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INTELLIGENT TRANSPORT SYSTEMS IN PUBLIC TRANSPORTATION – A CASE STUDY

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Purpose: The study aimed to assess the effectiveness of implementing modern ticket distribution channels in Bydgoszcz's public transportation, with research questions regarding the ticket distribution channels most frequently used by passengers and the impact of new technologies on single-use and periodic ticket sales.
Design/methodology/approach: The study employed a case study method and analysis of the documentation provided by the Municipal Roads and Public Transportation Authority [Polish: Zarząd Dróg Miejskich i Komunikacji Publicznej] in Bydgoszcz. It covered ticket sales data for 2019-2022. Statistical methods and data visualizations were used to identify trends and compare the sales results.
Findings: A dynamic increase in e-ticket sales, particularly via mobile applications and the Bydgoszcz City Card [Polish: Bydgoską Karta Miejska (BKM)], has been noted in 2019-2022. Single-use ticket sales via vending machines increased by 25%, and periodic ticket sales by 15%. The impact of the COVID-19 pandemic was particularly evident in 2020, when passengers shifted *en masse* to remote channels. The research has confirmed that passengers value the convenience and accessibility of modern ticket purchasing methods. Sales process automation and procedure simplification have significantly increased the attractiveness of public transportation.
Originality/value: The study has confirmed that the implementation of modern technologies has contributed to the increase in ticket sales in Bydgoszcz, while e-ticketing and mobile applications have alleviated the barriers to ticket accessibility. It is therefore recommended to expand the function of the Bydgoszcz City Card, by, e.g., integrating it with additional city services, and promoting mobile applications as the primary ticketing channel.
Keywords: public transportation, ticket distribution, intelligent transport systems.
Category of the paper: case study.

1. Introduction

In today's dynamic urban environment, the complex challenges of public transportation call for innovative and effective solutions. One of the key aspects of improving the quality of urban transportation entails optimization of the process involved in facilitating dynamic information on its operation, as well as improvement of ticket distribution channels, affecting directly the comfort of passengers and the availability of public transportation services (Bogacki, Bździuch, 2017). The present study is centered on a general presentation of the subject of urban public transportation, with particular emphasis on the application of modern technology in transportation, in this case, with regard to ticket distribution in public transportation as an element contributing to increased numbers of passenger, on the example of the city of Bydgoszcz (Goras, Gadziński, 2019)

As one of the country's major dynamic urban centers, Bydgoszcz has been targeting ambitious urban mobility goals. The city and its local transportation agency - the Municipal Roads and Public Transportation Authority [Polish: Zarząd Dróg Miejskich i Komunikacji Publicznej (ZDMiKP)] – need to ongoingly respond to the constant challenges involved in increasing the efficiency and attractiveness of public transportation through implementation of modern ITSs, including DPI (Dynamic Passenger Information systems) and single-use and periodic ticket distribution systems. It is the online public transport search engines and the systems facilitating the purchase of tickets which are the first elements residents, prospective bus or trolley passengers, interact with.

The trigger for an in-depth study of ticket sales levels in the various distribution channels came from the noticeable changes in passengers' ticket purchase preferences, the widely introduced cashless payment, and the uptake of single-use and periodic e-tickets. One additional stimulus noticeably affecting ticket distribution channels was the COVID coronavirus pandemic, which effected an evolution throughout the entire public transportation system, indicating that adequate introduction of innovative ticket distribution solutions holds potential (Grzegorzewski, 2020). New ticket distribution technologies, as well as new e-ticket offers, such as cards, in-app tokens, and QR codes, not only have streamlined the process of consuming the service of transportation, but also increased the attractiveness of public transportation for the residents of Bydgoszcz (Krawiec K., Krawiec S., 2019).

