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OPTIMIZING PARKING OPERATIONS USING SMART CITY SOLUTIONS

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Purpose: The aim of the research was to compare the functioning of paid parking systems in two cities – Rzeszów and Košice – and to identify their optimization potential.
Design/methodology/approach: The research results presented in this paper were obtained through the use of benchmarking methods, document analysis, and expert interviews. The comparative analysis allowed for the compilation of data on paid parking systems in the analyzed cities. The analysis of city documents allowed for a review of mobility strategies and city reports. Expert interviews were conducted with city hall employees in Rzeszów and Košice responsible for the operation of the paid parking system to obtain information on the principles of operation, organizational structure and planned directions of development of the system.
Findings: In the context of the cities being compared, analyzing optimization opportunities allows us to assess which solutions are most effective in a given urban environment and how they can be adapted to other cities. Conclusions from such a comparison can form the basis for formulating recommendations for effective parking space management and the development of intelligent mobility systems.
Research limitations/implications: The research conducted is based on secondary data from official city sources, reports, and resolutions. It doesn't include empirical verification of user opinions.
Practical implications: The research results can serve as diagnostic and advisory material for local decision-makers when designing urban mobility policies.
Social implications: In the broader perspective, paid parking systems that help reduce the number of cars in city centers can contribute to improving residents' quality of life by reducing traffic congestion, noise, and air pollution. They therefore play a significant role in achieving sustainable development goals and promoting more conscious travel behaviors in urban society.
Originality/value: This work presents a comparison of similar mid-sized cities, allowing for a focus on technological and organizational factors while eliminating the influence of social and economic differences. Another original element of the work is an attempt to identify optimization potential in the context of different countries, which may be useful for city decision-makers planning modernization or introducing new parking solutions based on international experience. This ensures that the research results have practical and cognitive value, offering implications for both science and urban mobility management practice in various countries.
Keywords: smart city, paid parking system, intelligent parking, sustainable urban management.
Category of the paper: research paper.

1. Introduction

Modern cities face enormous challenges related to traffic management and limited parking space. The increase in the number of private vehicles in recent decades has led to problems such as congestion in city centers, excessive exhaust emissions, and a decline in residents quality of life. One of the key tools local governments use to mitigate these phenomena is paid parking systems. Their primary function is not only to generate revenue for the city budget but, above all, to regulate demand for parking spaces through the use of economic mechanisms. From a transport policy perspective, an effectively designed paid parking system can serve as an optimization tool, balancing driver needs with the efficient use of urban space. Key elements include the tariff structure, paid parking zones, digital systems for managing payments (e.g., mobile apps, e-parking meters), and mechanisms for dynamic pricing based on demand. Recent years have seen a growing interest in cities implementing smart parking solutions that combine IT technologies with real-time data analysis. These solutions not only enable better parking space management but also reduce search traffic, resulting in reduced congestion and emissions (Bismantoko et al., 2018). Smart Parking Systems utilize technologies such as space occupancy sensors, mobile applications, real-time information systems, and electronic payments to increase the efficiency of urban space use and reduce traffic congestion. Implementing such solutions aligns with the concept of a smart city, which bases decisions on data and strives to optimize urban processes through the digitalization of public services (Attaran et al., 2022; Battarra et al., 2018; Zapolskyt et al., 2020).

The authors of many studies on parking management focus on optimizing the use of the limited number of parking spaces in cities. The goal of optimization is primarily to promote sustainable urban mobility. Through appropriately designed pricing policies, zoning, and the use of digital technologies, paid parking systems can influence residents' travel behavior and reduce excessive car traffic in city centers. These include research areas such as forecasting parking space occupancy using data from actual parking systems (Badii et al., 2018; Balmer et al., 2021), determining indicators describing system efficiency (Cats et al., 2016; Kuo et al., 2024; Zhu et al., 2018), and research on technical solutions for intelligent parking (Alkheder et al., 2016; Singh et al., 2022; Bismantoko et al., 2018; Hilmani et al., 2018).

Despite the extensive literature on urban parking policy, there is still a lack of comparative studies that consider the international context and analyze the optimization potential of existing solutions. Comparing paid parking systems in different cities allows for an assessment of the effectiveness of the solutions implemented and their optimization potential. The selection of two urban units with diverse spatial structures and approaches to transportation policy allows us to see the extent to which administrative and technological decisions influence the effectiveness of parking space management. Such an analysis can serve as a starting point for formulating recommendations for local governments regarding the further development of

parking systems, taking into account user needs, sustainable mobility principles, and the potential use of analytical and optimization tools.

