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PARKING INFRASTRUCTURE MANAGEMENT AS AN ELEMENT OF THE SMART CITY CONCEPT

Moving around an urban area by vehicle and the act of parking are an almost integral part of everyday urban travel. Proper organization of parking spaces and the convenience of using them by drivers is key to follow the idea of sustainable urban development and manage the mobility of urban infrastructure users. Parking is influenced by many technical, organizational, economic and social factors. The aim of this work was to analyze and evaluate the functioning of the paid parking zone in Rzeszów, a voivodeship city located in the south-eastern Poland. In the presented case study, the authors, based on data collected from the Metropolis Intelligent Paid Parking System (PPS), determined the occupancy levels of parking subzones in the studied periods of time and analyzed the obtained results. The data and designated indicators available in the system can be the basis for taking appropriate steps to enable effective city management, which will result in, among others increasing the quality of life of residents.

Keywords: smart cities, smart parking systems, planning and management, parking management, parking occupancy.

1. INTRODUCTION

Sustainable development is understood as striving to permanently improve the quality of life of current and future generations by shaping appropriate interactions between three elements: social, environmental and economic. Depending on the aspect, the challenges to the concept of sustainable development are different:

- environmental dimension-e.g. global warming, degradation of ecosystems, depletion of non-renewable raw materials, high exploitation of renewable resources, threat to the health of living beings;

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- economic dimension-e.g. lack of employment stability, low level of satisfaction of needs, high prices, inflation, economic imbalance, state debt, inadequate distribution of income;
- social dimension-e.g. problems with democracy and the rule of law, poverty, demographic problems, conflicts, internal and external insecurity, burdens on health and quality of life.

The concept of sustainable development is also reflected in the assumptions of urban logistics (Huk, Górak, 2021). Creating a balance between social and economic, technological and environmental development is necessary for the city to develop effectively. Today's cities and agglomeration areas face many economic, social, economic and environmental challenges resulting from their dynamic development. The world's population is increasingly concentrated in cities-currently over 50% of the population lives in urban areas, and according to United Nations Organization (UN) forecasts this share will increase to 70% by 2050. Cities occupy only 3% of the Earth's surface, but are responsible for 60–80% of energy consumption and 75% of carbon dioxide emissions (https://www.un.org/sustainabledevelopment/cities). It is estimated that there are over 1.5 billion vehicles in operation worldwide, of which almost 1.2 billion are passenger cars. On the other hand, cities are obliged to guarantee residents not only general access to public services (including transport), but also effective urban distribution of goods, taking into account economic and environmental factors.

In the context of sustainable urban development, the most important role is played by the quality of life of residents, which is influenced by many factors. These include, among others: the state of the natural environment, the wealth of society, access to education and culture, health, safety, sense of belonging, interpersonal relations and participation in social life.

One of the concepts that improves the quality of life of residents is the Smart City concept. It currently has a significant impact on the spatial management of cities. A city managed in accordance with the guidelines of the Smart City concept effectively solves social, environmental and long-term problems. The implementation of this concept is based on knowledge, innovation and the use of information and communication technologies (Trindade, Hinnig, da Costa, Marques, Bastos, Yigitcanlar, 2017)

Cities are areas that concentrate economic and social potential for economic development. They provide jobs and locations to live, relax and enjoy culture. Cities also provide places to meet other life needs, such as shopping, culture, entertainment. An integral element of most of these aspects is transport, including inside the urban structure. This is one of the main factors in the mobility of urban space users. Transport has a significant impact on the degradation of the natural environment. Therefore, the idea of sustainable urban development focuses mainly on stopping the negative ecological effects caused by transport. It is worth mentioning that the negative impact of transport on the urban environment is significantly related to traffic congestion and its effects.

An important element that should be taken into account in implementing the idea of sustainable transport development in cities is social exclusion, which is identified in several categories:

- spatial exclusion-low quality of transport services caused by low population and building density in some areas;
- temporary exclusion-lack of access to public transport at times tailored to the needs of society;

- personal exclusion-inappropriate infrastructure and quality of transport services, e.g. for people with disabilities and elderly people;
- economic exclusion-low or no income.

The concept of sustainable development assumes that all three dimensions, i.e. social, economic and ecological, will develop at an even pace and level. Therefore, sustainable development of transport will focus on eliminating existing social exclusions, while reducing the negative impacts of transport on the environment, including: transport congestion in cities. These activities are also called sustainable urban mobility plans (Cruz, Paulino, 2020; Leo, Morillón, Silva, 2017). Their goal is:

- providing residents with access to public transport at the time and scope appropriate for them;
- improving the security situation;
- reduction of environmental pollution with exhaust gases and noise and reduction of energy consumption;
- improving efficiency and cost effectiveness for passenger and freight transport;
- making the urban environment more attractive with a focus on residents and the economy.

