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DAILY VARIABILITY OF THE USE OF PARKING SPACES IN THE PAID PARKING ZONE COVERED BY DYNAMIC PARKING INFORMATION BEFORE AND DURING THE COVID-19 PANDEMIC

Summary. Currently, more inhabitants use a car for their travels. The consequence of the increase in traffic on the roads is the deterioration of road conditions, decrease in the level of road safety, increasing air pollution, as well as the problem of finding a place to park a vehicle. This article analyzes the daily variability of the use of parking spaces in the Paid Parking Zone (PPZ) covered by Dynamic Parking Information (DPI) in Gliwice before and during the COVID-19 pandemic. In the first stage of the work, the daily variability of the use of parking spaces and the rotation indicator were analyzed in parking spaces at PPZ covered by DPI before and during the COVID-19 pandemic. The Wilcoxon test was performed to verify whether the differences are statistically significant. The results indicate that the COVID-19 pandemic contributed to the decrease in the use of parking space and the rotation indicator in the parking spaces at PPZ. In addition, the research shows that collecting fees for parking a vehicle in a parking space increases the use of space and the rotation indicator. Due to this, parking spaces are available for more drivers.

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1. INTRODUCTION

Currently, more inhabitants use a car for their travels. The consequence of the increase in traffic on the roads is the deterioration of road conditions, decrease in the level of road safety, increasing air pollution, as well as the problem of finding a place to park a vehicle. The parameters of road traffic conditions depend on many factors [5, 10, 12, 17, 19]. These factors may be constant, for example, the geometry of the road, the presence of various types of intersections, the presence of traffic calming elements, spatial planning, etc. Factors may also vary over time, for example, weather conditions, road works, time of day, day of the week, season of the year, the presence of holidays and other random events, etc. All these elements make the traffic on roads in the city, road safety, as well as the use of parking space variable over time.

The lack of parking spaces is visible mainly in the city center. The dense development makes it impossible to build new areas where it would be possible to leave a vehicle. The largest number of travel destinations are located in the city center. Therefore, Paid Parking Zones (PPZ) are being introduced in many cities in Poland and around the world. Collecting parking fees contributes to shorter stops for drivers in parking spaces, which in turn increases the availability of parking spaces for more people. Another problem in such areas is the traffic caused by searching for vacant space to leave vehicles. The introduction of Dynamic Parking Information (DPI) allows drivers to be informed about vacant parking spaces in real-time.

In March 2020, an epidemic caused by the SARS-CoV-2 - COVID-19 virus was announced in Poland. In schools and universities, classes were conducted remotely, where possible, work was remote due to the spread of the virus and the increasing number of infections. In addition, some places were closed, among other things, shopping centers, cinemas, theaters, gyms, restaurants, cafes, etc. [15]. This caused changes in the communication behavior of the inhabitants. They limited their travels to the necessary minimum. In May 2020, the number of infected people decreased, which resulted in the opening of some activities [15].

This article aims to analyze the variability of the daily use of parking spaces in the Paid Parking Zone covered by Dynamic Parking Information in Gliwice before and during the COVID-19 pandemic. It consists of 4 parts. In the third part, after the introduction and literature review, the characteristics of the research area and the conducted research are presented. Then, in section four, the results of the analysis of the daily variability of the use of parking spaces and the rotation indicator in parking spaces in PPZ covered by DPI before and during the COVID-19 pandemic are presented. First, the values of the use of parking space and the rotation indicator in particular weeks in 2019 and 2020 were compared with each other. In the second stage of the analyzes, the Wilcoxon test was carried out to check whether the differences in the values of the use of parking space are statistically significant. The article ends with a summary and conclusions from the research.

2. FACTORS INFLUENCING THE TEMPORAL VARIABILITY OF ROAD TRAFFIC PARAMETERS IN THE CITY

In the literature on the subject are papers, which discuss the results of research on the factors influencing the temporal variability of road traffic parameters in the city. These factors also influence the choice of the means of transport. The factors studied include, among other things, weather conditions, the presence of various types of intersections, the presence of public holidays, random events, etc.

The paper [13] presents the results of the study of traffic variability on particular days of the week. The authors indicate that the Friday afternoon peak stretches further during the day compared to the other weekdays based on the analyzes. Road traffic on Saturdays and Sundays varies from working days. Liu and Sharma [8] conducted a study of the variability of movement during the 12 Canadian holiday periods based on data from 20 years. The results of the research allow for the conclusion that the presence of holidays influences the distribution of traffic on the city's transport network on particular days of the week. In turn, Al-Dabbagh et al. [8] examined the impact of the type of intersection on traffic congestion. The results indicate that the roundabout intersection has the least impact on the occurrence of delay time.