2. Public transportation and modern ticketing technologies

Basic transportation infrastructure constitutes a key component of the world's economic structure. It comprises the fundamental means and institutions essential to the movement of people and the transfer of material goods. Transportation entails a complex system, encompassing all activities involved in the movement of people and goods, including cargo management and essential logistics. Transportation infrastructure consists of a variety of engineering elements, such as roads, railroads, ports, airports, intermodal terminals, and advanced technologies essential in traffic flow optimization, e.g., traffic signals, transmission stations, power supply facilities, transshipment and forwarding sites. In shaping the development of transportation infrastructure, the institutions managing transport organization play an important role by ensuring safe, efficient and sustainable transportation of people and goods (Gadziński, Goras, 2019).

Efficient management of transport and mobility in urban areas has become one of the most important policy issues for local governments. Modern cities are places characterized by particularly highly-concentrated movement of people and goods within a small area. This causes significant exacerbation of transportation problems. Typically, the needs and expectations of different traffic participants, businesses or residents vary greatly. Also, the effects of transport activities can substantially affect the environment - the natural environment, public space, urban development. It is therefore imperative today to carry out transportation development policies in the most sustainable manner possible (Szubra, 2017; Obserwatorium Polityki…, 2021).

Mobile technologies have become a permanent aspect of our daily lives, and the use of a combination of such technological features as Wi-Fi, cell phone networks, GPS, RFID, as well as the widespread availability of the Internet, open up new pathways of obtaining and communicating information relevant to various aspects of our lives (Kumar Singh, Singh, Zear, 2016). One area in which the above-mentioned technologies can substantially improve our information needs is public transportation. The various technological solutions employed in this sector not only can expedite and facilitate traveling by public transportation, but also render it more enjoyable. In specific cases, they can even contribute to improved travel comfort and safety.

The nature of public transportation dictates the movement of the means of transport in accordance with a fixed timetable providing key information to passengers regarding the planned route and hours. Traditionally, passengers acquire this knowledge from paper placards displayed by the carriers at bus stops. Despite the widespread use of this solution, it does come with some inconveniences. First, in order to obtain timetable information, passengers need to visit a given stop in person. Second, the timeliness of the information displayed at bus stops depends on the regularity of the carriers' activity in this regard. Even temporary timetable

changes oblige them to update the placards at each stop. When changes are not physically posted on bus stop placards, passengers are presented with outdated information. Third, placards in public places are exposed to vandalism. It is well known that passengers are obliged to pay the fares for the public transport vehicle service when using public transportation. The traditional fare payment procedure is to purchase and validate a ticket, but this classic method entails certain inconveniences. To purchase a ticket, passengers must first locate an active ticket outlet. Another inconvenience lies in the need to pay in cash for the ticket, and when purchased from the bus driver, exact change is often requested. Moreover, a paper ticket is subject to damage, such as crushing, tearing or dampening.

One solution to the above problems is to render timetable information independent of its physical representation in the form of traditional bus stop placards, by posting it on the Internet. This solution comes with a number of advantages, including up-to-dateness of the timetables displayed, owing to the feasibility of simple modification, as well as accessibility anyplace Internet service is available. Standard placards can also be replaced by variable message boards displaying dynamic public transportation schedule information directly at bus stops (Miller, 2012).

The road infrastructure investment constraints widely encountered at the turn of the last few years, as well as the terrain limitations on the expansion and construction of new urban transportation infrastructure, with a simultaneous rapid increase in the rate of motorization, have led to increased development of road telematics systems. The availability and spread of road telematics has been positively received by road managers and transportation authorities, who have launched investment activities in this area. Modern traffic management systems, utilizing the broad concept of telematics, have also found application in Poland over the past dozen or so years, especially on urban roads, the multifaceted functions of which can thereby be combined with existing smart city solutions, yielding tangible benefits by utilizing the maximum capabilities of the existing transportation infrastructure.

