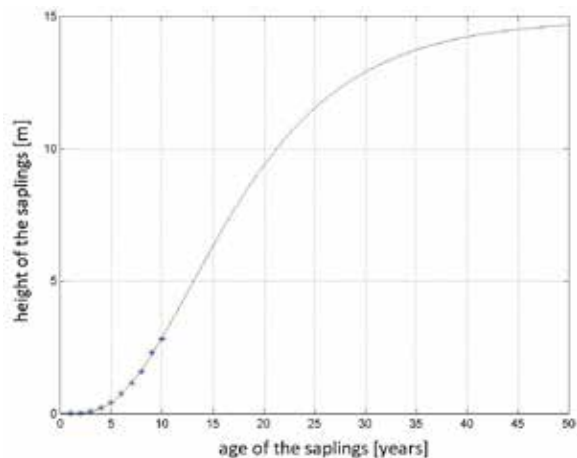


Figure 3 Approximation, first 50 years.

The graph develops into the sigmoid shape, characteristic of tree growth. It follows that in the given habitats it is realistic to expect an asymptotic height of slightly less than 15 meters, and that half of that height would only be reached between the fifteenth and twentieth year. Aleppo pine sprouts easily, but the forest regenerates quite slowly.

The mathematical techniques utilized in this illustration are within the grasp of Polytechnics students, coupled with fundamental knowledge of MATLAB for computational tasks, as demonstrated in Figure 4.

```

>> vektor=[8.14661240339005 0.14 4.3201597170942]';
vektor =
    8.14661240339005
    0.140000000000000
    4.32015971709420

>> [v1,v2]=ff2vektor(x,y,vektor); vektor=vektor-ff2japr(x,y,vektor)/v2
vektor =
    0.48973136315167
    0.13984923954557
    4.77735494113375

>>

function z=ff2japr(x,y,vekt)
1 function z=g21(x,y,A,C,D)
2 s=0;
3 for k=1:size(x,2), s=s+(A*(1-exp(-C*x(k)))-D-y(k))*(1-exp(-C*x(k)))^2;
4 end
5 z=s;

function z=ff2vektor(x,y,vekt)
1 function [v1,v2]=ff2vektor(x,y,vekt)
2 A=vekt(1); C=vekt(2); D=vekt(3);
3 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
4 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
5 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
6 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
7 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
8 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
9 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
10 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
11 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
12 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
13 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
14 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
15 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
16 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
17 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
18 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
19 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
20 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
21 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
22 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
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24 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
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26 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
27 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
28 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
29 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
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31 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
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34 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
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37 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
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39 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
40 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
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45 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
46 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
47 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
48 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
49 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
50 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
51 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
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58 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
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61 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
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69 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
70 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
71 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
72 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
73 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
74 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
75 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
76 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
77 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
78 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
79 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
80 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
81 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
82 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
83 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
84 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
85 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
86 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
87 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
88 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
89 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
90 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
91 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
92 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
93 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
94 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
95 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
96 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
97 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
98 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
99 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);
100 z=1e6*(g21(x,y,A+1e-6,C,D)-g21(x,y,A,C,D)); g22(x,y,A,C,D)=g22(x,y,A,C,D); g23(x,y,A,C,D)=g23(x,y,A,C,D);

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Figure 4 Some of the MATLAB functions used

5. Second example

It is easy to imagine a criticism of the data collected in the previous example: they do not originate from the same location, the sites were chosen arbitrarily and without a more detailed analysis of the chemical and physical properties of each one of them. Ideally, the data should come from the same location, a new Aleppo stand, regenerated from a burnt fertile old Aleppo forest, observed over ten or more years after the fire. Unfortunately, due to the frequency of the wildfires, it is not easy to find a new forest that is older than ten years in the vicinity of Split. Also, the intention was to illustrate, and not to carry out detailed research, since the authors of this paper are mathematicians, not foresters. It is hard to find a study of the heights of new Aleppo pines on burnt sites for ten years or more to support the needs of the least squares method for more points, possibly for the very reasons mentioned.

In order to carry out a more thorough analysis the data from Dubravac and Barčić (2012) are analysed. The data are given in Table 4. In their study, natural regeneration after fires on the permanent sample plot set of Žurića brdo in NP “Krka” is researched. The old Aleppo pine afforestation of the site, approximately 60 years old, was completely burned down in 1999. Over the successive five-year survey (from 2001 to 2005) they monitored growth and development of vegetation by type, number and height-age classes. They observed a successful, highly abundant natural regeneration of Aleppo pine which grew and fully covered the burned area.