The aim of this article is to compare paid parking systems in two selected mid-sized cities and assess their potential for optimizing urban space utilization and improving traffic flow. The analysis will consider aspects such as the systems' organizational structure, fee calculation method, technological solutions, and the effects of implemented regulatory mechanisms.

2. Methods

The aim of the study is to compare the operation of paid parking systems in two cities across different countries and identify their optimization potential. To achieve this goal, a variety of qualitative and quantitative research methods were employed: document analysis, benchmarking, and expert interviews. The use of several complementary methods allowed for a more comprehensive and credible picture of the phenomenon under study. The primary research method was document analysis, which involved a systematic review and interpretation of available written sources regarding the operation of paid parking systems. Primarily, official and planning documents were used, such as city council resolutions, paid parking zone regulations, reports on the activities of system operators, and city transport strategies. This qualitative analysis allowed us to determine the formal foundations of the systems operation, their organizational structure, pricing principles, zone validity periods, and the technological solutions used. The information obtained served as a starting point for further comparative analysis and interpretation of differences between the studied cities. The second method employed was comparative analysis, aimed at comparing and assessing selected features of the paid parking systems in the two cities in terms of their effectiveness, organization, and accessibility. Benchmarking allows for the identification of good practices and solutions used in various urban centers, which can serve as models or benchmarks for other local government units. The study utilized a mixed quantitative and qualitative approach. On the one hand, a set of measurable indicators was analyzed (e.g., the number of parking spaces and rates), while on the other, a descriptive interpretation of differences in pricing policies, space management, and the implementation of technological solutions was provided. This allowed for the benchmarking not only to compare numerical values but also to understand the organizational and legal context of the systems' operation. Document analysis and benchmarking were supplemented by expert interviews, which allowed us to obtain information directly from city hall employees in Rzeszów and Košice who have knowledge and experience in managing paid parking systems. Questions addressed, among other things, the objectives of introducing the paid parking system, its operational principles, management tools used, and development plans. The data obtained from the interviews allowed for a deeper quantitative

analysis with a practical and interpretative perspective, revealing the factors determining the effectiveness of individual solutions.

3. Research object

Two medium-sized cities – Rzeszów (Poland) and Košice (Slovakia) – located directly adjacent to the Polish-Slovak border were selected for the analysis. Rzeszów and Košice were chosen as the study subjects due to their similar size, administrative functions, and similar challenges related to the organization of paid parking systems. Both cities are regional development centers experiencing increasing traffic volumes and the need for effective parking space management. The aim of the analysis is to identify optimization measures and indicators that influence the efficiency, accessibility, and social acceptance of paid parking systems. Comparing Rzeszów and Košice will allow for the identification of differences in organization, technology, pricing policy, and integration with the urban transport system, as well as for identifying areas where improvements or the adoption of best practices are possible.

Rzeszów is a voivodeship capital located in southeastern Poland. It has a population of 198,000 and covers an area of 129.01 km² (Figure 1). The city is the capital of the Podkarpackie Voivodeship and a major economic, commercial, industrial, cultural, and academic center. It is located at the intersection of important road routes, close to the borders with Slovakia and Ukraine. Rzeszów has a clearly defined downtown development zone, which has a radial-concentric layout, with industrial and residential districts clearly demarcated. Within Rzeszów, transportation needs are met by public transport, including buses and individual vehicles. Individual transportation within the city requires access to infrastructure, including parking spaces. The current paid parking zone was established in 2016 (Dobrzański et al., 2023). A detailed description of the zone is presented in the Results section.

Figure 1. An overview map showing the location of the analyzed cities.
Source: Own study.

The second city analyzed is Košice. It is the second largest city in Slovakia, located in the eastern part of the country, and serves as a regional economic, cultural, and transportation center (Figure 1). Covering an area of approximately 243.7 km² and with a population of approximately 225,000, the city is a significant urban and metropolitan hub. In terms of transportation, Košice plays a significant role in the national and international transportation network – expressways and European routes, including the E571, run through the city, and the existing bypass helps alleviate transit traffic in the city center. Within the city, there is a well-developed public transportation system, including buses and an active tram network, which is a key element of public transportation. A paid parking zone was introduced in Košice in 2009 and was modified in 2023. Detailed characteristics of the zone is presented in the Results section.

