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Article

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A COMPREHENSIVE ANALYSIS OF THE ELECTRONIC FARE COLLECTION SYSTEMS EFFECTIVENESS IMPLEMENTATION ON PUBLIC TRANSIT AND PROSPECTIVE DIRECTIONS OF ITS APPLICATION IN UKRAINE

The object of research is the effectiveness of the implementation of electronic fare collection systems on public transit. Applying the electronic fare collection systems is a general trend in improving public transport services for users. In the pre-war period, the systems began to be implemented in many cities of Ukraine. At the same time, this activity was not of a systemic nature and at the current stage it is mainly considered as a means of ensuring more convenient conditions for the use of scheduled passenger transport services for passengers. The article focuses on a broader understanding of the effectiveness of the fare collection systems implementation, their role in ensuring the internal integration of the multi-modal public transport system, increasing the operational efficiency, providing the safety of transportation and increasing the attractiveness of public transit services for the population as a real alternative for the private cars to use. The implementation efficiency of the electronic fare collection systems in public transit should be expressed through various aspects. There are 9 aspects to be considered: system integration; comfort ensuring; transportation safety assistance; operational efficiency and passengers' travel time reduction; integration into the management and planning systems; implementation of the flexible fare system; conduction of the flexible fare policy; development of reasonable income distribution system; increase of the scheduled passenger transport services attractiveness. It is suggested to use systemic approach for integrated multimodal public transit system creation. It requires the development of an intelligent transport system that would integrate separate functions of the electronic fare collection system into controlling, managing and planning subsystems. The practical introduction of the solutions proposed regarding the prospects to develop electronic fare collection systems in the cities of Ukraine will make it possible to increase the efficiency of their use and contribute to the improvement of the quality of transport services for passengers.

Keywords: *public transit, electronic fare collection systems, smart card, fare system, integrated transport system.*

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1. Introduction

Use of electronic fare collection systems is a general trend in improving the public transport services for users. In the pre-war period, these systems began to be implemented in many cities of Ukraine. At the same time, the activity was not of a systemic nature and at the current stage it is mainly considered as a means of ensuring more convenient conditions for the use of scheduled passenger transport services for passengers.

For studying the electronic fare collection systems effectiveness, a sufficiently large number of studies have been done. This article covered some of them.

The main advantages of the fare collection systems implementation are: easy usability by passengers, income management efficiency, inter-modality adequacy, easy «operator-to-operator» cooperation, systematic data collection and gathering tools, planning process improvement [1]. In addition to the fare collection function, the smart card systems can be useful for providing data to both planners and researchers. This data can serve to enhance the strategic, tactical and operational performance of transit authorities [2].

In the article [3], the promising areas of automated fare collection data implementation were outlined: generation of an Origin – Destination (OD) matrix from the transactions or trips, trip purpose or activity type determination, route choice modeling, public transit performance evaluation and policy assessment based on automated fare collection data.

The article [1] deals to an OD matrix calculation using entry-only automated fare collection data from trip-chaining

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method. It was performed at stop level, and was further aggregated at the zone level, considering the geographic zones currently used by the operators.

In the paper [4], authors introduced a passengers' clustering approach from their temporal habits using smart card data. In the paper [5] the smart-card data applied to measure the variability of urban public transit network use. The study [6] proposed an effective data-mining procedure to simulate the travel patterns of transit riders. Transit riders' trip chains are identified from the temporal and spatial specifications of their smart card transaction data. Authors of [7] used the smart card data for estimating passenger's route choice in a complex metro system.

The survey [8] applied a methodology of obtaining the spatiotemporal crowding data and estimating the travel time variability in a congested public transport network to improve accessibility calculations. It relied on using smart card and automatic vehicle location data.

The following research issues were identified as potential challenges for smart card implementation by the authors [2]: technological improvements, data validation, economic feasibility, journey validation and new modelling approaches.

In the article [9], the authors analyzed the automated fare collection solutions in public transportation systems. The main attention was paid to adapt the mobile devices for ticketing solutions to fully automate the fare collection. Introducing the automated fare collection solutions in urban transportation was expected to have a significant positive impact on customers' satisfaction.

