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Article

Innovative NFC-validation system for accounting of income and expenses of public transport enterprises

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INNOVATIVE NFC-VALIDATION SYSTEM FOR ACCOUNTING OF INCOME AND EXPENSES OF PUBLIC TRANSPORT ENTERPRISES

Abstract. *To control pricing in passenger transportation, monitor the functioning of urban transport networks, reduce direct contacts during the COVID-19 pandemic, it is advisable to implement a system of NFC validation of fares. NFC (Near-Field Communication) technology provides primary information on public transport and travel fares. The article aims to improve the method of application of the technology of automated NFC-validation of fares in urban passenger transport to account for and control provided transport services. The tasks include research of mechanisms of the automated identification and counting of quantity of the transported passengers to account incomes of the motor transport enterprises; selection of calculation units for automated determination of the cost of provided transport services; development of control methods of drivers work, the operation of vehicles, transportation of privileged categories of citizens, pricing, etc. Theoretical and methodological aspects of NFC-validation technologies for public transport fares for accounting purposes have been studied based on general research methods – institutional and innovative; economic and mathematical methods of analysis and polynomial trend using Excel spreadsheets were used to predict the pace of implementation of NFC-devices; methods of bibliographic and comparative analysis using the information resource «ResearchGate» – to determine promising areas for new technologies in the provision of transport and passenger services. It is proved that the most effective unit of cost calculation of transport services is «passenger-kilometer», which corresponds to the peculiarities of the functioning of urban passenger transport, as it takes into account the number of passengers and distance of travel. The procedure for distribution of income from the sale of electronic tickets and budget subsidies between carriers based on information on the total number (including privileged categories) of transported passengers has been developed. The method of automated cost accounting by the «passenger-kilometer» meter for fuels and lubricants, staff salaries, depreciation of vehicles, and its current repairs, which define the cost of transport services, is improved. Implementing NFC fare validation technology will facilitate automated accounting of costs, revenues, and cash receipts from transport services, the introduction of effective control over the work of drivers, vehicles, concessional transportation, pricing, timeliness, and reliability taxes on urban transport.*

Keywords: accounting, accounting automation, income and expense accounting, automated validation of fare payment, passenger transportation, public transport, NFC technology.

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Introduction. The level of development of transport infrastructure is an indicator of the socio-economic well-being of cities and public territorial associations. An effectively functioning network of passenger vehicles not only provides spatial mobility but is also a tool for social protection and an administrative method of urban zoning space. However, the commercialization of passenger traffic almost always leads to a conflict of economic interests between carriers, passengers, and local governments. Privately owned motor transport enterprises to obtain additional economic benefits can unreasonably increase the cost of passenger transportation. The economic inexpediency of transportation justifies the increased fare for public passenger transport due to the permanently increased cost of transport services. However, the population and public authorities representing their interests do not have effective mechanisms to control pricing in the field of urban passenger transport. In addition, the requirement of local self-government to provide free transportation for privileged groups might lead to increased fares. In the conditions of preferential travel guaranteed by the legislation to certain groups of citizens, there is no effective method of controlling the number of passengers transported free of charge. Currently, the average indicators of passenger traffic are calculated, the use of which may lead to the interpretation of the economic inexpediency of the operation of certain public transport routes that provide transportation of a significant number of privileged passengers. Passenger flow management problems are solved by introducing automated accounting and control over traffic based on the system of automated validation of fares. Validators («valid» – used according to a set of official conditions that often include a time limit: valid, able to be accepted, legitimate) – electronic or mechanical-electronic devices designed to display and/or verify information documents (public transport tickets, passes), recorded on contactless electronic media for operational control over the entrance (exit) of the passenger in the bus, trolleybus, tram, landing platform in the subway, rail and other modes of transport (Validator).

Literature Review. Intensification of research on the application of automated validation of fares in public transport has taken place in the last decade with the mass implementation of NFC technology. NFC (Near-Field Communication) is a technology of wireless high-frequency radio with a short range of «one-touch», allowing information exchange between devices at a distance of up to 10 cm. Since 2014, the market capitalization of NFC technology has grown from 3.1 billion USD to 25.5 billion USD in 2021. Based on the polynomial trend of statistics, it is estimated that the size of the global market for NFC devices will double exponentially and reach 47.3 billion USD in 2024 (Fig. 1).