Table 4 Number and distribution of Aleppo pines by years of monitoring

Height class	Number of plants by years of measurement (per 150 m ² and per ha)				
cm	2001.	2002.	2003.	2004.	2005.
<30	1095	436	144	28	13
31-60	501	1080	815	385	170
61-130	-	239	850	1090	899
131-150	-	-	8	180	203
151-200	-	-	-	47	254
201-250	-	-	-	-	10
total	1596	1755	1817	1730	1549
per ha	106293	116883	121012	115218	103163

Note: Source of data is Dubravac and Barčić (2012)

Utilizing the upper limits of the intervals as the heights of the tallest pines on the site (Table 5), one can readily replicate the procedure outlined in the preceding example.

Table 5 Tallest Aleppo pines height depending on their age by Dubravac and Barčić (2012)

Age [years]	2	3	4	5	6
Height [m]	0.60	1.30	1.50	2.00	2.50

Applying formula (18) like in the first example and using graphical method (Figure 5) yields the initial approximation $C_0 = 0.15$. Newton iterations are presented in Table 6 and the approximation for the first fifty years is provided.

Approximation shows that the limit height of the forest on this site is 8.30583056699945 m.

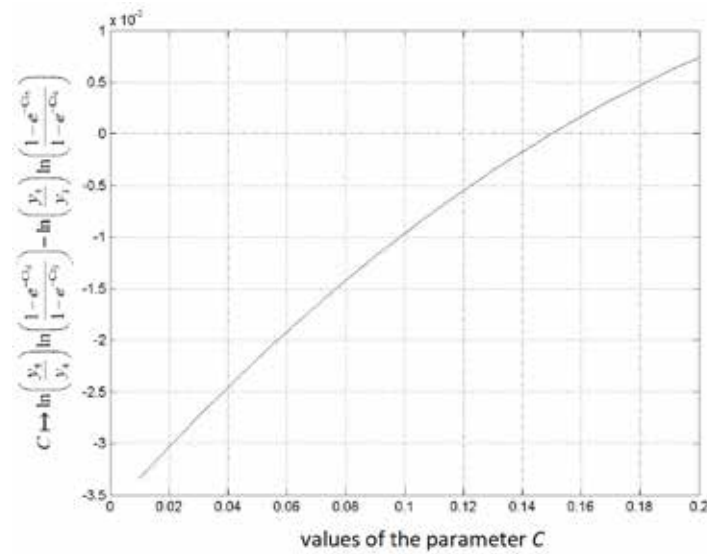


Figure 5 Choosing the initial approximation C_0 of the parameter C for Dubravac and Barčić (2012) data

Table 6 Approximate values obtained by Newton method for $A_0 = 6.79825529110539$, $C_0 = 0.15$ and $D_0 = 1.89880281565893$ with $\varepsilon = 10^{-6}$ for the approximation of the Jacobi matrix

k	A_k	C_k	D_k
0	6.79825529110539	0.15	1.89880281565893
1	4.58453326182717	0.14706743389935	1.31431330874700
2	5.39969420749084	0.14647433922906	1.51115816058347
10	7.26803991746360	0.10430671957776	1.41968823486615
20	8.30583126636402	0.08909289006897	1.37507321256789
31	8.30583056699945	0.08909289921916	1.37507323917415
32	8.30583056699945	0.08909289921916	1.37507323917415

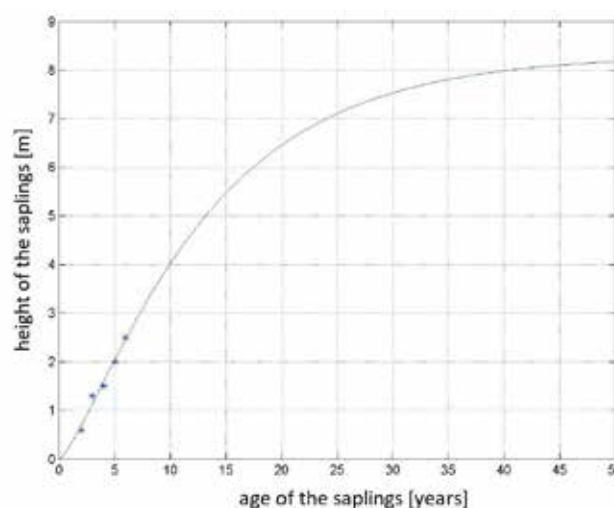


Figure 6 Approximation for first 50 years, Dubravac and Barčić (2012) data

It is open to discussion why the model estimates the asymptotic height of the new forest to roughly half of the one in the first example. Could it be the quality of the soil, the slope of the terrain, exposure to the sun, or could it be attributed to the insufficient number of readings? On the other hand, it should be noted that Barišić (2016) studies 36 years old afforested Aleppo

pine stands in the vicinity (between Skradin and Benkovac), with tree heights in the range from 7 m to 11.5 m and the average height of 9.34 m. Lesser heights could be caused by erosive deterioration of the habitat. While it's true that further observations in subsequent years could enhance the accuracy of the approximation, the uncertainty remains, especially considering that the pines at Žurića brdo, the focus of Dubravac and Barčić's (2012) study, were once again devastated by fire in 2016.