4. Results

The aim of this research phase was to determine the extent to which the solutions operating in the two analyzed cities meet the assumptions of an effective paid parking system and what optimization potential they demonstrate. The analysis is based on a combination of selected organizational, economic, functional, and socio-environmental indicators, which allow for the assessment of the effectiveness and development of the systems studied. The use of indicators enables a comparative assessment based on objective data from publicly available sources, such as city reports, strategic documents, and data from city hall staff in Rzeszów and Košice managing the paid parking systems. The indicators were selected to capture key aspects of the systems' operation: from their organizational structure and tariffs, through economic efficiency, to social and environmental impact. The indicators were divided into four main groups:

- organizational, describing the scale and structure of the system,
- economic, relating to tariff policy,
- functional, relating to the availability of parking spaces and technology,
- socio-environmental, illustrating the impact of the system on residents and the quality of life in the city.

4.1. Organizational indicators

Analysis of organizational metrics allows us to identify areas requiring improvement and implement optimization measures, such as better adapting zones and the number of spaces to actual demand, modifying fee collection hours, or implementing modern digital solutions that increase the efficiency and availability of the parking system. The metrics detailed here include the number of paid parking subzones, the number of spaces subject to fees, the area of paid zones, the hours of application of fees, and the level of system digitalization.

In the case of Rzeszów, the range of the external border of the Paid Parking Zone in Rzeszów was determined primarily taking into account the natural boundaries occurring in the city space such as the river bed, railway tracks (Figure 2). Initially, the zone consisted of two subzones: I and II. In 2020, it was expanded to include two additional subzones: III and IV. Subzone I, marked in blue, covers the city center and downtown Rzeszów, including the area around the train station. Subzone II, marked in orange, covers the areas surrounding the city center. Subzone II complements Subzone I. This area surrounds subzone I and is not interrupted by it anywhere. Subzone II serves a crucial function, separating subzone I from the area without parking restrictions to the south, where there is no natural boundary. Besides providing convenient parking for residents, an additional benefit of the buffer zone is that the cars parked in the blue subzone are distributed over a much larger area, improving the overall parking situation in the Paid Parking Zone. The remaining two subzones, III and IV (green and red), encompass the area of two residential developments. The layout of each subzone is shown in Figure 2a. In Rzeszów, the zone is valid on weekdays, Monday through Friday, from 8:00 a.m. to 8:00 p.m. Parking is free at all other times and days. The Municipal Market and Parking Administration in Rzeszów, an organizational unit of the Rzeszów City Hall, has been appointed as the administrator of the Paid Parking Zone (Municipal Market and Parking Administration in Rzeszów, 2025). In 2021, in cooperation with the Rzeszów Municipality and Asseco Data Systems S.A., a parking space metering system was created within the Paid Parking Zone (Asseco Poland SA, 2025). Rzeszów is the first and only city in Poland to implement this type of solution for monitoring available parking spaces, based largely on camera image analysis, on such a large scale. This system perfectly aligns with the Smart City concept. The metering covers subzones I and II, and partially subzone IV. Subzone I contains 1,577 public parking spaces, and subzone II has 542 spaces. All are metered. Zone III contains 919 public parking spaces that are not metered, while Subzone 4 contains 453 public parking spaces, 81 of which are metered. The entire Paid Parking Zone has a total of 3,491 parking spaces. The area covered by the Paid Parking Zone is 3.8 km², of which Subzone I covers 1.06 km².

Residents can use the e-PARKING mobile app, available on Android and iOS. This app is a crucial part of the parking space occupancy information system in Rzeszów's Paid Parking Zone. It provides drivers with the most up-to-date and detailed information about available and occupied spaces. This information is generated based on data from cameras and sensors that continuously monitor and analyze parking space occupancy. The app is designed to support users in real-time while searching for available spaces, and at the end of the journey, present individual available spaces within the selected parking area. The app utilizes navigation provided by Google Maps. The app simplifies the user's search for available parking spaces. The map displayed within the app makes it easy to locate available spaces. During navigation, the system continuously verifies whether the selected parking lot still has spaces. If all spaces are occupied, the app has mechanisms that notify the driver in advance, allowing them to react

and potentially change their destination to a new space suggested by the system near their initial choice. While navigating to a destination, the app also reports the number of drivers heading to the same parking lot at the same time. The app menu also includes a function that allows you to start a countdown to the end of your paid parking time if you paid at a parking meter. Before the designated time expires, the app sends the user a reminder, allowing you to avoid additional fees for exceeding the parking time. In Rzeszów, variable message boards have also been implemented, providing information on the level of available parking spaces.