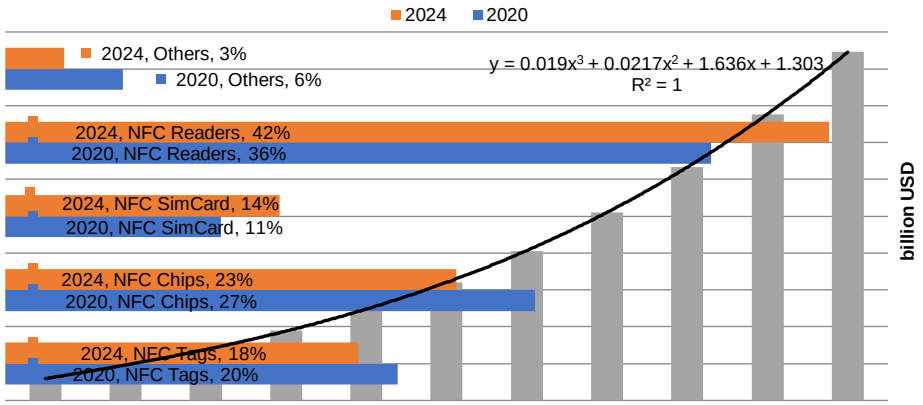

Figure 1. Development of the global NFC technology market by 2024
Sources: developed by the authors on the basis of (Statista, 2015).

The largest share in the market growth of NFC technology is occupied by the radio readers production (36% in 2020, 42% in 2024) due to the widespread use of technology in various sectors of the economy. Short-range radio communication technology is mainly implemented in large business entities and their associations in public utilities, information communications, and transport (Fig. 2).

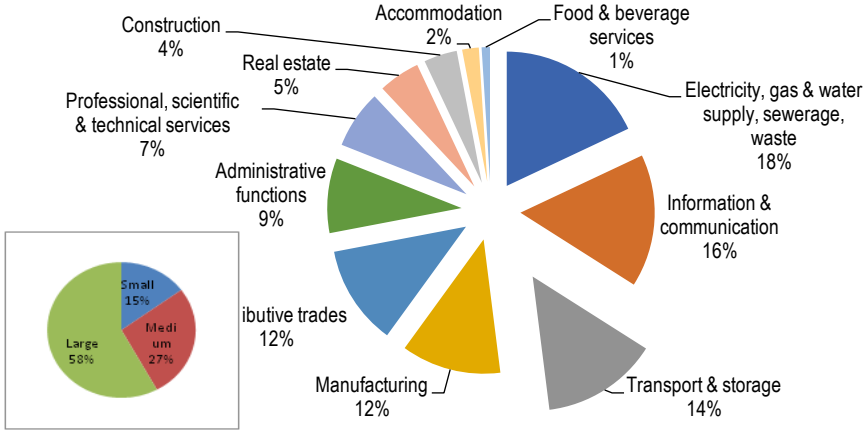

Figure 2. The proportion of enterprises that use NFC technology for commercial purposes, by size of business and sectors of the EU economy, %

Sources: developed by the authors on the basis of (AMR, 2021).

The use of NFC devices is associated with significant capital and operating costs, which makes it difficult to implement technology in small and medium-sized businesses. The prospects of these sectors of the economy to use innovative information technologies are justified by the social orientation to meet the socially important needs of the population. Fig. 3. reflects the generalized data of the sociological survey in the EU countries on the importance of information technologies in the passenger transportation.

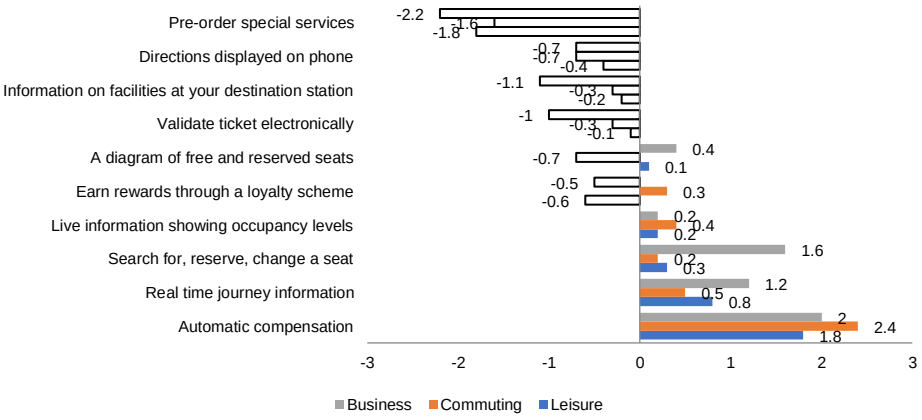

Figure 3. Passengers' priority in information technology in optimizing the activities of urban passenger transport in the EU

Sources: developed by the authors on the basis of (Oliveira et al., 2019).