The idea of solutions generally referred to as Intelligent Transportation Systems (ITSs) was officially endorsed at the inaugural World Congress on Intelligent Transport Systems held in Paris in 1994. ITSs are complex systems employing a variety of technologies to optimize traffic and transportation, improve safety, environmental protection and the ability to actively manage transportation systems using reliable data. They are characterized by high efficiency, flexibility and, most importantly, adaptability to changing traffic conditions (Wałek, 2021).

3. Research methodology

The article aimed to analyze and assess the application of modern technologies in public transportation ticket distribution in Bydgoszcz, including its impact on the increase in passenger numerosity. In achieving this objective, the focus was on the analysis of the source materials providing data on ticket sales in individual ticket distribution channels across the territory of the city of Bydgoszcz, acquired from the local transportation authority - the Municipal Roads and Public Transportation Authority in Bydgoszcz (Mennica Polska..., 2023). The study has also analyzed the level of ticket sales via the available distribution channels in 2019-2022. As a background to the analysis, a general characteristic of urban transportation and the qualitative and quantitative changes affecting it is presented, describing in particular the ticket distribution channels available in Bydgoszcz.

4. Research results

The city of Bydgoszcz is located in the central part of Poland. It forms a robust industrial, commercial, academic and cultural center. Currently, Bydgoszcz, due to its decreasing in size and aging population, is facing an unfavorable demographic situation, affecting its socio-economic development. The trend of population decline in Bydgoszcz results mainly from the observed suburbanization of Polish metropolitan areas, with residents of such cities as Bydgoszcz moving to the outskirts or the neighboring sparser municipalities serving as suburbs. With the creation of optimal working conditions and the optimization of the city's transportation development, the percentage of registered unemployed residents decreased in 2001-2022. The difference between 2001 and 2022 totaled as much as 7 percentage points. As one of the largest economic centers in the country, Bydgoszcz too maintains a well-developed transportation network within the city. The foundation of a sound transportation system within a city is a well-developed road and track infrastructure system.

The ongoing study of traffic volumes, the implementation of measure-appropriate road system modernization as well as the application of proven and repeatable engineering solutions contribute to traffic safety improvement and encourage the use of the infrastructure. Today, systematic monitoring of the changing traffic realities and road users' behavior is facilitated by modern measuring devices and the widely used video monitoring. One example of modern solutions in automatic traffic monitoring, traffic management and public transport optimization is the ITS implemented in 2015 as ‘Intelligent Transport Systems in Bydgoszcz [Polish: Inteligentny Systemy Transportowe w Bydgoszczy].’ The various subsystems comprising it have been implemented under a single master application serving as a specialized tool enabling

visualization of the events occurring in the city's transportation system at the Traffic and Transportation Management Center [Polish: Centrum Zarzadzania Ruchem i Transportem] of the Municipal Roads and Public Transportation Authority [Polish: Zarząd Dróg Miejskich i Komunikacji Publicznej] in Bydgoszcz.

Owing to the modernization of bus and trolley fleets in many Polish cities, a steady increase in passenger satisfaction with the quality of public transportation services has been observed. This is attributable to, inter alia, the equipment of new vehicles with additional devices and systems.

Nowadays, a growing number of public transport passengers expect solutions improving travel comfort, providing access to current transport service information, as well as facilitating access to transport services via modern mobile devices, Internet-based access channels, cashless payments and virtual tickets. People today, most of whom own smartphones and payment cards, seek to maximize the use of these functionalities in the process of daily commuting.

Active use of the transportation services provided by urban public transportation entails possession of a fare ticket. A ticket represents a type of contract, between a passenger and a carrier, for a specific route, including the conditions under which the trip is to be realized. The number of single-use and periodic ticket sales reflects, so to speak, the degree of growth in the interest in a given city's public transportation services, i.e., it characterizes directly the increase in the number of passengers.

Both traditional (paper) and electronic tickets are operable in Bydgoszcz. The most popular form of e-ticketing is the Bydgoszcz City Card, on which periodic tickets are encoded. In addition to encoding tickets on the so-called BKM [Polish: Bydgoska Karta Miejska], tickets can also be encoded in electronic form on payment cards and electronic student ID cards. This varied form of public transport tickets has forced the introduction of different types of ticket distribution channels.