In order to apply the idea of sustainable development in the area of urban logistics, first of all, the assumptions of the sustainable transport development policy should be applied, with particular emphasis on the priorities in this area. These priorities include:

- introducing solutions to rationalize the use of individual vehicles;
- making public transport more attractive;
- the use of intelligent technologies in city infrastructure and means of transport;
- introduction of "good practices" in the use of existing city infrastructure.

Sustainable urban mobility plans are recognized as an appropriate strategic instrument for the development of an integrated approach to urban logistics targeting all modes and means of transport throughout the functional area of a city or urban agglomeration: public and private transport, taxis, passenger and freight transport, motorized and non-motorized traffic, removals, parking.

Mobility plans developed by European cities to improve urban logistics are seen as part of the smart city program (Attaran, Kheibari, Bahrepour, 2022; Battarra, Gargiulo, Tremiterra, Zucaro, 2018; Raspotnik, Grønning, Herrmann, 2020; Winkowska, Szpilko, Pejić, 2019; Zapolskyt, Burinskienė, Trépanier, 2020). In a broad sense, a smart city refers to the need to combine ecological, environmental and social issues. It can be considered that it is a contemporary version of a sustainable city, in which the cooperation of various entities, integration of infrastructure solutions and services ensures the most optimal functioning of the city as a whole (Rui, Othengrafen, 2023). The smart city concept is a modern idea of city development that is a response to the increasing urbanization processes. Thanks to information and communication technologies, smart cities use available resources more effectively to improve the quality of life in the city and ensure its sustainable development.

Intelligent mobility in smart cities is primarily the adaptation of advanced solutions in the field of information technology, making it easier for residents to use all mobility services in the city, with particular emphasis on sustainable, environmentally friendly solutions-e.g. an intelligent transport and communication system based on advanced technologies (Oliveira, Gabrich, Ramalhinho, Oliver, Cohen, Ochi, Gueye, Protti, Pinto, Ferreira, Coelho, Coelho, 2020). Thanks to it, it is possible to use the existing infrastructure rationally, without creating new facilities, and therefore no resources are wasted, including natural ones-which is the basis of the idea of sustainable development. The basic goals to be met by intelligent mobility in relation to this concept are to reduce pollutant emissions and, as a result, car traffic especially congestion.

Smart parking solutions fit very closely into smart mobility schemes, and smart city schemes in general (Fokker, Koch, Leeuwen, Dugundji, 2022; Janak, Pritikana, Sanjaykumar, 2020). City authorities see the costs associated with the impact that congested streets have on both the economy and the quality of life of residents (Yan-Ling, Xin, Ming-Chun, 2016). Therefore, the trend of creating smart parking lots is getting stronger (Chou, Dewabharata, Zulvia, 2021). The search for a parking space is one of the main factors generating the so-called senseless move. Multiple crossings while looking for a place are responsible for up to 30% of this phenomenon. The introduction of intelligent solutions can significantly reduce this factor (Bismantoko, Haryono, Widodo, 2018; Hilmaniy, Maizate, Hassouni, 2018).

Intelligent transport management systems not only improve the quality of life of residents, but also have a positive impact on the environment by reducing exhaust emissions. Intelligent urban traffic management and micromobility are one of the most important aspects of the functioning of modern smart cities (Olayode, Tartibu, Okwu, Uchechi, 2020; Pereira, Cunha, Lampoltshammer, Parycek, Testa, 2017; Tahmasseb, 2022). The concept of smart cities includes, among others: increasing road safety, as well as caring for the natural environment by reducing exhaust emissions. One of the biggest challenges faced by cities aspiring to become smart cities is sustainable transport, i.e. low--emission, safe, comfortable and economical transport. The authorities of smart cities promote alternative means of transport, such as city bikes, and encourage the use of public transport. It must ensure mobility for citizens, i.e. quick movement between different points of the city. The implementation of a system integrating various means of communication is also important. However, residents who stay with their own car must struggle with many problems. Finding a free parking space becomes quite problematic. A comprehensive solution to parking problems in a smart city is possible thanks to the integration of several systems, including: surveillance cameras, analytical tools and navigation applications. Such a system could, among others: generate warnings in case of incorrect parking. This would eliminate practices such as blocking entrances for emergency vehicles, blocking bicycle paths or leaving cars on lawns.

Parking problems in cities are not new. The issue of managing parking spaces and removing inconvenience to residents due to incorrect parking of vehicles was already known to city residents several dozen years ago. Already in the 1930s, the first mechanical parking meter was developed and installed in the USA. In Europe, the first parking meters were installed in the 1950s. In 1952 on the streets of Switzerland, two years later in Germany, and in 1958 in Great Britain.