In the literature are works on the influence of weather conditions on the number of trips as well as on the choice of the means of transport. Guo et al. [6] examined the effects of temperature, rainfall, snowfall, wind, and fog on daily travel by bus and rail. The research shows that bad weather reduces the number of trips. Additionally, the authors indicate that bus transport is more sensitive to weather conditions than rail transport. The most sensitive to weather conditions is bicycle transport because cyclists are not protected by the body of the vehicle, as in the case of passenger cars or public transport. The works [11, 18], show that lower temperature reduces bicycle traffic. In Poland, Banet [2] conducted a study of the impact of temperature on the number of city bike rentals for the cities of Krakow and New York. A comparative analysis of these two days showed that in Krakow, the use of bike-sharing systems is more sensitive to weather conditions than in New York.

The outbreak of the COVID-19 pandemic contributed to the reduction of the number of trips to the necessary everyday life. The ability to work remotely, teach in schools and at universities remotely, as well as online shopping, have changed the way of traffic in many cities around the world. The modal split has also changed. In the literature, some works present the results of research into the impact of a pandemic on communication behavior. The paper [7] discusses the impact of the COVID-19 pandemic on the number of passengers in public transport in 3 regions of Sweden. Jenelius and Cebecauer indicate that the number of public transport passengers has decreased by approx. 40-60% (depending on the area) On the other hand, Marinello et al. [9] examined the number of vehicles traveling on the road during the pandemic and the level of air pollution. The number of vehicles traveling in the city decreased by approx. 82% and air pollution decreased by approx. 30%. Studies on the impact of the COVID-19 pandemic on the traffic volume in the city were also examined in Poland. Smieszek et al. [16] presented the results of research showing that traffic in Rzeszów decreased by 40-60% in the first months of the pandemic.

3. CHARACTERISTICS OF THE RESEARCH AREA AND THE CONDUCTED RESEARCH

The city of Gliwice is located in the southern part of Poland. In Gliwice, in 2019, were registered 692 passenger cars per 1,000 inhabitants. There is a Paid Parking Zone in the city center, which is divided into two sub-zones: A and B. There are 751 parking spaces covered by the Dynamic Parking Information system (Figure 1). The use of DPI allows the display of information on vacant parking spaces on the Variable Message Sign (VMS) boards. Due to this, drivers do not waste time looking for a vacant parking space and the share of the search traffic in this area [3, 14].
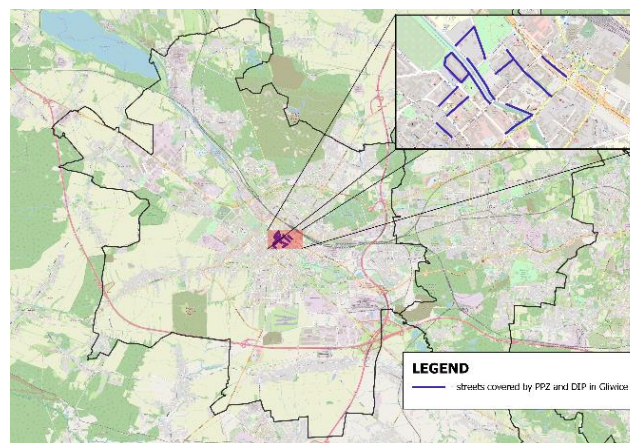

Fig. 1. Localization of parking spaces covered by PPZ and DPI in the city of Gliwice

Data on the occupancy of parking spaces in PPZ covered by DPI were obtained from the Municipal Roads Authority in Gliwice. They covered every day from January to June 2019 and 2020. In the first stage of the work, the year was divided into weeks for a comparative analysis of the daily variability of parking spaces in 2019 and 2020. The 1st week in the year was not included in the analyzes as it was not a full week, both in 2019 and 2020. Table 1 shows the year in weeks and holidays in 2019 and 2020.