In the case of Košice, before 2023, the Paid Parking Zone consisted of: a central urban subzone, 10 subzones for residents, and special parking lots (excluding the central urban subzone and the residential zones). This division was based on the concept of static traffic solutions, with minor changes within the zone boundaries. Parking spaces in these zones (excluding parking lots with barriers) are primarily linear parking lots along sidewalks and roads – with the possibility of longitudinal, diagonal, or perpendicular parking. The regulations also cover so-called barrier parking lots with regulated entry, which are subject to a special tariff system and are located within the Paid Parking Zone or are part of special parking lots. In 2023, changes were introduced, resulting in six zones and special parking spaces being designated (Figure 2). The first subzone, designated as A, covers the city center, while the remaining five subzones are so-called residential zones. Special parking spaces are located near the shopping center and the Public Cemetery. The layout of the individual subzones is shown in Figure 2b. There are 8,099 parking spaces in the paid parking zone. The paid parking zone in Košice operates at different hours depending on the tariff zone type. Information on its validity periods is presented in Table 1. The area covered by the Paid Parking Zone is 4 km², including subzone A covering 1.44 km².

a) b)

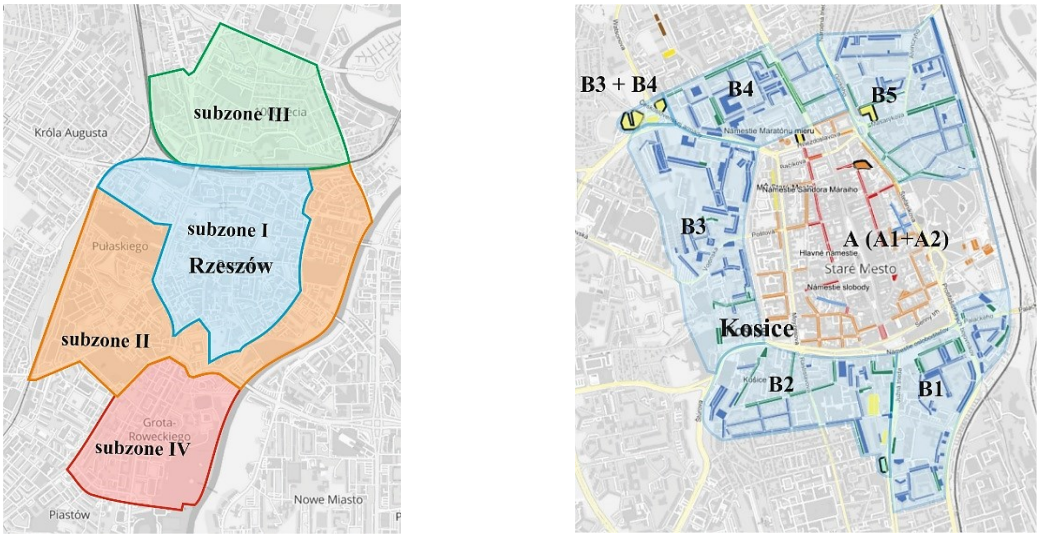

Figure 2. Paid parking zones in the cities of Rzeszów and Košice.

Source: own study based on data from the parking.kosice.sk – 06.10.2025.

Table 1.
Charging period in Košice Paid Parking Zone

Tariff zone	Basic rate (30 min.)
A1	Mon. – Sat. 00:00 – 12:00 a.m.
A2	Mon. – Sat. 00:00 – 12:00 a.m.
BN	Mon. – Fri. 07:30 – 18:00 p.m.
CN	Mon. – Sun. 07:30 – 04:00 p.m. (max. 4 hours per day) Outside of charging hours, parking is only possible with a resident card or local subscription card.
N	Mon. – Fri. 07:30 – 18:00 p.m.

Source: parking.kosice.sk – 06.10.2025.

Until 2019, the Paid Parking System was managed by the private company EEI a.s. Subsequently, the Košice Municipality, specifically the Department of Parking, Road Maintenance, and Public Lighting at the Košice City Hall, took over exclusive management of the zone (Kosice City Hall, 2025). This year, the City of Košice developed a conceptual plan – Smart City Košice, which envisages the introduction of an intelligent parking system, including space occupancy sensors, navigation to available spaces, and smart payment. Currently, mobile apps enable payment for parking.