Currently, the basic idea of smart cities is to provide their residents with a high standard of living through the use of modern technological solutions that facilitate everyday functioning. Here, the idea of Smart City is inextricably linked to the idea of IoT (Internet of Things)-interconnected devices can communicate with each other and share data with users via the Internet (Bellini, Nesi, Pantaleo, 2022).

The Smart City concept is characteristic of cities in which a number of projects and programs are implemented to implement modern technologies that facilitate the functioning of various areas of city life-from WiFi networks available in public spaces, through intelligent traffic control, the use of Big Data, to intelligent sensors. making it easier, for example, to look for parking spaces in the city (Gebresselassie, Sanchez, 2018; Ouafiq, Raif, Chehri, Saadane, 2022; Ullah, Al-Turjman, Mostarda, Gagliardi, 2020).

The use of modern technological solutions, including the Internet of Things, is still not widespread enough. To ensure proper city management, it is advisable to implement intelligent solutions using the above-mentioned technologies.

An example of a city where solutions consistent with the Smart City idea are being implemented is Rzeszów. One of such solutions is the PPS implemented on December 20, 2021. This is the first solution of this type in Poland and one of the first in Europe.

The aim of this article is to present the capabilities of the PPS both in online applications and as a valuable source of data, the analysis of which may contribute to taking appropriate steps to enable effective city management, which will result in, among others: increasing the quality of life of residents. The article is divided into four sections. The first section presents general assumptions regarding the idea of sustainable development and smart city. The second chapter contains the characteristics of the city presented in the article and the intelligent parking system implemented in it and research methodology. The third chapter presents the results of the analysis of the collected data, the aim of which was to assess the functioning of the paid parking zone in Rzeszów (Poland). The whole article ends with a summary.

2. RESEARCH OBJECT AND RESEARCH METHODOLOGY

A voivodeship city from south-eastern Poland was chosen as an example for analysis. This city is Rzeszów with an area of 129.01 km^2 and over 197 000 inhabitants. Rzeszów is an economic, industrial, commercial, academic and cultural center. The city is located close to the borders with Slovakia and Ukraine. In recent years, there has been an increase in the number of inhabitants and the number of registered passenger vehicles. This is shown in Figure 1. With the development of population, the city area increased and thus the length of the routes necessary to travel between the place of residence and the destination increased.

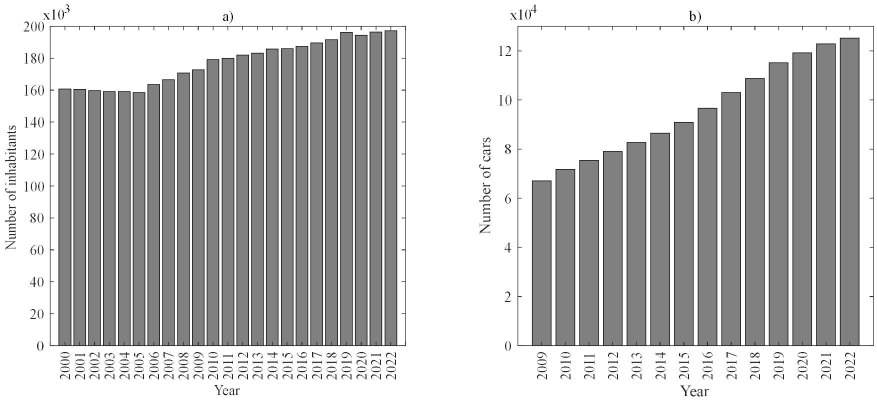

Figure 1. Indicators characterizing the city: a) number of inhabitants, b) number of passenger cars

Source: Prepared on the basis of (https://bdl.stat.gov.pl/bdl/dane/podgrup/teryt).

In Rzeszów, transport needs are met by public and individual transport (Dobrzański, Śmieszek, Dobrzańska, 2020; Śmieszek, Dobrzańska, Dobrzański, 2016). In the case of individual transport in the city, access to infrastructure is necessary in the form of, among others: parking spaces. On public roads in the city of Rzeszów, from January 1, 2016, a paid parking zone was introduced, in which two paid parking zones were distinguished.

In 2020, the area of the paid parking zone was expanded and divided into subzones: “blue”, “orange”, “green”, “red”. Fees for parking motor vehicles on public roads in the Zone are collected on weekdays, Monday to Friday, from 8:00 a.m. to 8:00 p.m. The location of parking zones is shown in Figure 2.

Figure 2. Parking zone in the city of Rzeszów

Source: Prepared on the basis of (https://bip.erzeszow.pl/120-miejska-administracja-targowisk-i-parkingow/4852-strefa-platnego-parkowania/4853-mapa-strefy-platnego-parkowania.html).

In 2021, in cooperation with the City of Rzeszów and Asseco Data Systems, the PPS was implemented. At that time, Rzeszów was the first city in Poland to implement a solution for monitoring the status of available parking spaces. PPS allows Rzeszów to become part of the Smart City idea.