6. Discussion and conclusion

Sustainable development, as defined, entails meeting the needs of the current generation while safeguarding the capacity of future generations to fulfil their own needs. This paper explores the management of public resources like space, air, forests, and water. Its objective is to raise awareness, provide clarity, and maintain perspective. Without this understanding, there's a risk of confusing causes and effects, leading to misinterpretation of the facts.

For that purpose, in this paper is presented how mathematical methods and models familiar to students can be utilized to tackle environmental issues in real-life ecological processes. That is achieved through the idea of sustainable development concerning the recovery of forests after wildfires in the Dalmatia and Mediterranean, showing to students not only the importance of forest conservation, but also the way they can apply their knowledge to real-life problems.

It's crucial to strongly challenge the prejudice surrounding the Aleppo pine, particularly labelling it as an "invasive species", "useless", "commercially unprofitable", or a "weed" that should be eradicated in favour of planting "autochthonous" plants like holm oak and black ash (Šarac, 2017). The reality, however, is that these plants struggle to thrive on karst terrain until the pine creates an adequate soil layer, which is precisely why foresters endorse its presence. On karst landscapes, the pine is actually a hero, not a villain. It prevents erosion, generates soil, offers shade and wind protection to more delicate species, and sets the stage for their emergence from its shadow over time, sometimes even after a century.

Regarding the tendency of Aleppo pine to spread in neglected agricultural regions, the real problem is the very fact that these regions are neglected. Neglected agricultural areas should be restored to their intended purpose through legal means such as taxation, or alternatively, left to revert to forest cover. Meanwhile, forests, whether privately or publicly owned, must be adequately and compulsorily maintained in accordance with sound forestry practices.

Once a wildfire is put out, the private or public fire site should be treated according to the procedure described in Dubravac and Barčić (2012). The remaining burnt trees should be cut down, the branches removed from the trunks and once the trunks are removed, chopped up with a chainsaw on the spot so that the remaining material adheres to the ground as much as possible. If it were not done, the new pine forest will densely overgrow the former paths and fallen dry walls, connect with the stumps of burnt trees into an impassable sharp barrier only to burst up in flames again on the first occasion, making it far more difficult to extinguish this time.

A pertinent question arises: Why do wildfires ravage Dalmatia with such frequency? This cannot be solely attributed to the supposed high flammability of the Aleppo pine. In the dry summer months, this pine burns no more readily than many other Mediterranean plants and does not ignite spontaneously. Shockingly, up to 95% of forest fires across Mediterranean countries are human-caused, stemming from negligence, carelessness, or deliberate arson. Moreover, the annual burnt area has doubled since the 1970s (Rosavec et al., 2012). Issues such as oversized and poorly located construction zones, inadequate infrastructure, illegal building practices, improper waste disposal, faulty land registries, as well as greed and corruption, although not unique to Croatia, serve as indicators of the true perpetrators in this narrative.

The fact that the majority of forest fires are caused by humans highlights the need to raise awareness, especially among young people, about the importance of forest conservation and reforestation. It is important to encourage them to actively participate in initiatives aimed at forest preservation and to promote awareness of their invaluable importance to the planet's health.

Future research could explore the application of various mathematical methods to diverse ecological problems, particularly those that resonate with students, either due to their presence in their surroundings or their close connection to areas of their interest. This could involve investigating how mathematical tools can be used to address ecological issues ranging from local environmental challenges to broader global concerns, thereby fostering a deeper engagement with real-world applications of mathematics among students.

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