4.2. Economic indicators

Economic indicators encompass the financial aspects of the paid parking system, such as the hourly rate structure, subscription fees, resident discounts, and pricing policy, as well as the average hourly cost of parking. These indicators allow us to assess the profitability and sustainability of the system, as well as the extent to which prices and tariffs meet actual user needs and the city's budget. Analyzing these indicators allows us to understand the impact of the adopted pricing policy on driver behavior and the efficiency of parking resource management.

Drivers parking in the Rzeszów Paid Parking Zone are required to pay the parking fee using one of the following methods: purchasing a parking ticket from a parking meter with a clearly defined parking time and vehicle registration number; paying via a mobile payment system; or purchasing one of the available subscription types. Monitoring the Paid Parking Zone by inspectors is a key element in ensuring the proper functioning of the city's parking infrastructure. Inspectors regularly patrol designated zones, verifying that parking fees have been paid by drivers. In the course of their duties, they use modern tools such as license plate readers, allowing them to quickly and effectively detect violations and issue any fines. The fee schedule for Rzeszów is presented in Table 2. The most expensive fees are in Parking Zone I, with the hourly rate increasing to the third hour of parking. For parking periods exceeding three hours, the fee is charged at the first hourly rate. When paying via mobile app, some apps allow drivers to pay only for the time the car was actually in the parking lot.

Table 2.
Fees in the Rzeszów Paid Parking Zone in

Subzone	First hour	Second hour	Third hour	Fourth hour and each subsequent hour
Subzone I	1,18 €	1,42 €	1,70 €	1,18 €
Subzone II	0,71 €	0,85 €	1,01 €	0,71 €
Subzone III	0,71 €	0,85 €	1,01 €	0,71 €
Subzone IV	0,71 €	0,85 €	1,01 €	0,71 €

Source: Own study.

It is also possible to purchase one of the available subscriptions: resident, standard, for people with disabilities, for a hybrid vehicle and for an electric vehicle. A vehicle with a purchased subscription can park within the zone or a specific subzone on all days of the week and during all hours of paid parking.

In Košice, the paid parking area is divided into various tariff zones (including A1, A2, BN, and N). Each tariff zone differs in location, fee amounts, and hours of charge. Zones closest to the city center (e.g., A(A1, A2)) have the highest hourly rates, while zones further away or with less traffic (e.g., N) have lower rates. Furthermore, in some zones, the fee may apply to weekends or afternoons, while in others, the fee may be shorter or may not apply during part of the week. A summary of the fee rates in each tariff zone is presented in Table 3.

Table 3.
Fees in the Košice Paid Parking Zone

Subzone	Basic rate (30 min.)	Maximum daily rate/ Price of daily ticket
Subzone A1	1,50 €	24,00 €
Subzone A2	1,00 €	16,00 €
Subzone BN	0,50 €	6,00 €
Subzone CN	0,30 €	3,60 €
Subzone N	0,30 €	3,00 €

Source: parking.kosice.sk – 06.10.2025.

Drivers using the Košice Paid Parking Zone pay the fees, just like in Rzeszów, using parking meters, mobile apps, or purchased resident cards or subscriptions. Additionally, payment can be made via SMS message on all mobile networks operated by Orange Slovensko, Slovak Telekom, O2 Slovakia, s, and SWAN), depending on the terms and conditions of the service provided to the specific mobile network user. A bonus system encourages users to use the Paid Parking Zone. The cheapest payment method is available via the app. A 10% discount will automatically be applied to the regular price. Some apps offer parking for less than 30 minutes (minimum 15 minutes), with the option to extend it at a per-minute rate. Košice residents can take advantage of a special 25% discount using the bonus card (combined with the 10% discount when paying via the app, a discount of up to 35%). The discount doesn't apply to payments via text message or parking at the barrier. For multi-day stays, it is possible to purchase a zone pass valid for 10 days. For long-term parking, it is advantageous to purchase a parking card. Paid Parking Zone monitoring is carried out by the municipal police, which operates a vehicle equipped with a camera and dedicated software. Connecting to the electronic

vehicle registration system allows for automatic checking of the database to determine whether a vehicle has a paid parking ticket for a given day and time, either via device or SMS message.