Tab. 1

Week number of the year and public holidays occurring in 2019 and 2020

Week number of the year	Month	Days in 2019	Public holidays in 2019	Month	Days in 2020	Public holidays in 2020
2	January	07-13	-	January	06-12	6th - Epiphany
3	January	14-20	-	January	13-19	-
4	January	21-27	-	January	20-26	-
5	January/February	28.01-03.02	-	January/February	27.01-02.02	-

6	February	04-10	-	February	03-09	**-**
7	February	11-17	-	February	10-16	**-**
8		18-24	-		17-23	**-**
9	February/March	25.02-03.03	-	February/March	24.02-01.03	**-**
10	March	04-10	-	March	02-08	**-**
11		11-17	-		09-15	**-**
12		18-24	-		16-22	**-**
13		25-31	-		23-29	**-**
14	April	01-07	-	March/ April	30.03-05.04	**-**
15		08-14	-	April	06-12	-
16		15-21	-		13-19	13th - Easter Monday
17		22-28	22nd - Easter Monday		20-26	**-**
18	April/May	29.04-05.05	01st – 02nd - May weekend	April/May	27.04-03.05	01st – 02nd - May weekend
19	May	06-12	-	May	04-10	**-**
20		13-19	-		11-17	**-**
21		20-26	-		18-24	**-**
22	May/June	27.05-02.06	-		25-31	**-**
23	June	03-09	-	June	01-07	**-**
24		10-16	-		08-14	11th – Corpus Christi
25		17-23	20th - Corpus Christi		15-21	**-**
26		24-30			22-28	**-**

The data allowed for the following analyzes:
- comparison of the value of the use of parking space in the weeks before the pandemic (week 2-9), during the introduction of restrictions (week 10-17), and in the period of removing the restrictions (week 18-26) in 2020 and the corresponding weeks in 2019;
- comparison of the value of the rotation indicator in the weeks before the pandemic (week 2-9), during the introduction of restrictions (week 10-17), and in the period of removing the restrictions (week 18-26) in 2020 and the corresponding weeks in 2019;
- Wilcoxon test for the use of parking space in weeks 5, 13, 26 in 2019 and 2020.

4. ANALYSIS OF THE DAILY VARIABILITY OF THE USE OF PARKING SPACES IN THE PAID PARKING ZONE COVERED BY DYNAMIC PARKING INFORMATION BEFORE AND DURING THE COVID-19 PANDEMIC

Figure 2 shows the values of the use of parking space in the weeks before the pandemic (week 2-9), during the introduction of restrictions (week 10-17), and in the period of removing the restrictions (week 18-26) in 2020 and the corresponding weeks in 2019. The value of the use of parking space was higher in 2020 compared to 2019 (Figure 2a, b) in the case of the weeks before the pandemic (week 2-11). On March 20, 2020 (week 12), the epidemic was introduced in Poland. The value of the use of the parking space was lower in 2020 compared to 2019 in week 11 on Friday. In the following weeks (from week 12 of 2020), this value was lower in 2020 compared to 2019. The removal of the restrictions began at the beginning of May 2020 (19th week). The value of the use of parking space in 2020 increased and became equal to the value of parking space utilization in 2019 in weeks 23 and 24. On Saturdays and Sundays, the use of parking space was lower than in the case of working days in all weeks, both in 2019 and 2020. The occurrence of public holidays caused less use of the parking space (17th, 18th, and 25th weeks in 2019; 16th, 18th and 24th weeks in 2020).

Further, Figure 3 shows the values of the rotation indicator in the weeks before the pandemic (week 2-9), during the introduction of restrictions (week 10-17), and in the period of removing the restrictions (week 18-26) in 2020 and the corresponding weeks in 2019. The value of the rotation indicator was higher in 2020 compared to 2019 before the pandemic (week 2-11). In the 11th week on Friday, the value of the rotation indicator was lower in 2020 compared to 2019 in the case of using the parking space. In the following weeks (from week 12 of 2020), this value was lower in 2020 compared to 2019. The rotation indicator in 2020 increased from week 19. This can be caused by the removal of restrictions. As in the case of using the parking space, on Saturdays and Sundays, the rotation indicator in all weeks, both in 2019 and 2020, was lower than in the case of working days. Also on public holidays, the rotation indicator was lower than on working days (17th, 18th, and 25th weeks in 2019; 16th, 18th, and 24th weeks in 2020).

Figures 2 and 3 show that the values of use of the parking space and the rotation indicator differ in 2019 and 2020. The Wilcoxon test was performed to check whether these differences are statistically significant. Wilcoxon test is a non-parametric test [4]. The following hypotheses were formulated:

H_0: There are no differences in the use of parking space in weeks 5, 13, and 26 in 2019 and 2020,
and an alternative hypothesis,
H_1: There are differences in the use of parking space in weeks 5, 13, and 26 in 2019 and 2020.