Respondents were asked to describe the need for innovative information processing technologies in urban public transport. The results of the survey are processed in the form of a histogram with values from - 3 (minus three) to + 3 (plus three), where negative and positive values characterize the absence or priority of the need for information technology (Oliveira et al., 2019). The method of validation of fare payment is not a priority for passengers to optimize the activities of public transport. Statistics confirm the dissonance between business understanding of the prospects of fare validation technology and the needs of passengers in it. Public transport companies need an effective mechanism to control passenger traffic and revenues from providing transport services. But automated fare validation technology can also be useful for passengers and the public in controlling the pricing process in the transport sector.

Marunych and Vakarchuk (2012) studied automated methods of tracking passenger flow on public transport routes. Handziuk (2014) developed technical and organizational aspects of the implementation of toll validators. Peculiarities of introduction and identification of social cards for privileged passengers in public transport are considered by Kondziuba and Dukhonchenko (2011). Ferreira et al. (2014) have developed a methodology for the concept of a single electronic ticket with mobile phone payment through validators in public transport. Di Pietro et al. (2015) studied the market for mobile applications for public transport fares. Couto et al. (2015), compared electronic ticketing technologies and their use for public transport. Fadeev and Alhusseini (2020) substantiated the procedure for checking information from toll validators with a database of electronic tickets. Barry et al. (2009) have explored the prospects of using passenger validation technology to gather information for the management of transport companies. Shuran and Xiaoling (2020) researched information interaction between different information technologies (NFC, RFID, QR-code, and others). Boada et al. (2021) identified areas of commercial use of NFC technology for data exchange with telecommunications devices and smartphones. A methodology for identifying a person's location by NFC tags, which may be useful for validating tolls, has been developed by Chze et al. (2021). Arfaoui et al. (2014) investigated the method of using smartphones to generate electronic tickets for public transport: Hargude et al. (public transport) (2020); Brumercikova and Bukova (2020) (regional long-distance transport): Komsta et al. (railways) (2016); Veloz-Cherrez and Suárez (other modes of transport) (2019) continued their research on the implementation of an electronic fare payment system based on NFC technology. However, scientific papers ignore socio-economic processes in the automated fare payment system from the standpoint of the need to establish effective accounting and control of passenger carriers and pricing monitoring in the transport sector.

The purpose of the article is to improve the application of automated NFC validation of fare in urban public transport for accounting and control of provided transport services. The tasks include research of mechanisms of the automated identification and counting of quantity of the transported passengers to account incomes of the motor transport enterprises; selection of calculation units for automated determination of the cost of provided transport services; development of control methods of drivers work, the operation of vehicles, transportation of privileged categories of citizens, pricing, etc.

Methodology and research methods. Theoretical and methodological aspects of NFC-validation technologies for public transport fares for accounting have been studied based on general research methods - institutional and innovative. The institutional, methodological approach to studying the theoretical foundations of accounting is based on its important socio-economic role in the modern information society. The innovative approach is used to reveal the prospects of using innovative NFC-validation technologies for accounting, analysis, and control purposes.

When forecasting the pace of implementation of NFC devices, the emphasis is on economic and mathematical modeling methods using Excel spreadsheets. Based on the construction of a polynomial trend line using approximated and forecast data, the indicators of development of the global market of NFC-validation technology, its popularity in different sizes of business and industries of EU countries are determined.

Methodological tools of bibliographic and comparative analysis became the methodological tools of the study. The empirical study was conducted using a bibliometric approach known as «analysis of common words» and the information resource «ResearchGate».

Results. For effective accounting and control of the public passenger carriers, it is recommended to equip all vehicles with toll validators. Their use makes it possible to identify the entry (exit) of the passenger and the fare by an automated broadcast of generalized information about the provision of services to interested stakeholders. Fare is paid through the electronic ticket validation by an automated NFC controller. It is recommended to use the technology of automated NFC-validation of fare also for accounting and control of the operation of urban passenger vehicles. Information from validators on the date of travel, passenger traffic, duration and distance of travel, transportation of privileged categories of the population in electronic form is sent to the issuer of electronic tickets, carriers, public authorities, and the public. Figure 4 presents the information scheme of accounting and control of the functioning of urban public transport in the conditions of automated NFC validation of fare payment.