Paper [10] as a goal of «mobility as a service» approach indicated the encouraging the use of public transport services by bringing together multi-modal transportation and users' choice and, in this way, facilitating them in their intermodal trips. In achieving this goal, a key role was taken to the payment and information technologies integration. Regarding payment integration, the smart cards were the main way to reach it. The smart cards offer a large amount of information that can be used both in the planning and operation stages.

The analysis of the existing studies indicated that considerable attention was paid to the issues of the electronic fare collection systems effectiveness. At the same time, there is a lack of papers to systematize individual areas of their application from the position of integrated transit system creation.

Therefore, *the purpose of the article* is a comprehensive analysis comprehensive analysis of the effectiveness of the implementation of electronic fare collection systems on public transit and prospective directions of its application in Ukraine. From the scientific point of view, comprehensive electronic fare collection systems effectiveness analysis conducting will allow to theoretically substantiate the most effective directions and conditions of the systems application with taking into account modern technologies and experience of using. From a practical point of view, it will make it possible to increase the efficiency of their usage and contribute to the improvement of the quality of transport services for passengers.

2. Materials and Methods

The object of research is the effectiveness of the implementation of electronic fare collection systems on public transit. To achieve the aim of the study, theoretical research methods were used, conclusions and proposals were formed from the application of a systemic approach.

3. Results and Discussion

Taking into account the current tendency to ensure the priority development of scheduled passenger transport and level of service increase to solve the transport problems of cities, the implementation of the electronic fare collection systems is an integral part of the incorporation of advanced intelligent technologies in urban passenger transportation.

The effectiveness of the implementation of electronic fare collection systems on public transit services can be considered from different points of view. The following were highlighted as the main aspects:

- system integration;
- comfort ensuring;
- transportation safety assistance;
- operational efficiency and passengers' travel time reduction;
- integration into the management and planning systems;
- implementation of the flexible fare system;
- conduction of the flexible fare policy;
- development of reasonable income distribution system;
- increasing of the scheduled passenger transport services attractiveness.

System integration. The key condition providing the efficient public transit system is the introduction of a single smart card to use all available transit modes. The possibility of travel paying with a single smart card is one of the background to integrate a multimodal system of urban passenger transport. Payment integration will create conditions for the harmonization of relations between the participants of the city passenger transportation market, it will ensure the transition from competitive conditions to conditions of cooperation in order to obtain the maximum systemic effect. Creation of a single operating agency is important to cover all public transit modes and perform control, management and strategic planning functions at the system level.

Comfort ensuring. Electronic fare collection systems usage should be resulted in passenger satisfaction. This enables the passengers have the opportunity not to use cash because it is more convenient for them. They also have to store a free amount of money on the smart card, be able to check the account online, make payments using a mobile phone.

Transportation safety assistance. An additional function assigned to the driver (payment collection) should be considered as a distraction from the main activity – vehicle driving. Removing a driver from this activity will allow more direct attention to driving the vehicle. It will contribute to increasing the transportation safety.

Operational efficiency and passengers' travel time reduction. The implementation of electronic fare collection systems in urban passenger transport, where the function of collecting fares is assigned to the driver, helps to reduce vehicle dwell time at intermediate stops due to passenger boarding acceleration. It is due to the fact that passengers can board through all the doors designated for this and less time spent for one boarding. In turn, this affects the growth of operational speed. Two fundamentally different cases can be considered here. First, the introduction of electronic fare collection system can ensure a situation where a passenger flow can be serviced by a smaller number of vehicles (situations of vehicle release). This situation occurs when the turnaround time is reduced to the value equal or greater than the available headway. In this case, the effect of the electronic fare collection system implemen-

tation can be measured in the operating costs reduction. Second, when the turnaround time reduction is less than actual headway and the same number of vehicles operates on the route, the implementation effect has an additional manifestation which consists of passengers waiting time and vehicle occupancy reduction.

Integration into the management and planning systems. Obtaining a smart card data information is useful for operating management and planning tasks to solve. For the dealing with the operating management tasks, the real-time crowding information is required. This data can be used in passenger information systems. In order to identify the number of passengers who do not pay for travel, a comparison of data on the number of passengers obtained using electronic fare collection systems and automatic passenger counting systems should be provided. It should be taken into account that automated passenger counting systems are prone to generate a measurement error to increase along with the vehicle occupancy level.