Table 2 presents the Wilcoxon test statistics. The p-value and the T and Z statistics for groups of the 5th and 13th weeks, as well as 13th and 26th weeks in 2019, indicate that there are no differences in the use of parking space. In turn, these values for the groups of the 5th and 13th weeks and the 5th and 26th weeks in 2020 indicate differences in the use of parking space. The COVID-19 pandemic contributed to the reduction of the use of parking space in 2020.
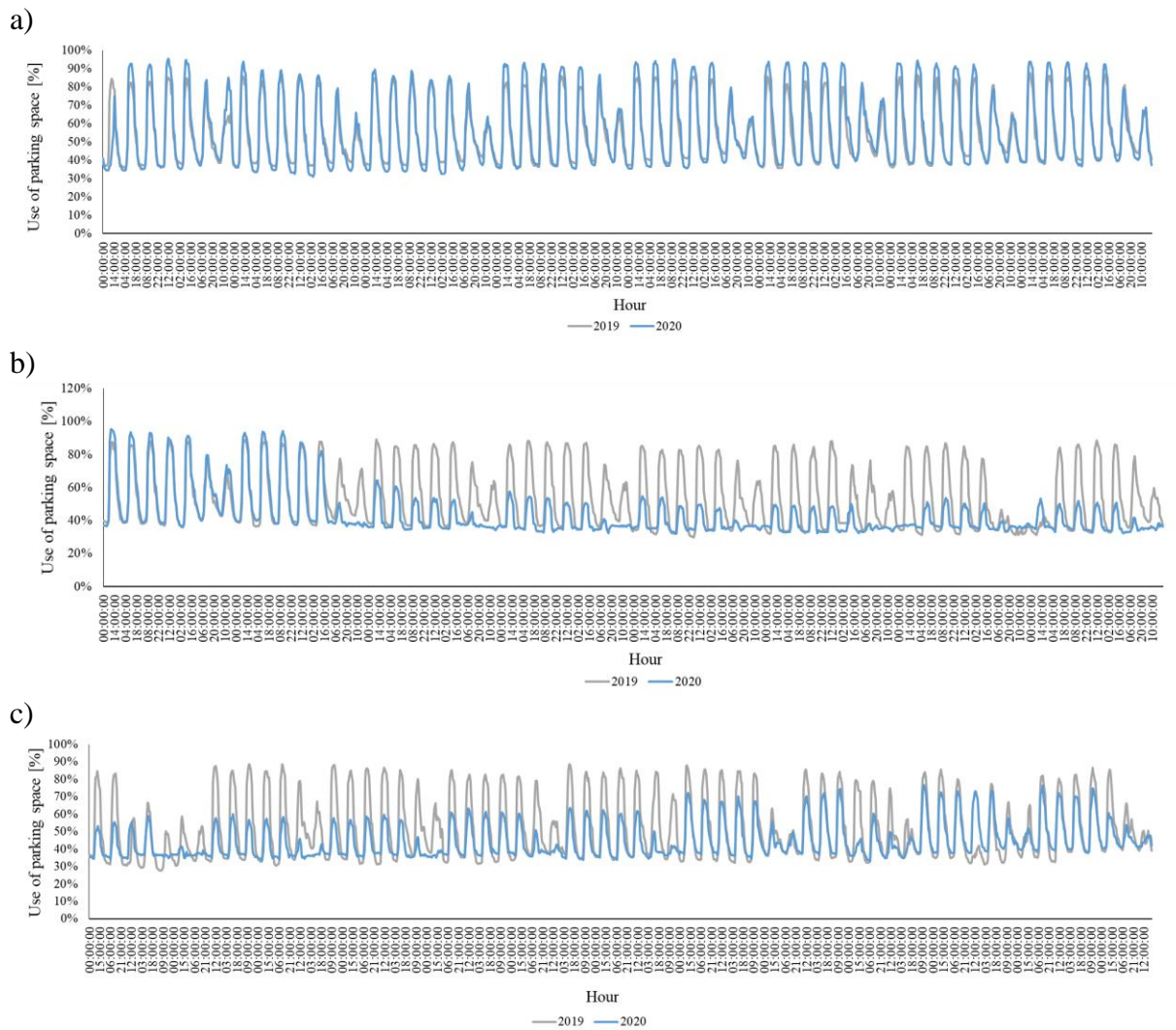
a)

b)

c)