Based on the presented fee tables, the average hourly parking cost was calculated. This indicator is important because it allows for comparison of fee levels across different paid parking zones and an assessment of the overall affordability of parking spaces. Parking costs were analyzed in central urban subzones. Significant differences were found between the cities studied. In Rzeszów, the relative parking cost was 17% of the minimum wage, while in Košice it reached 58%. This means that parking costs in Rzeszów are relatively low, which may encourage vehicles to stay longer in the zone and thus limit parking space turnover. In Košice, however, the high financial burden on minimum wage earners may discourage some drivers from using the zone. The index calculated relative to the minimum wage allows for an assessment of economic accessibility for the most vulnerable income group. The results suggest that in the former, parking is relatively accessible, while in the latter, the zone is burdensome for those with the lowest incomes. Considering the optimal relative cost of parking in central subzones in relation to optimization policies, it typically falls within the range of 15-25% of the minimum wage. Indicators below this level suggest the possibility of introducing short-term parking mechanisms or moderate rate increases to increase turnover. Indicators significantly above this range require consideration of fee reductions or the introduction of discounts for residents and businesses to increase the efficient use of parking spaces. In the case of Rzeszów, this indicator is within the norm, while Košice implements a system of discounts and bonuses.

4.3. Functional indicators

Functional indicators allow us to assess the efficiency of the parking system from a user perspective and the effectiveness of urban space management. They focus on how quickly and easily drivers can find a space, how often spaces are used by different users, and the extent to which technologies support the daily operation of the system.

The parking space occupancy rate in Subzone I of the paid parking system in Rzeszów is 50-60% (Dobrzański, Dobrzańska, 2025). Similar results are achieved in Subzone A in Košice.

In the case of parking spaces for people with disabilities, they constitute approximately 4% of all public parking spaces in Rzeszów, while in Košice the figure is over 5%.

In Rzeszów, the fee for a parking permit for people with disabilities is 0.24€, unless they park in designated spaces, known as envelopes. If a driver parks on an envelope and has a European Parking Card, they are completely exempt from parking fees in the zone. The same rate applies to subscriptions for drivers with electric cars. In Košice, vehicles with a disabled parking permit and parked in designated disabled spaces, regardless of whether they are located in the city center or in residential areas, are exempt from parking fees. However, free parking is not available in parking lots with barriers. Parking in designated disabled spaces is not time-limited. Residents with disabilities can also benefit from discounts for purchasing a resident card.

4.4. Socio-environmental indicators

Socio-environmental indicators allow us to assess the impact of the Paid Parking Zone on residents, vehicle traffic, and the quality of the urban environment. They encompass demographic and mobility aspects, such as the number of residents, the number of cars per 1,000 residents, the number of passenger kilometers, as well as the ecological impact, including NO_2 emissions in the city's central zone.

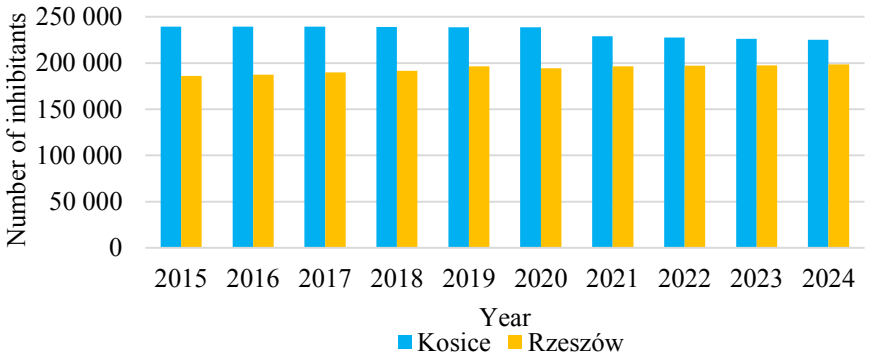

Figure 3. Number of inhabitants in Rzeszów and Košice.

Source: own study based on data from the Local Data Bank database – 16.06.2025 and Central meta information system of public administration 01.10.2025.

In terms of population, the city of Košice is slightly larger than Rzeszów. In 2024, Košice had 225,000 inhabitants, while Rzeszów had 198,000. Over the years, Košice's population has declined slightly, by approximately 0.5% year-on-year. The exception is 2021, when the population declined by 4% year-on-year. This may be due to the census conducted that year, which updated the data. Rzeszów, on the other hand, has seen a steady population growth of approximately 1% year-on-year. Only 2020 saw a decline in population. This may be linked to the effects of the Covid-19 pandemic (Figure 3).