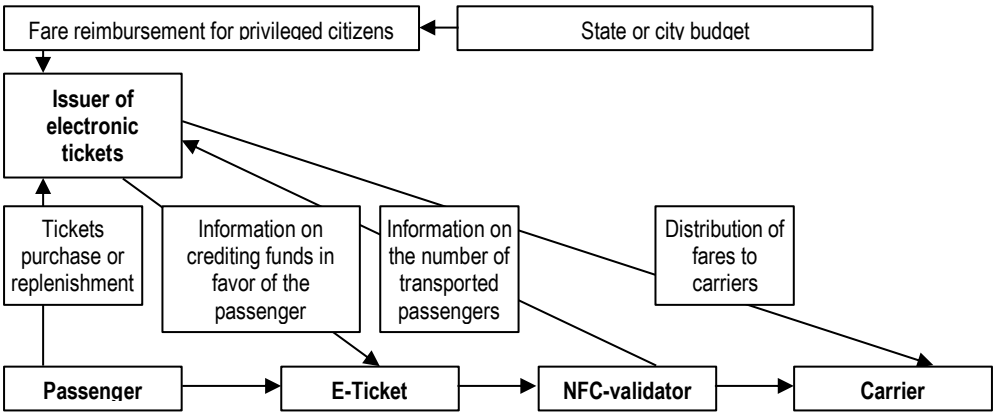

Figure 4. The scheme of information flows in the automated accounting and control of passenger carriers

Sources: developed by the authors.

The facts of receipt of fares from the sale of electronic tickets or replenishment of travel cards automatically reflect transactions in the accounts. It is expedient to recognize the received fares from the sale of electronic tickets or replenishment of travel tickets from the point of view of accounting as target financing. The main costs of the company that maintain the automated validation system of fare payment are its maintenance costs, production of electronic tickets, and the transferred fares to carriers. It is agreed with Bazyliuk and Malyshkin (2011) that a component of the cost of the passenger transportation is the remuneration of the issuing company for the maintenance of the NFC system of fare validation. The income of the issuer's company is the cost of services provided by transport companies, which includes the above fee for electronic card transactions. The number of funds received for e-tickets from future passengers should not be considered the income of the e-ticket issuer. One of the main principles of accounting is the principle of accrual, according to which the moment of sale of products (works, services) is the fact of providing such services but not their fares instead of them. The funds accumulated from the transport services should be permanently distributed among carriers according to the number of transported passengers, including privileged ones. Expenses for transportation of privileged passengers are reimbursed from the local (state) budget not in favor of the carrier, as is the case now, but in transit through the issuer of electronic tickets (travel). The issuer is an intermediary in receiving and distributing

budget subsidies for preferential transportation of the population. The social positioning of privileged categories of citizens is undergoing transformations, the transportation of which may be undesirable for carriers, as it leads to a decrease in revenues from transport services. The passenger carrier is losing interest in monitoring the facts of paid or free transportation of passengers, which contributes to quality transport services to all citizens without exception.

To minimize the abuse of frequent transportation of privileged categories of the population, it is advisable to issue personalized travel documents with a fixed number of free trips. The controller performs NFC-validation of individual electronic travel documents, and the facts of preferential provision of transport services are recorded in the accounting and control system. The funds transferred by the issuer per the number of concessional travels in favor of carriers should be recognized as expenses of future periods of the issuer. They are subject to depreciation in proportion to reimbursements from the budget. Implementing an automated accounting and control system based on the technology of automated NFC-validation of fares will promote a fair distribution of revenues from transport services between carriers, limiting unfair competition. Implementing the technology of automated NFC-validation of food on public transport will discipline privileged passengers, who independently manage the number of free travels.

Automated NFC fare validators will increase control over the drivers who will not have direct access to cash. Due to the lack of access of drivers or controllers to cash received as a fare, financial fraud in public transport is prevented. NFC fare validators can simultaneously act as fiscal registrars. They send accounting information on the number of passengers carried and the cost of transport services provided to the fiscal service. The carrier is deprived of the opportunity to hide income from transport services. It would contribute to the full and effective taxation of activities. Figure 5 shows the implementation of control capabilities in urban passenger transport based on automated NFC validation of fare.