Data on parking lot occupancy is collected in the field 24 hours a day and sent for analysis using neural networks in the Supervision Center system at the headquarters of the Municipal Administration of Markets and Parking Lots (MAMPL). They are obtained from cameras and sensors detecting parking vehicles, and then displayed in real time on VMS information boards in the parking zone and the e-Parking mobile application. Video monitoring, which covers 2,200 parking spaces, required the installation of 338 cameras, 305 magnetic-radar sensors, 10 VMS information boards with a connection to the power supply and an IT network in the very center of Rzeszów. In addition to building a new parking metering infrastructure, it was also necessary to modernize the city's Data Processing Center to ensure efficient and reliable operation of the system. All elements of the solution were connected by a new fiber optic network (https://www.assecods.pl/). The e-Parking application was also implemented as part of the project. The creation of the system was co-financed by the European Union under the European Regional Development Fund, Operational Program Eastern Poland 2014–2020. The city authorities decided to implement this type of system for purposes closely related to the idea of sustainable urban development. The system makes it possible to shorten the time of searching for a parking space, reduce individual vehicle operating costs, and thus reduce air pollution emissions due to exhaust fumes and noise. The e-parking application works based on data from

Google Maps. Virtual, metered parking spaces were superimposed on the maps, showing the level of availability of parking spaces in particular areas. Screenshots of an example view are shown in Figure 3a.

a) b)

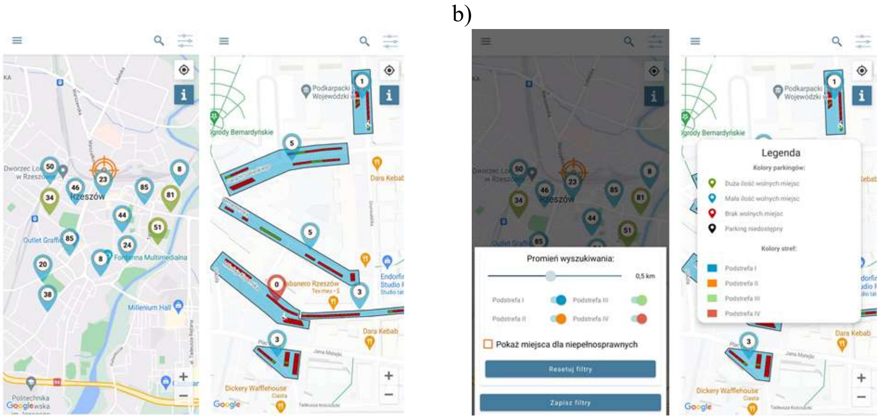

Figure 3. Maps with the level of availability of parking spaces in the e-parking application (a), Filters and legend of markings in the e-parking application (b)

Source: Prepared on the basis of (https://play.google.com/store/apps/details?id=pl.assecods.matip&pcampaignid=web_share).

The colored pins, which are visible in Figure 3a, show the number of free parking spaces in individual areas in the paid parking zone. Parking spaces come in different colors:

- green, meaning that the parking space is free;
- red, meaning that the parking space is occupied;
- black, meaning that the parking space is out of use.

In the application, it is also possible to enable navigation to the selected pin. In the application, it is possible to set filters that make it easier for users to use it and significantly speed up finding a free parking space. The possible use of filters and the legend of symbols are presented in Figure 3b. The user can also select a subzone in which can select a free parking space and specify whether the space should be adapted to the needs of people with disabilities.

In addition to the option to adjust the application settings and license conditions, the application also allows you to check the fee rates for parking in the paid parking zone and browse applications that allow you to pay for parking your vehicle. Additionally, there is also an option to start a stopwatch that counts down the time until the end of the paid period. The application sends the user a reminder before the end of the time, which allows you to avoid additional fees related to exceeding the parking time. The number of spaces in the paid parking zone, including spaces for people with disabilities, which are subject to accessibility monitoring, is approximately 2,200. The number of metered spaces and their percentage share in the total number of parking spaces in individual subzones are presented in Table 1.

The measurement covers the entire subzone I, called “blue”, and subzone II, called “orange”, as well as part of subzone IV, called “red”-approximately 17.88% of parking spaces. The remaining part of the “red” zone and subzone III called “green” are excluded from monitoring. The reason for excluding these areas from metering is the fact that in subzones III and IV, most parking spaces are located in housing estates and these spaces are mostly used by residents. Subzones I and II, as well as part IV, are established in the very center of the city and its vicinity. These areas contain mostly service and administrative points, which are often visited by people living outside these zones. The implementation of the monitoring system in these areas is intended to encourage drivers to park in these specific subzones, relieving the burden on subzones III and IV, which were introduced at the request of residents complaining about the shortage of parking spaces near their homes.