Fig. 2. Distribution of the value of using the parking space per day in weeks:
a) 2-9; b) 10-17; c) 18-26 in 2019 and 2020

Tab. 2

Wilcoxon test statistics for use of parking space
and rotation indicator in PPZ in 2019 and 2020

Wilcoxon test statistics	5th & 13th weeks		5th & 26th weeks	
	2019	2020	2019	2020
T	5970	48	6437	2951
Z	1.79	11.17	1.05	6.57
p-value	0.074	0	0.295	0

a)

b)

c)
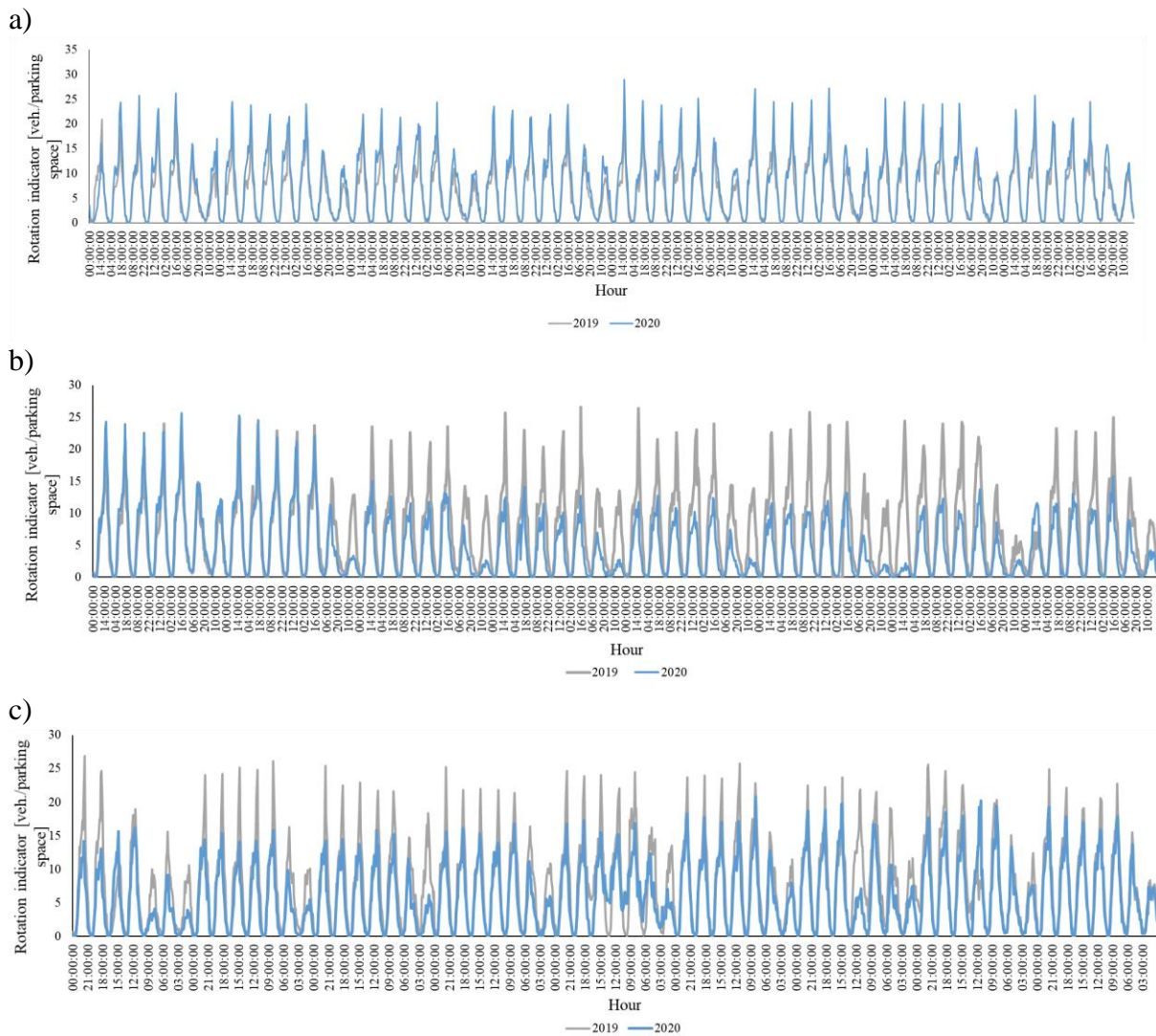
Fig. 3. Distribution of the value of the rotation indicator per day in weeks:
a) 2-9; b) 10-17; c) 18-26 in 2019 and 2020