In order to obtain information on passenger flows, the combined use of electronic fare collection systems and automatic positioning systems should be provided. Systems in which passengers must use a smart card during boarding and disembarking directly provide information about the passenger exchange at the stops (places of the start and end of the journey). The availability of the information is important, for example, in the case of solving tasks of assessing the feasibility of limited-stops service, shortened lines etc.

It should be noted that systems in which the card is used only at the time of boarding the vehicle also make it possible to establish an OD matrix, but as a result of a longer observation period and with a greater error. For this purpose, additional calculation algorithms should be developed and applied. Completion of a missing information can be ensured by analyzing the sequence of activation of cards in space and time, for example, during transfers, determination of the journey stops origin during different day periods, etc.

Comparing systems of automated passenger counting and automated fare payment is possible to find a relationship of interchangeability and complementarity. These systems are interchangeable at the route level. The use of smart card data allows obtaining the additional transport demand information, analyzing the trips at the network level and considering the trip chains. From a theoretical point of view, smart card data can be used to study the passengers' transport behavior from a practical point of view – transit network optimization.

Implementation of the flexible fare system. The currently available in Ukrainian cities flat fare system for public transport services is not the best solution in modern practice. The main advantage of this system is simplicity. For a route, the fare is set, which is fixed and does not depend on the trip distance, travel time and period, level of services, etc. This is a fairly simple solution when the fare collection is left to the driver or conductor. The main drawback is the lack of justice. Under flat fare system, passengers who receive qualitatively different services pay the same money. This situation can become a barrier when implementing the policy to encourage city residents in using the public transport services in order to reduce the number of trips using individual cars. More socially fair conditions are provided to users under the introducing differentiated fare systems (by time or distance), zone fare and so on.

Conduction of the flexible fare policy. Formation of proposals to use of public transportation according to the «use more – pay less» principle. The possibility of the «mobility as a service» concept to allow the creation of fare options of using the systems of various city passenger transport modes, including the sharing micromobility systems, sharing car rental systems, taxi services, under one fare plan.

Development of reasonable income distribution system. The implementation of flexible fare and single smart card system provides for the simultaneous accumulation of funds received from payments with their subsequent distribution among the participants of the transport services market. The effectiveness of this effort is achieved only if the distribution system will be objective, justified and transparent. Objectivity can be achieved if the actual operating parameters and costs would be recorded in real time.

Increasing the attractiveness of scheduled passenger transport services. Another aspect related to increasing the attractiveness of scheduled passenger transport services is the reduction of negative perception of transfers. Its related with a number of aspects. First, transfers are usually associated with additional time costs (walking time during transfers, waiting at stops, usually greater non-linearity of connections). Under conditions, trips with transfers may take less time than direct trips (without transfers). For example, the combined use of shuttle routes and the subway can provide lower travel time costs compared to traveling without transfers only by bus services. Time savings can be more noticeable with the longer trip distance. At the same time, under the conditions of a flat fare, movement is associated with a higher toll. In this context, the application of differentiated or zonal fare systems creates conditions when transfers are perceived by passengers as less undesirable.

Most of the aspects mentioned are interrelated and should be considered together. However, the increasing in the scheduled passenger transport services attractiveness is the most common one. Some of the specified efficiency aspects arise as a natural result of electronic fare collection system implementation. This list can include comfort ensuring; transportation safety assistance (if under the existing system fare collection was performed by the driver); operational efficiency and passengers' travel time reduction.

Other aspects will require an additional action from the local authorities in order to promote a transport policy directed at the priority of the public transit development. In this case, the implementation of the electronic fare collection systems may consider as a precondition for their planning and applying. It lies in the following aspects:

- system integration;
- integration into the management and planning systems;
- implementation of the flexible fare system;
- conduction of the flexible fare policy;
- development of reasonable income distribution system.

In contrast to well-known studies in which the aspects of the electronic fare collection systems in public transport application were considered, the use of a systemic approach that combines individual functions from the standpoint of forming an integrated multimodal public transit system was proposed. The implementation of the above-stated approach needs the creation of an intelligent transport system that would integrate separate functions

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of the electronic fare collection system into controlling, managing and planning subsystems.

It should be noted that the measures proposed are of a theoretical nature and can be considered as the strategic directions for improving public transit operation in the Ukrainian cities. At the same time, bringing the tasks considered to the practical application is associated with a number of limitations. In our opinion, the main delaying factors lie in the financial, technical, technological and organizational spheres. In addition, the current situation of military aggression faced by Ukraine does not contribute to the public transportation improvement. From the above, the development of public transport will be a topical issue for the post-war reconstruction of Ukrainian cities.