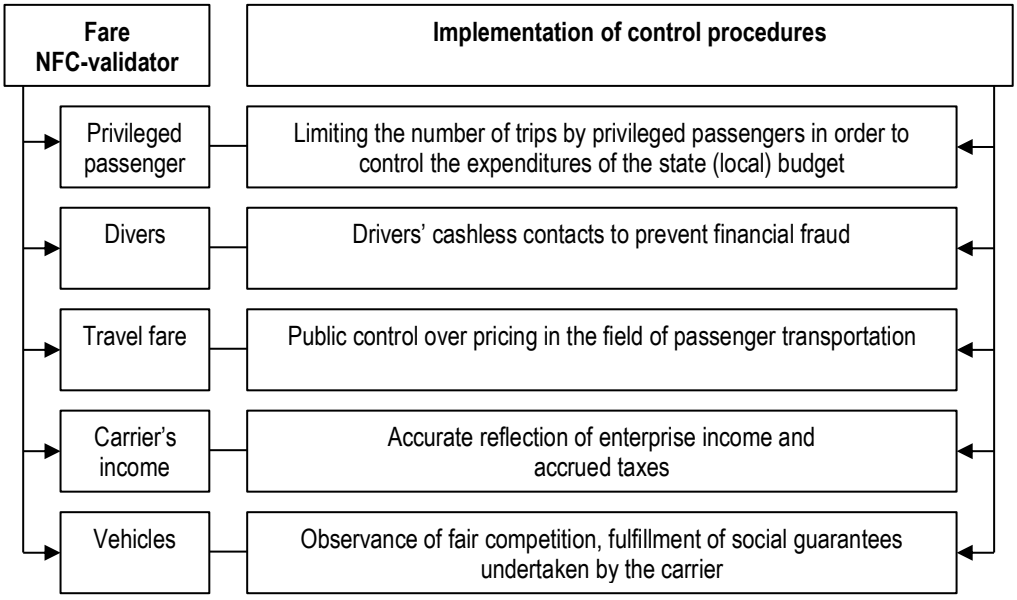

Figure 5. Implementation of control procedures in urban passenger transport using automated NFC-validation technology

Sources: developed by the authors.

The automated system of accounting and control of public transport is an information resource for public control over pricing in the transport sector. Using the accounting data on the cost of fuel and lubricants, depreciation of vehicles and drivers' salaries, and other operating costs, one can calculate the profitability of transport services. Economically justified higher fares for transportation of one passenger can be set on long-distance routes and a small number of passengers. Conversely, to prevent excessive fare growth, public control over the pricing process is possible.

The problematic point is the choice of the correct unit of account to reliably determine the cost of transport services provided (Zadorozhnyy et al., 2021). Passenger carriers use such meters as one kilometer, one passenger transported, one full flight from the initial to the final stop of public transport. Most costing units are inefficient for automating the accounting and control of urban public transport. In the case of exclusive consideration of the mileage of the distance traveled by car, the number of transported passengers is ignored when calculating the cost of transport services provided. Temporary, seasonal transportation can be the cause of low passenger traffic with constant vehicle mileage. This situation is relevant for public transport, which is operated on flights regulated by the city's transport network, despite the lack of passengers.

Similarly, when accumulating transport costs for one full flight between the endpoints of the urban public transport route, the accounting specialist can operate only with planned (approximate) indicators of passenger turnover. Without passengers at the initial stage of departure of the vehicle and low expectations of congestion, the flight may be canceled as on long-distance routes. Thus, the choice of the calculation unit «fact of transportation» does not allow to determine the cost of provided transport services reliably. The use of the indicator «number of transported passengers» as a unit of account without taking into account the distance traveled by vehicles does not allow to reliably determine the cost of transport services provided. Significant volatility in passenger traffic for short distances can lead to distortions in the economic performance of carriers. Dynamic change in the number of transported passengers between different central and long-term territorial locations stops makes it impossible to calculate the cost of transportation for companies that use the zonal principle of pricing. In other words, the cost of travel in differentiated areas of public transport may differ due to the variable number of people transported.