To acquire information on the changes in seasonal revenues from the sale of single-use and periodic tickets, taking the differentiation into available ticket distribution channels during the period 2019-2022 into account, data from the transportation authority – ZDMiKP - in Bydgoszcz was obtained.

In the analyzed period, i.e., 2019-2022, a change has been observed in the ticket purchasing method preferences, caused by the spread of new distribution channels employing modern IT solutions, the progressive abandonment of traditional paper tickets in favor of virtual tickets encoded on various types of media, e.g., the Bydgoszcz City Card, or in the applications available on mobile devices and smartphones. The move towards the use of new digital ticketing technologies, in many aspects of daily life, has been an inevitable and desirable process for the majority of the population.

The Covid pandemic, which in Poland began in late February/early March 2020, also contributed significantly to the change in consumers' ticket purchasing practices. The event of this magnitude, global in scope, was the first since the outbreak of World War II. The sudden

imposition of numerous restrictions on the population, including restrictions on the use of public transportation, and the general widespread fear of coming into close contact with anything and anyone caused a sudden drop in ticket sales.

The results of the survey indicate significant changes in the single-use ticket purchasing method offered in available distribution channels during 2019-2022. The previously widely used channels of single-use ticketing, i.e., ticket vending machines, mobile ticket machines or information kiosks, were displaced by more modern distribution channels utilizing internet-based, cashless payments, including the Open Payment System (OPS) enabling contactless in-vehicle payments, launched at the end of 2018. The turning-point year in the distribution of single-use tickets was 2020, when as many as 5 out of 6 distribution channels recorded ticket sales declines. The only channel with further increases was the OPS cashless, contactless sales, processed in public transportation vehicles directly. The sales declines in the remaining distribution channels, ranging in volume from 26% to as much as 54%, coincided with the coronavirus pandemic and the restrictions imposed on the use of public transportation. In 2021, ticket sales significantly increased in two modern channels: OPS and mobile phone applications. Other channels either saw minor increases or continued declines; or, as in the case of information kiosks, sales via such devices were discontinued altogether. By the end of 2022, only 4 channels of single-use ticket distribution survived on the Bydgoszcz market: one of the old type, i.e., ticket vending machines, with 3 modern channels geared up for electronic ticket distribution (QR code, token): OPS, terminals, and mobile phone applications, which dominated the sales.

In the case of periodic tickets, no such significant intensification of the purchasing trend, e.g., as the one observed in the sale of single-use tickets, has been noted in modern distribution channels. Periodic tickets have been for years available in electronic form exclusively, encoded on various types of media: city cards, payment cards, student IDs. Periodic tickets have been around for a long time in the digital world, thus are less sensitive to the changes presently offered by modern distribution channels. In analyzing the source data on the proceeds from the sale of periodic tickets via different distribution channels in different years, and referencing it against the level of ticket sales in 2019, a variation in the sales has been observed. The largest decrease in sales occurred in 2020, as in the case of single-use tickets. This decline was caused by the restrictions of the Covid coronavirus pandemic and the limitations in the use of public transportation. Immediately after the largest sales declines in the third quarter of 2020, an additional new distribution channel, linking periodic tickets with payment cards, was introduced, which was welcomed by passengers. In 2021, a rebound in sales has been noted, shifting to an upward trend in most of the available distribution channels, reaching, in 2022, a sales increase in all five channels enabling the purchase of periodic tickets today. The largest increases in 2022 have been noted in ticket purchases via the Internet (44%), using payment cards (47%) and at the transport authority's ticket counters, which saw a sales increase of up to 61%, owing to the introduction of new-user price preferences for the purchase of

periodic tickets (for people who have not used periodic transport tickets for at least a year), available only at the ZDMiKP ticket counters in Bydgoszcz.