Thus, some issues of expanding the functions of electronic fare collecting systems indicated in the article needs to be more studied at the tactical level. In particular, the implementation of a flexible fare policy is of the substantiation of fare options, fare value and system. Integration of electronic fare collection systems into the passenger transportation management and planning system requires the development of information systems originating from advanced intelligent technologies. These issues will be the focus of the future research.

4. Conclusions

The efficiency of implementing electronic fare collection systems in public transport should be expressed in several aspects. The following were highlighted:

– system integration;
– comfort ensuring;
– transportation safety assistance;
– operational efficiency and passengers' travel time reduction;
– integration into the managing and planning systems;
– implementation of the flexible fare system;
– conduction of the flexible fare policy;
– development of reasonable income distribution system;
– increase of the scheduled passenger transport services attractiveness.

Most of the mentioned aspects are interrelated and should be considered comprehensively. From a practical point of view, it is important to use systemic approach for integrated multimodal public transit system creation. It requires the development of an intelligent transport system that would integrate separate functions of the electronic fare collection system into controlling, managing and planning subsystems.

To increase the public transit services attractiveness in Ukrainian cities, the flexible fare system and policy conduction should be foreseen based on the principle «use more – pay less» and provide the different tariff options.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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References

1. Hora, J., Dias, T. G., Camanho, A., Sobral, T. (2017). Estimation of Origin-Destination matrices under Automatic Fare Collection: the case study of Porto transportation system. *Transportation Research Procedia, 27,* 664–671. doi: https://doi.org/10.1016/j.trpro.2017.12.103
2. Pelletier, M.-P., Trépanier, M., Morency, C. (2011). Smart card data use in public transit: A literature review. *Transportation Research Part C: Emerging Technologies, 19 (4),* 557–568. doi: https://doi.org/10.1016/j.trc.2010.12.003
3. Kim, H., Faroqi, M., Mesbah, J. (2018). Applications of transit smart cards beyond a fare collection tool: a literature review. *Advances in Transportation Studies, 45,* 107–122.
4. Mohamed, K., Côme, E., Baro, J., Oukhellou, L. (2014). Understanding passenger patterns in public transit through smart card and socioeconomic data. *ACM SIGKDD Workshop on Urban Computing.*
5. Morency, C., Trépanier, M., Agard, B. (2007). Measuring transit use variability with smart-card data. *Transport Policy, 14 (3),* 193–203. doi: https://doi.org/10.1016/j.tranpol.2007.01.001
6. Ma, X., Wu, Y.-J., Wang, Y., Chen, F., Liu, J. (2013). Mining smart card data for transit riders' travel patterns. *Transportation Research Part C: Emerging Technologies, 36,* 1–12. doi: https://doi.org/10.1016/j.trc.2013.07.010
7. Zhao, J., Zhang, F., Tu, L., Xu, C., Shen, D., Tian, C., Li, X.-Y., Li, Z. (2017). Estimation of Passenger Route Choice Pattern Using Smart Card Data for Complex Metro Systems. *IEEE Transactions on Intelligent Transportation Systems, 18 (4),* 790–801. doi: https://doi.org/10.1109/tits.2016.2587864
8. Arbex, R., Cunha, C. B. (2020). Estimating the influence of crowding and travel time variability on accessibility to jobs in a large public transport network using smart card big data. *Journal of Transport Geography, 85,* 102671. doi: https://doi.org/10.1016/j.jtrangeo.2020.102671
9. Bieler, M., Skretting, A., Budinger, P., Gronli, T.-M. (2022). Survey of Automated Fare Collection Solutions in Public Transportation. *IEEE Transactions on Intelligent Transportation Systems, 23 (9),* 14248–14266. doi: https://doi.org/10.1109/tits.2022.3161606
10. Jittrapirom, P., Caiati, V., Feneri, A.-M., Ebrahimigharehbaghi, S., González, M. J. A., Narayan, J. (2017). Mobility as a Service: A Critical Review of Definitions, Assessments of Schemes, and Key Challenges. *Urban Planning, 2 (2),* 13–25. doi: https://doi.org/10.17645/up.v2i2.931

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