Table 1. Number of metered parking spaces in the paid parking zone and their share in the total number of spaces in the zone – data provided by the MAMPL in Rzeszów

Subzone	**Parking spaces in the paid parking zone *(including parking spaces for people with disabilities)***	**Parking spaces in the paid parking zone are covered by an occupancy measurement system**	**% parking spaces in the paid parking zone co-vered by an occupancy measurement system**
Subzone I	1577	1577	100.00%
Subzone II	542	542	100.00%
Subzone III	919	0	0.00%
Subzone IV	453	81	17.88%

Source: Prepared on the basis of data provided by the MAMPL in Rzeszów.

The e-parking application was used to collect data. Data collection took place twice, 7 days each, for a total of 14 days, in the periods from November 8, 2022 to November 14, 2022 and from December 18, 2022 to December 24, 2022. Measurements were performed five times a day: approximately 9:00 a.m., 12:00 p.m., 3:00 p.m., 6:00 p.m. and 9:00 p.m. In total, data was collected from 70 time stops.

Parking spaces, including spaces for people with disabilities, covered by the occupancy measurement system are divided into 75 areas. The division into areas and the specification of streets are shown in Figure 4.

a) b) c)

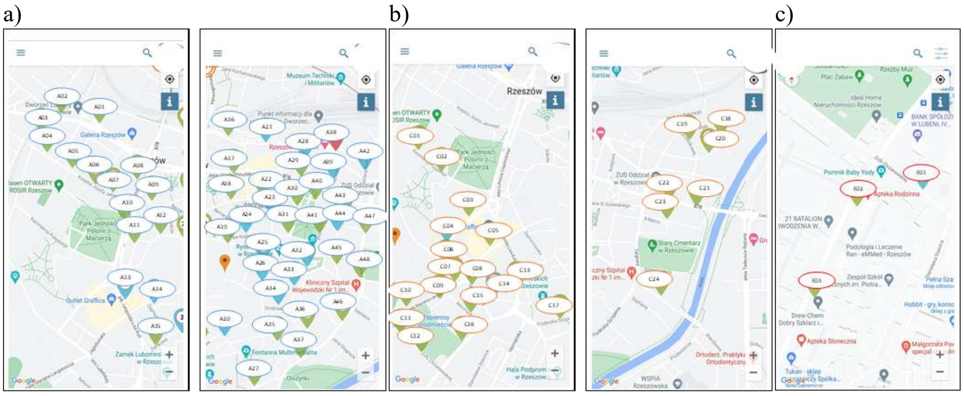

Figure 4. Locations of areas accepted for research in: a) I „blue" subzone, b) II „orange" subzone, c) IV „red" subzone

Source: Prepared on the basis of (https://play.google.com/store/apps/details?id=pl.assecods.matip&pcampaignid=web_share).

For subzone I, 48 measurement areas were designated. They were marked with the symbol AXX, where XX was the next number of the area. 24 areas have been designated for subzone II and marked with the symbol CXX. However, three areas have been designated for subzone IV, marked with EXX symbols.

Additionally, separate measurements were carried out only for places intended for people with disabilities. They were divided into 21 areas shown in Figure 5.

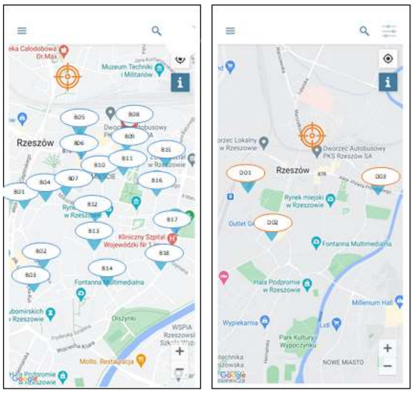

Figure 5. Locations of areas with parking spaces for people with disabilities accepted for research

Source: Prepared on the basis of (https://play.google.com/store/apps/details?id=pl.assecods.matip&pcampaignid=web_share).

It is worth noting that places for people with disabilities are metered only in subzones I and II. For subzone I, 18 measurement collection areas were designated and marked with the symbols BXX, where XX is the sequential number of the area. However, three areas have been designated for subzone II and are marked with DXX symbols.

3. RESULTS AND DISCUSSION

The analysis was divided into two measurement periods A and B. Period A can be characterized as a normal working week. Only November 11 (Friday) was a day off from work. Sunday, November 13, was a day off from trading. Period B is the week before Christmas. Due to the approaching Christmas holidays, greater traffic was expected in the center due to preparations for days off from work and trade. The last day of measurements, i.e. Saturday, December 24, was Christmas Eve. December 19 was the last trading Sunday before Christmas. Moreover, it is worth noting that before the beginning of period B there was heavy snowfall, and during the measurements there was snow on the streets and difficult road conditions.