Figure 4 shows the number of cars per 1000 residents. Data for Rzeszów and Košice are presented alongside data for the European Union, Poland, and Slovakia. Over the years, a systematic increase in the number of cars has been observed. This indicator reflects the level of urban mobility's dependence on individual transport. Its systematic growth indicates the growing demand for parking spaces, as well as challenges in traffic management and sustainable transport policies. This trend is upward for both Poland and Rzeszów, and for Slovakia and Košice. However, in the case of Poland and Rzeszów, the indicators were 595 and 655 cars per 1000 residents, respectively. In Slovakia, the indicators were 487 and 333 cars per 1000 residents, respectively. Thus, Košice has a value of this indicator that is more than half that of Rzeszów.

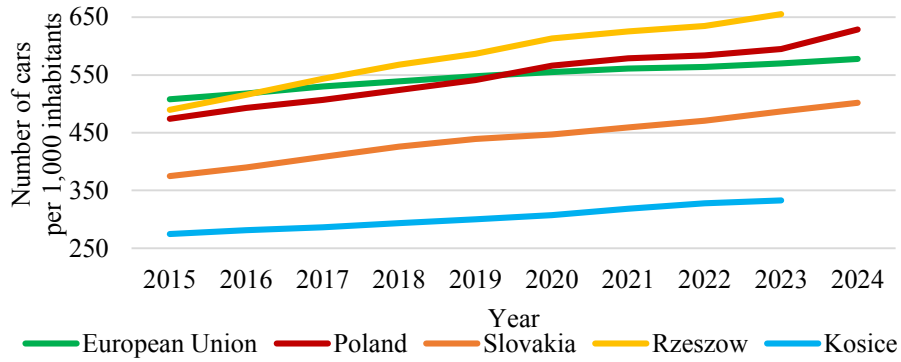

Figure 4. Number of cars per 1000 inhabitants.

Source: own study based on data from the Eurostat database - 20.09.2025.

An upward trend can also be observed when analyzing the number of passenger kilometers (Figure 5). In Poland, this increase was 2% in 2022 compared to 2021, while in Slovakia, it was 6%.

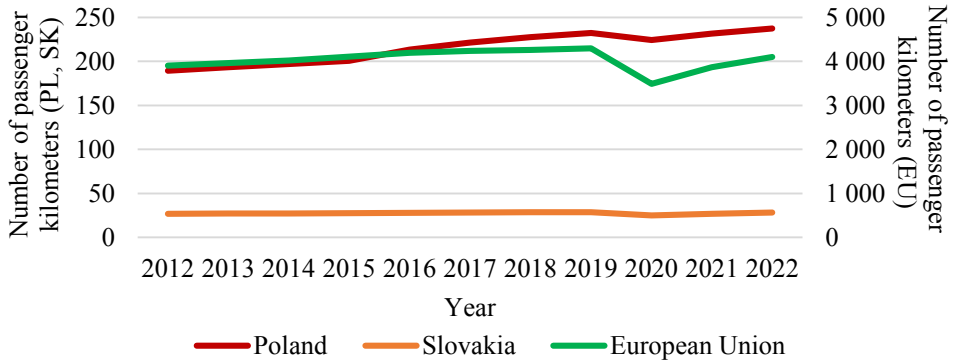

Figure 5. Number of passenger kilometers.

Source: own study based on data from the Eurostat database - 20.09.2025.

The next indicator analyzed was NO_2 emissions for the cities of Rzeszów and Košice. Data for Rzeszów and Košice are presented in the figure 6.

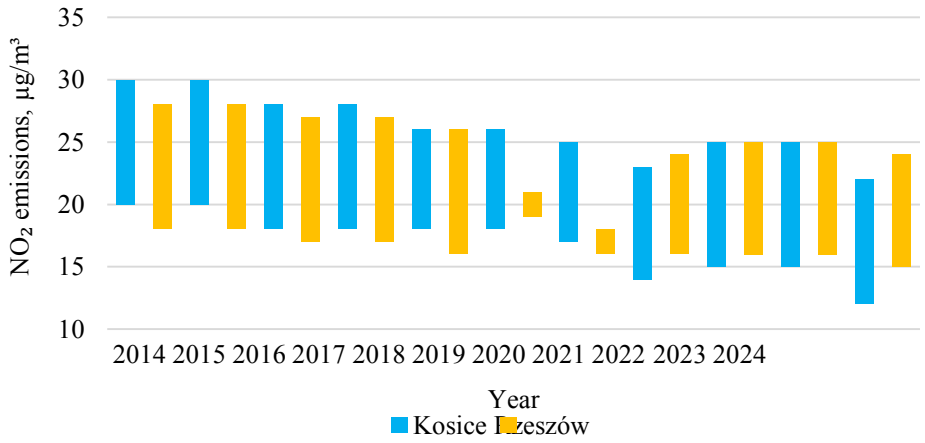

Figure 6. NO_2 emissions for the cities of Rzeszów and Košice.