There are two options: the growth of zonal passenger traffic leads to an increase in the cost of transportation to optimize profits from the provision of services. Reducing the number of people transported over long distances between stops requires maximizing the fare to compensate for rising transport costs. In both cases, the calculation of the cost of one transported passenger does not provide the necessary accounting information to make management decisions to establish a reasonable price for transport services. Therefore, the importance of using the meter «passenger-kilometer» as a basic calculation unit in public transport is increasing. The integrated combination of meters contributes to the detailed accounting of the passenger carriers in two projections: the number of transported persons and the mileage of the distance traveled by vehicles. For companies that have implemented the automated NFC-validation of fares, it is possible to use two options for identifying and calculating the cost of transport services using the meter «passenger-kilometer». The first method involves automated identification of the moment a person enters the vehicle to determine the number of passengers carried and track the distance traveled using the Global Positioning System (GPS-navigation) (Shevchuk et al., 2020). The average hourly, daily, monthly, etc. works of city public transport are automatically calculated in passenger-kilometers. Otherwise, it is necessary to automatically identify the moment of entry and exit of the passenger and the spatial location of the vehicle using global positioning technology. Fare may be charged upon arrival of the passenger at the destination, based on the cost of transport services. The mileage, the area of the territorial location of the stop, the number of stops since boarding, etc., are taken into account. The fare varies depending on the type of public transport stop at which passengers board and disembark.

Calculating the cost of transport services using a two-dimensional unit of account in comparison with the classic meters «one kilometer», «one passenger» provides an increase in the reliability and

completeness of accounting information. The largest share in the cost of transport services is the cost of fuels and lubricants. Based on calculations only on the mileage of the travel does not allow to establish the impact of gross vehicle weight on fuel consumption, transmission oil, engine oil, coolants, etc. Depletion of fuels and lubricants should be carried out in proportion to the indicators of passenger-kilometers of the carrier, which helps to identify a direct link between fuel consumption and weight gain of the vehicle with the increasing number of passengers. The number of passengers carried has a similar effect, only to a lesser extent, on the service life of tires and other spare parts.

Based on the number of passenger kilometers of the carrier's work, it is appropriate to calculate the depreciation of vehicles by the production method. The state of wear of vehicles also depends on the odometer of the car and the number of transported passengers. If the moving parts of the vehicle are subject to wear depending on the number of kilometers covered, the quality of the cabin equipment is related to the level of passenger traffic. Based on the planned performance of the vehicle and the current number of passenger kilometers of activity, it is possible to depreciate monthly, or, if necessary for management purposes, and shorter periods. The use of a dual unit of calculation will help reliably calculate the level of wear of the carrier's rolling stock and predict the possibility of breakdowns. After achieving critical indicators (guaranteed or uninterrupted operation), it is appropriate to a preventive technical inspection of certain units. If necessary, preventive maintenance work is performed, which minimizes the likelihood of vehicle failure and suspension of the carrier.

The received accounting data on passenger-kilometers of motor transport work can serve as an information basis for drivers' salaries and service personnel. To increase the motivation of employees of the transport company, data on the number of passengers transported or the distance traveled by the vehicle during the work shift can be used to calculate additional and compensatory payments. If drivers get a fixed basic salary, the number of additional payments will depend on the quantitative parameters of the travels.

Similarly, this can account for the salaries of cashiers, conductors, dispatchers, repairmen, etc., which will be recognized in accounting overhead costs. However, the first two jobs will disappear when using NFC - validation. At the end of the reporting period, overhead costs can be distributed for the same facilities for which the tariff is calculated, i.e., one passenger kilometer. Using a two-dimensional unit of account will contribute to the reliable positioning of overhead costs as part of the cost of transport services provided.

Generalized information on the number of transported passengers, duration of travel, income, and expenses in terms of modes of transport, routes, carriers, time frames, privileged categories of passengers is recommended to be officially covered in electronic media to inform the public about their social protection. Generalized credentials should be automated with a high-efficiency level on the official web resources of local authorities, bus stations, and carriers (Derij et al., 2021).

Conclusions. It is recommended that automatic NFC validation of fares be used to arrange the accounting and control of the operation of urban passenger transportation. It is recommended to split the earnings from the sale of electronic tickets (replenishment of travel) and budget subsidies between carriers and issuers of electronic tickets based on the information automatically collected by NFC-validators on the total number of carried passengers. The deployment of automatic NFC-validation of fares technology contributes to the strengthening of control over carrier activities and cost monitoring for the provision of transportation services in order to justify the accuracy of pricing procedures. The «passenger-kilometer» is widely acknowledged as the most efficient unit of measurement for determining transportation costs.In order to organize the accounting and control of the functioning of urban passenger transport, it is recommended to use the technology of automated NFC validation of fares. Based on the information automatically collected by NFC validators on the total number (including privileged categories) of transported passengers, it is advisable to distribute the proceeds from the sale of electronic tickets (replenishment of travel) and budget subsidies between carriers and issuers of electronic tickets. The implementation of the technology of automated NFC-validation of fares contributes to strengthening