First, the level of average occupancy of parking spaces in the paid parking zone was compared, divided into periods A and B and subzones. The obtained results are presented in Table 2.

The results indicate that both in periods A and B, the subzone that was most occupied was subzone I. In period A, parking spaces in subzone I were occupied by 68.37%, and in period B by 57.90%. This result results from the fact that subzone I covers the very center of the city, where there are many service points, places of culture and entertainment, as well as administrative organizations.

Table 2. Average occupancy level of parking spaces in the paid parking zone

Subzone	**Period A**	**Period B**	**Average**
Subzone I	68.37%	57.90%	63.14%
Subzone II	51.49%	50.93%	51.21%
Subzone IV	54.61%	27.94%	41.28%
Average	58.16%	45.59%	

Source: Own study.

In period A, subzone II was the least occupied 51.49% of parking spaces, and in period B, subzone IV 27.94%. The occupancy level of parking spaces in subzone IV in period B is less than half as compared to period B. This may be due to the fact that subzone IV includes parking spaces near housing estates. During the pre-Christmas period, residents could spend more time outside their homes, and thus their vehicles did not take up parking spaces.

The values for the entire paid parking zone covered by the occupancy measurement system, divided into two measurement periods, indicate that in November the overall occupancy of the zone (i.e. 58.16%) was higher than in December (i.e. 45.59%). It was expected that in December, during the pre-Christmas period, there would be higher parking space occupancy values, but this was not the case. Factors influencing the lower result in period B could include, among others: weather and road conditions. Snow on the streets could discourage drivers from using private vehicles in the city. Residents then stayed at home, giving up on pre-Christmas matters, or decided to use public transport services. An important factor could also be drivers' fear of difficulties in finding a free parking space during the busy pre-Christmas period. This element could also influence the decision to travel by public transport. Based on the data obtained, the occupancy rates of the subzones at particular times of the day were compared. The results for different periods are presented in the chart in Figures 6 and 7.

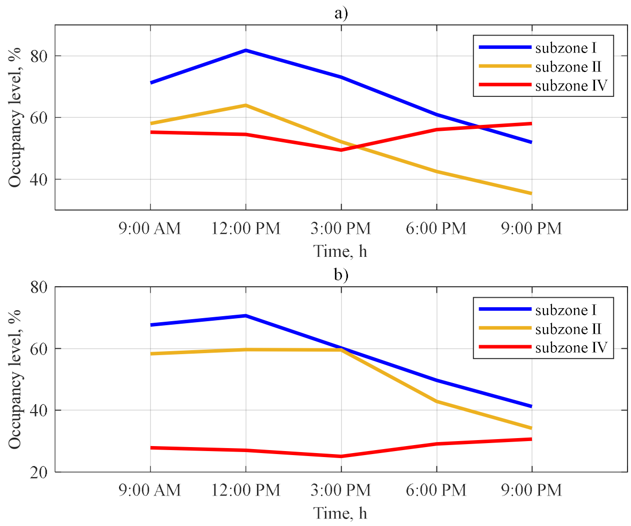

Figure 6. Paid parking zone occupancy level by hours in period A (a), period B (b)

Source: Own study.

Figure 6 clearly shows that the occupancy levels in subzones I and II increase from 9:00 a.m., peak around 12:00 p.m., and then decrease almost equally until 9:00 p.m. In period B, the peak occupancy of parking spaces in subzone II was extended and lasted from approximately 12:00 p.m. to 3:00 p.m. In subzone IV, occupancy levels decrease from 9:00 a.m. Then, around 3:00 p.m., parking lot occupancy levels are at their lowest point of the day, and from 3:00 p.m. to 9:00 p.m., occupancy levels increase. The charts presented in Figure 6 clearly show that subzone IV is an area dominated by housing estates. In the afternoon, most vehicles are parked within the boundaries of subzones I and II, covering the very center of the city, and outside these hours, when residents return to their homes after work or running errands, an increase in the occupancy rate of parking spaces in subzone IV is visible.

The average level of occupancy of parking spaces in the paid parking zone was also compared by day of the week. The results are presented in Figure 7.

In Figure 7, the dominance of subzone I in terms of the occupancy rate of parking spaces is clearly visible, regardless of the day of the week. It is worth taking a look at the results for Sunday in both periods.