Source: own study based on data from the Local Data Bank database – 16.06.2025 and Central meta information system of public administration 01.10.2025.

An analysis of estimated annual NO_2 concentrations shows that Košice saw a significant decline in average concentrations between 2014 and 2024, while NO_2 levels in Rzeszów remained relatively stable. This is despite the implementation of an intelligent parking system. This suggests that the system may reduce local cruising for parking spaces, but it is not sufficient to significantly reduce emissions across the entire area, especially with high vehicle numbers and additional pollutant sources.

5. Discussion

An analysis of the paid parking systems in both cities shows that each has developed a different approach to parking space management, tailored to its own demographic, spatial, and organizational characteristics. Rzeszów has implemented an intelligent parking space occupancy monitoring system, which enables the ongoing collection and analysis of data on parking space utilization. A mobile app allows drivers to check space availability in real time, simplifying trip planning and reducing parking search times. The system also supports municipal services in more efficient zone management and control. This solution exemplifies a modern approach to traffic management in the city center, based on the use of information technology and operational data.

In Košice, however, a system with a more diversified organizational structure has been implemented, allowing individual streets and subzones to have different fee application times and rates. This solution allows for flexible response to local needs and demand conditions. Additionally, a discount system has been introduced to support specific user groups, which increases public acceptance of fees and promotes a balance between the interests of residents and visitors. Inspections in Košice are conducted using a monitoring vehicle, streamlining the process of verifying paid fees and increasing the effectiveness of supervision.

In both cities, the occupancy rate in the city center remains similar – approximately 50-60% in Rzeszów and 50% in Kosice – indicating relatively stable parking space utilization. The two systems analyzed are therefore characterized by different management philosophies: in Rzeszów, the emphasis is on the use of modern technologies and data in the management process, while in Košice, it is on organizational flexibility and adapting rules to local conditions. Both approaches have their advantages and demonstrate different paths to achieving efficiency in parking space management.

6. Summary

From the perspective of urban parking infrastructure management, the optimization process can be considered at three levels: economic, organizational, and technological. At the economic level, dynamic pricing based on occupancy levels plays a key role. This allows for increased parking space turnover while simultaneously balancing traffic in the city center. At the organizational level, optimization potential is associated with better planning of paid parking zones and their flexible adaptation to changing user needs. Analyzing parking occupancy data can support decisions regarding the expansion or modification of zone boundaries, as well as differentiating rates between districts with different functions (e.g., business and residential). The introduction of intelligent reporting systems also facilitates improved monitoring and enforcement of fees, resulting in greater efficiency for the entire system. Finally, at the technical level, smart parking systems are gaining in importance. Integrating space occupancy sensors with mobile applications, information displays, and navigation systems allows drivers to quickly find available spaces, reducing the phenomenon of search traffic. Additionally, data collected by these systems can form the basis for optimization models, allowing for more sustainable and cost-effective planning of parking infrastructure development. In the context of the cities being compared, analysis of optimization options allows for assessing which solutions are most effective in a given urban environment and how they can be adapted to other cities. Conclusions from such a comparison can form the basis for formulating recommendations for effective parking space management and the development of intelligent mobility systems.

The benchmark analysis of paid parking systems in the studied cities provided significant benefits from an urban management perspective, serving as a tool supporting local government planning and decision-making processes. It allowed for the identification of the most effective organizational and regulatory solutions for parking space management, promoting the rational use of urban space and improving the system's operational efficiency. At the same time, it is important to emphasize that the effectiveness of transferring the identified best practices to cities with different spatial or socioeconomic conditions has not been empirically verified, necessitating their adaptation to local management conditions. Another limitation of the study is the lack of data-driven scenarios and quantitative models that allow for precise estimation of the effects of implementing specific parking policy instruments. However, the obtained results can serve as a starting point for further research focused on the development of analytical tools supporting parking system management, including the development of decision-making models, cost-benefit analyses, and pilot tests as part of a long-term urban mobility policy.

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