control over the activities of carriers and monitoring costs for the provision of transport services to justify the correctness of pricing processes. The «passenger-kilometer» is recognized as the most effective unit of calculation in calculating the cost of transport services provided. Two-dimensional calculation optimally corresponds to the peculiarities of urban passenger transport functioning, as it considers the number of transported passengers (data from NFC-toll validators) and the distance traveled by vehicles (data from GPS-navigators). The method of automated cost accounting using the «passenger-kilometer» meter for fuels and lubricants, staff salaries, depreciation of vehicles, and its current repairs, which are the cost of transport services. Thus, the introduction of NFC-validation of fare payment will facilitate automated accounting of costs, revenues, and cash inflows from the provision of transport services, allowing the introduction of effective control over the work of drivers, vehicles, and concessional transportation, as well as pricing, timeliness, and reliability of taxes in urban transport.

Author Contributions. All authors contributed equally to the research development, the literature, data collection, research methodology and concluding sections.

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Інноваційна система NFC-валідації для обліку доходів і витрат підприємств громадських перевезень

У статті підлягають розгляду питання доцільності імплементації системи NFC-валідації оплати за проїзд при здійсненні контролю за ціноутворенням у сфері пасажирських перевезень, моніторингу функціонування урбанізованих транспортних мереж, зменшення прямих контактів між пасажирами в умовах пандемії COVID-19. Використання технології NFC (Near-Field Communication – бездротового високочастотного радіозв'язку малого радіуса дії) забезпечує збір первинної інформації про перевезення пасажирів громадським транспортом та оплати за послуги проїзду. Метою статті є удосконалення методики застосування технології автоматизованої NFC-валідації оплати за проїзд в міському пасажирському автотранспорті для обліку і контролю наданих транспортних послуг. Для досягнення поставленої мети було поставлено наступні завдання: дослідження механізмів автоматизованої ідентифікації та підрахунку кількості перевезених пасажирів з метою обліку доходів автотранспортних підприємств; селекція калькуляційних одиниць для автоматизованого визначення собівартості наданих транспортних послуг; розробка методів контролю за роботою водіїв, функціонуванням транспортних засобів, перевезенням пільгових категорій громадян, ціноутворенням тощо. Теоретичні й методичні аспекти використання технологій NFC-валідації оплати за проїзд у громадському транспорті для облікових цілей досліджувалися на базі загальних методів наукових досліджень – інституційного та інноваційного; для прогнозування темпів імплементації NFC-пристроїв у практичну діяльність використано економіко-математичні методи аналізу й поліноміального трендування з використанням електронних таблиць Excel; для визначення перспективних напрямків використання новітніх технологій у наданні транспортно-пасажирських послуг – методи бібліографічного та компаративного аналізу зі застосуванням інформаційного ресурсу «ResearchGate». Доведено, що найбільш ефективною калькуляційною одиницею при розрахунку собівартості наданих транспортних послуг є «пасажиро-кілометр», що відповідає особливостям функціонування міського пасажирського автотранспорту, оскільки враховує кількість перевезених пасажирів та пройдену автотранспортом відстань. Розроблено порядок розподілу доходу від реалізації електронних квитків та бюджетних дотацій між перевізниками на основі інформації про загальну кількість (у тому числі – пільгових категорій) перевезених пасажирів. Удосконалено методику автоматизованого обліку витрат з використанням вимірника «пасажиро-кілометр» на: паливо-мастильні матеріали, заробітну плату персоналу, амортизацію автотранспорту та його поточний ремонт, що становлять собівартість наданих транспортних послуг. За результатами дослідження встановлено, що імплементація технології NFC-валідації оплати за проїзд сприятиме автоматизованому обліку витрат, доходів та надходження грошових коштів від надання транспортних послуг, запровадженню ефективного контролю за роботою водіїв, транспортних засобів, пільговими перевезеннями, ціноутворенням, своєчасністю і достовірністю нарахування податків на підприємствах міських пасажирських перевезень.

Ключові слова: облік, автоматизація обліку, облік доходів і витрат, автоматизована валідація оплати за проїзд, пасажирські перевезення, публічний автотранспорт, технологія NFC.