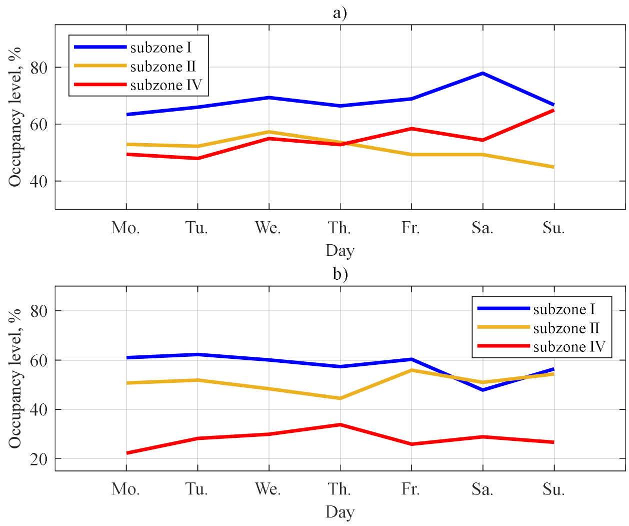

Figure 7. Paid parking zone occupancy level by days of the week in period A (a), period B (b)

Source: Own study.

In period A (Figure 7a), when the Sunday covered by the measurement was non-trading, there was a clear decline in the occupancy level of parking spaces in subzones I and II and a sharp increase in subzone IV. Due to the Sunday trading ban, drivers had no need to travel to the city center. The increase in occupancy in housing estates was caused by the fact that most residents decided to stay in their homes on that day. There is also an increase in interest in stopping in subzone I on Saturday during period A. This was most likely due to the preceding day off from work (i.e. Friday, November 11) and a non-trading Sunday on the following day. People most likely wanted to use this Saturday to do their business in the city center and use the services of the shops located there. In turn, in period B, when shopping Sunday fell, there was an increase in interest in parking in the city center and a decrease in the level of occupancy in the area of housing estates. Also interesting is the phenomenon that became visible on Saturday in period B, i.e. December 24, Christmas Eve. The level of interest in parking in subzone I, in the city center, dropped sharply and was the lowest for this subzone during the entire two-week measurement period. Human behavior and attachment to tradition are clearly visible, consisting in giving up traveling to the city center on Christmas Eve, when time should rather be spent with family.

Analyzing data on the availability of parking spaces, there are clearly visible areas where there is a high demand for parking vehicles. The demand for parking spaces is associated with an indicator called the availability level. It was calculated for each of the 75 designated areas.

After calculating the accessibility level index for each of the subzones covered by the measurements, 10% of the areas with the greatest demand for parking spaces were determined. These areas are presented in Table 3.

Table 3. Areas in paid parking subzones where there is the highest demand for parking spaces

Subzone	Area	Streets covered by the area	Availability level
Subzone I	A32	B. Joselewicza	22%
Subzone I	A39	Kolejowa – S. Żeromskiego	51%
Subzone I	A25	J. Słowackiego	63%
Subzone I	A14	Zamkowa	65%
Subzone II	C04	M. Mochnackiego – ks. J. Poniatowskiego	32%
Subzone II	C01	K. Pułaskiego	49%
Subzone IV	E02	gen. J. Dąbrowskiego	54%

Source: Own study.

The lowest level of availability and therefore the highest interest in the entire paid parking zone occurs in the area of A32 at Berka Joselewicza Street. Ultimately, there will be 23 parking spaces there. The availability level is approximately 22%. The largest number of available parking spaces in this area throughout the entire period under study was 6, and the smallest was 1. It turns out that parking spaces on this street were occupied almost all the time. This phenomenon may result from the fact that Berka Joselewicza Street borders directly with the Rzeszów town square and the promenade in the very center of the city. The concentration of catering outlets, service outlets, municipal administration, schools and religious places in the immediate vicinity causes drivers to constantly be interested in this area to park their vehicles there.

The second area with the most critical accessibility indicator in the entire zone is area C04. It is the intersection of Maurycy Mochnacki and Książe Józef Poniatowski streets. The availability of parking spaces in this area is approximately 32%. A large number of medical points are located on the above-mentioned streets, such as clinics, private medical offices, laboratories, and the Municipal Social Welfare Center. There are also two schools, a kindergarten, the Chamber of Legal Advisers and a shopping mall in the vicinity.

Table 4 presents data on the number of vehicles and people living in Rzeszów and the borders of the adjacent Rzeszów county per one parking space in the paid parking zone. The analysis assumed that vehicles, including motorcycles and scooters, are mostly driven by people over 15 years of age. These people may need to use parking spaces in the paid parking zone. When calculating the indicators, the number of vehicles and inhabitants in two counties was taken into account – in the county city of Rzeszów and the bordering Rzeszów county. It was calculated that there was more than one person per vehicle in both counties. Therefore, up to approximately 88 people in approximately 65 vehicles, assuming that all residents of both counties would like to park their vehicles in the zone at the same time, may request one parking space in the paid parking zone at the same time. However, it should be taken into account that the parking lots in the zone are used by also people from outside these two counties. However, if parking spaces in the paid parking zone in Rzeszów could only be used by city residents, the need would be reported by approximately 47 people in approximately 35 vehicles. However, the analysis of data from the obtained measurements and the determined occupancy rate indicate that the demand is actually lower. Therefore, it can be said that the number of parking spaces in the paid parking zone in Rzeszów is sufficient.