Figures 4 and 5 show box plots for use of parking space values in weeks 5, 13, and 26 in 2019 and 2020. Box plots refer to the median, first quartile, third quartile, and outliers data. The range of values between the first and third quartile is at a similar level in all analyzed weeks in 2019. In the case of 2020, in the 5th week, the range of values is similar to the analyzed week in 2019. However, the smallest is in the 12th week in 2020. Outliers were in the 12th week in 2020. This confirms the earlier conclusion that the COVID-19 pandemic resulted in less use of the PPZ parking space in Gliwice.
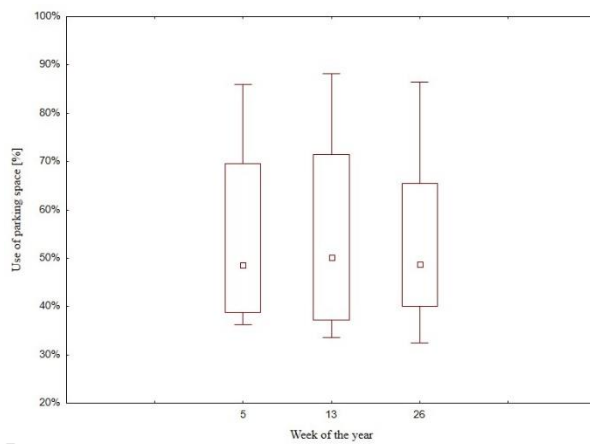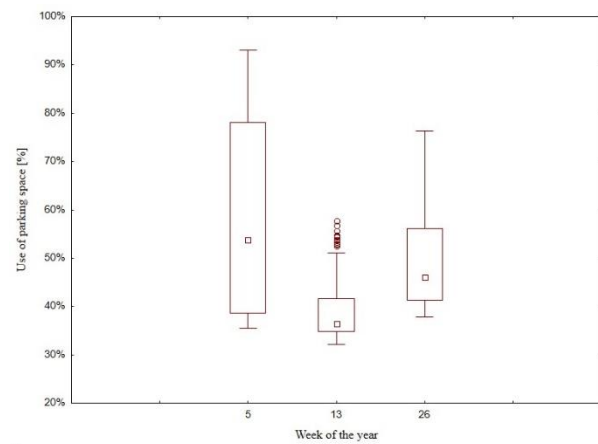
Fig. 4. Box plots for use of
parking space in 2019

Fig. 5. Box plots for use of
parking space in 2020

4. CONCLUSIONS

The article aimed to analyze the variability of the daily use of parking spaces in the Paid Parking Zone covered by Dynamic Parking Information before and during the COVID-19 pandemic. The analyzes carried out in the work allow for the formulation of the following conclusions:

- The value of the use of parking space and the rotation indicator in 2020 was higher than in 2019 in the weeks before the pandemic (week 2-11);
- In the 11th week on Friday, the value of the use of parking space and the rotation indicator was lower in 2020 compared to 2019. In the following weeks, these values in 2020 became lower than in 2019;
- From weeks 23 and 24, the use of parking space in 2020 increased and became equal to the value of parking space in 2019. In turn, the value of the rotation indicator increased from week 19 of 2020. This may be related to the removal of restrictions;
- On Saturdays and Sundays, the value of the use of parking space and the rotation indicator was lower than in the case of working days in all weeks in 2019 and 2020. Also on public holidays, these values were lower than on working days. It can therefore be concluded that the charging of parking fees contributed to the increase of availability of parking spaces for a larger number of people;
- The values of the Wilcoxon test statistics show that there were no differences in the use of parking space in weeks 5 and 13, and weeks 13 and 26 of 2019. In turn, the values of the Wilcoxon test statistics for weeks 5 and 13 as well as weeks 5 and 26 of 2020 indicated differences in the use of parking space;
- Box plots confirmed that the use of parking space in weeks 12 and 26 of 2020 (occurrence of the COVID-19 pandemic) differed significantly from week 5 of 2020 and weeks 5, 13, 26 in 2019 (before the COVID-19 pandemic)

Further studies of the impact of the pandemic on the use of parking spaces can be planned based on the conducted analysis. The results of the research may be helpful for traffic managers as an appropriate response in subsequent COVID-19 waves or the occurrence of a new pandemic.

Acknowledgment

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