Public transport passengers, through their choice of new distribution channels relying on electronic (virtual) ticketing and electronically encoded periodic tickets, have indicated a clear direction of their preferred further growth of public transport fare collection in Bydgoszcz. The passengers' choice of ticket purchasing at locations in the immediate vicinity of the means of transport, via an app or at the ticket machines installed in the vehicles, is now an indication of a new trend in the city's transportation system, as evident from the analysis. Further expansion of modern ICT-based distribution channels has been gaining passengers' acceptance. One example of a swiftly accepted novelty in the city's public transportation system was the implementation, in 2018, of the OPS - direct payment for travel using payment cards, which quickly became a leading modern ticket purchase channel, as confirmed by the continually growing number of users purchasing tickets via the OPS.

Conclusion

The study indicated that the sales of single-use and periodic tickets via modern distribution channels, such as OPS, mobile apps and the Internet, shows an upward trend, compared to traditional methods involving stationary devices or sales at ticket counters. The introduction of these channels contributed to halting the decline in public transport ticket sales triggered by the Covid-19 pandemic, bringing the sales back to pre-pandemic levels. Modern solutions, employing remote and online sales, have been received positively both by passengers purchasing single-use tickets as well as periodic ticket users.

Ticket machines have been observed to be location-dependent in their popularity - interest in devices installed directly in vehicles and allowing contactless payments has been growing, while stationary ticket vending machines, located outside vehicles, have been losing momentum. After the Covid-19 pandemic, the trend in using modern distribution channels has solidified, indicating this change to be permanent. Moreover, distribution channels relying on cashless flows and ticket virtualization, such as QR codes or other forms of coding, may benefit transport authorities in the long run, by reducing the cost of maintaining these systems.

In conclusion, the increased revenues from ticket sales via modern distribution channels indicate a growing interest in such purchases, which translates into an increase in the number of public transport passengers utilizing these solutions.

References

1. Bogacki, M., Bździuch, P. (2017). *Transport miejski i regionalny*. Warsaw: Stowarzyszenie Inżynierów i Techników Komunikacji Rzeczypospolitej Polskiej.
2. Gadziński, J., Goras, E. (2019). *Obserwatorium Polityki Miejskiej "Raport o stanie polskich miast – Transport i mobilność miejska"*. Warsaw: Instytut Rozwoju Miast i Regionów, p. 8.
3. Goras, E., Gadzinski, J. (2019). *Raport o stanie polskich miast - Transport i mobilność miejska.* Warsaw: Instytut rozwoju Miast i Regionów.
4. Grzegorzewski, R. (2020). Wpływ pandemii na zmianę zachowań komunikacyjnych, poziom sprzedaży biltów i preferencji wyboru kanałów dystrybucji biletów. *Biuletyn komunikacji miejskiej*.
5. Krawiec, K., Krawiec, S. (2019). *Transport Miejski i Regionalny*.
6. Kumar Singh, P, Singh, Y., Zear, A. (2016). Intelligent Transport System: A Progressive Review. *Indian Journal of Science and Technology*.
7. Mennica Polska S.A, in cooperation with ZDMiKP in Bydgoszcz (2023). *Koncepcja wdrożenia internetowego systemu sprzedaży biletów okresowych komunikacji miejskiej, których identyfikatorem jest bankowa zbliżeniowa karta płatnicza.*
8. Miller, P. (2012). *Technologie mobilne usprawniające korzystanie ze środków komunikacji publicznej na przykładzie rozwiązań stosowanych w miejskim przedsiębiorstwie komunikacyjnym*. Studia i Materiały Polskiego Stowarzyszenia Zarządzania Wiedzą. Łódź.
9. Szruba, M. (2017). *Rozwój budowy dróg i nawierzchni drogowych*, pp. 46-48.
10. Wałek, T. (2021). *Inteligentne Systemy Transportowe jako instrument poprawy bezpieczeństwa.* Security, Economy & Law.