Table 4. The number of vehicles and people living in Rzeszów and the borders of the adjacent Rzeszów county per one parking space in the paid parking zone

	County City of Rzeszów	**Rzeszów county**	**Total for both areas**
Number of motor vehicles	122 830	102 342	225 172
Number of people over 15 years of age	164 145	142 237	306 382
Number of people per vehicle	1.34	1.39	1.36
Number of vehicles per parking space in PPS	35.18	29.32	64.50
Number of people per parking space in PPS	47.02	40.74	87.76

Source: Prepared on the basis of (https://bdl.stat.gov.pl/bdl/dane/podgrup/teryt).

Table 5 shows the average occupancy of places for people with disabilities in the metered part of the paid parking zone.

Table 5. Average occupancy of spaces for people with disabilities in the metered part of the paid parking zone

	Maximum number of parking spaces available for people with disabilities	**Average occupancy during period A**	**Average occupancy during period B**	**Average occupancy in both periods**
Subzone I	41	55.97%	46.20%	51.09%
Subzone II	7	38.72%	51.02%	44.87%
Total	48	47.35%	48.61%	47.98%

Source: Own study

Metered parking spaces for people with disabilities are located entirely in subzones I and II and constitute 100% of the total number of spaces for people with disabilities in these subzones. There are approximately 41 parking spaces in subzone I, and approximately 7 in subzone II. The remaining approximately 79 spaces for people with disabilities are located in subzone III and IV and are not covered by the occupancy monitoring system.

The overall average occupancy of metered parking spaces for people with disabilities was approximately 47.98%. In general, in subzone I there was a higher degree of occupancy of places for people with disabilities than in subzone II. In period A, a higher level of occupancy occurred in subzone I, while in period B-in subzone II.

Figure 8 shows the level of occupancy of places for people with disabilities in the paid parking zone, which varies at particular hours during the day. In order to achieve the results, data from a total of 14 days of the measured periods were compiled and averaged.

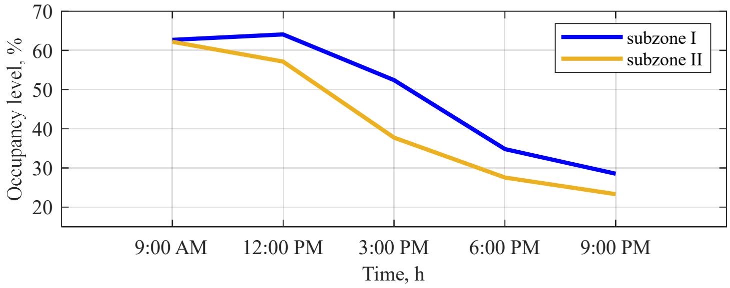

Figure 8. Occupancy level of places for people with disabilities in the paid parking zone by hours

Source: Own study.

The highest level of occupancy of places for people with disabilities in both subzones occurs between 9:00 a.m. and 12:00 p.m. and ranges from approximately 57.14% to 64.11%. After this period, the average occupancy of parking spaces for people with disabilities decreases to reach the minimum around 9:00 p.m., i.e. from approximately 23.3% to 28.54% of occupied parking spaces. It is noticeable that a higher average occupancy level occurs in subzone I, "blue", than in subzone II, "orange".

4. CONCLUSIONS AND FUTURE STUDIES

Parking in cities is becoming more and more problematic. The increasing number of cars and limited space make finding a place to park more and more difficult. Not everywhere urban infrastructure allows for quick movement around the city without a car, which is why residents choose to travel by car. The purpose of the trip also influences the choice of traveling by car. The lack of parking spaces is one of the main problems in city centers, which is an everyday problem for residents especially and affects their quality of life. The ecological aspect should also be taken into account. Frequent and long searches for a free space increase the emission of greenhouse gases and other air pollutants. Residents of city centers are especially exposed to the negative effects of air pollution caused by excessive car traffic. One of the solutions that enables smooth management of parking zones in cities is the so-called intelligent parking solutions. An increasing number of cities use modern technologies to manage parking.

Intelligent parking solutions are not only a solution to drivers' current problems. Cities that implement this type of systems can manage their activities more efficiently by predicting the demand for parking spaces, and analyzing the data collected by the systems used can also indicate which areas require more attention or when to plan renovation and maintenance works.

Using the parking solutions offered by the Smart City concept, it is possible to develop strategies to optimize the management of existing parking spaces. The number of available parking spaces in cities can only be increased to a limited extent because they are a limited resource. The results presented in the article made it possible to isolate factors influencing the occupancy of parking spaces, such as weather anomalies or days off from work. The influence of these factors can be used in the development of optimization stra-tegies.

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