TRANSPORT PROBLEMS 2021 Volume 16 Issue 1
PROBLEMY TRANSPORTU DOI: 10.21307/tp-2021-011

Keywords: road traffic volume distribution; road intersections; working days; holidays

Elżbieta MACIOSZEK*, Agata KUREK
Silesian University of Technology, Faculty of Transport and Aviation Engineering
Krasińskiego 8, 40-019 Katowice, Poland
**Corresponding author, E-mail:* elzbieta.macioszek@polsl.pl

ROAD TRAFFIC DISTRIBUTION ON PUBLIC HOLIDAYS AND WORKDAYS ON SELECTED ROAD TRANSPORT NETWORK ELEMENTS

Summary. As a rule, the road traffic volume distribution in particular hours on working days shows certain patterns on specific types of roads. Public holidays during the year cause disturbances and differences in the distribution of the daily traffic volume compared to working days. The road traffic volume distribution during the day is very important in the analysis of phenomena occurring in terms of road traffic. Knowledge of the values of traffic volumes during the day and their variability allows for the determination of a number of measures and parameters assessing traffic conditions prevailing on the elements of transport networks. Knowledge and understanding of changes in the distribution of traffic volume during a day are crucial for many aspects of transport engineering, such as road traffic control, road safety, and forecasting the traffic volume. This article evaluates the differences in the road traffic volume distributions during the day between public holidays and working days. The analysis was performed for selected intersections located in the city of Gliwice. The results of the statistical test show that on public holidays, there was less traffic volume compared to working days. The greatest decrease in the value of traffic volume occurred on 3rd May, 25th, and 26th December. This decrease ranged from 27.24% to 35.67%. It can be noticed that for all analyzed intersections, the smallest differences in the values of traffic volumes between a public holiday and a working day occurred on 1st November. Additionally, the nature of the impact of public holidays on the road traffic volume on days before and after public holidays was examined. The nonparametric hypothesis testing method was used to investigate changes in the road traffic volume patterns caused by public holidays. The results of Friedman's test show and confirm that there are differences in traffic volumes on the day before and after a public holiday and an average day.

1. INTRODUCTION

Nowadays, significant road traffic volume is observed on transport networks, which often leads to road congestion, decreased level of road safety, and increased negative impact of transport on the natural environment. Transport infrastructure in urbanized areas, which is an important element of the structure of the transport and spatial network of the city, should be adapted to the changing conditions of road traffic. The critical points of these networks are road intersections, the capacity of which determines the efficiency of traffic flow through a given intersection. Therefore, there is a need for continuous research and measurements of road traffic volume on the transport network. Information obtained from correctly conducted measurements and tests makes it possible to positively resolve unfavorable traffic conditions. Traffic volume measurements are most often carried out to modernize and expand as well as introduce changes to the organization of traffic on the transport network. The results of traffic volume measurements are used to prepare traffic forecasts and transport studies,

improve the quality of services offered by public transport, improve parking conditions and the level of road safety, and calculate the capacity of roads and streets. It is recommended to measure the traffic volume in the city transport network on Tuesdays, Wednesdays, and Thursdays. On weekends, i.e., Saturdays and Sundays, traffic is characterized by a different daily schedule, while days of the week such as Mondays and Fridays are affected by weekends (different daily traffic patterns on Fridays resulting from weekend trips and on Mondays resulting from weekend returns). Also, on public holidays and holidays, due to the different distribution of traffic volumes, no measurements and tests of road traffic are carried out. Moreover, traffic volumes are not measured in the winter months due to bad weather conditions.

Traffic volume studies are mainly carried out to design transport infrastructure and traffic organization, but also to analyze traffic as a sociological phenomenon. Traffic intensity fluctuates in individual periods of the day, weekdays, and months of the year [1, 2]. It depends on the location of the examined infrastructure element, road type, and type of vehicle [3]. Moreover, because of the changes in the traffic volume value, the distance traveled and the travel time during journeys on the transport network are varied [4]. This is mainly due to the fact that during the working period, these are mainly trips made to/from work, school, university, or other necessary trips in everyday life, such as healthcare, shopping, etc. These trips are usually characterized by short to moderate distances and travel times. For weekend and vacation trips, the purpose may be to visit family, friends, recreation, tourism, etc. In such cases, these trips are both longer in distance and time. On the other hand, the most common travel destinations on a public holiday are family and social meetings. These journeys are often longer in distance and time compared to journeys made during the working days. All such movements along the transport network generate an increase in road traffic.

Measurements, studies, and analyses of road traffic have been the subjects of numerous, multi-faceted scientific research. In the literature on the subject can be found research works dedicated the influence of various factors on the traffic volume values. They are, e.g., weather conditions or non-working days. From the research on the influence of weather conditions on traffic intensity presented in the work of M. Cools et al. [5], it can be concluded that snowfall, rainfall, and wind speed lead to lower traffic volumes, while high temperatures increase the traffic volume on the transport network. Another research work proving the influence of weather conditions on traffic volume was presented by H. Roh et al. [6-9], in which the authors also applied a non-parametric method. The work of M. Agarwal et al. [10] presented an analysis of the influence of weather conditions on the capacity and speed on a US highway. The results of the research carried out indicate that rainfall and snowfall reduce capacity and speed. Similar studies were conducted in Turkey. D. Akin et al. [11] also indicated that rainfall contributed to a reduction in speed and a reduction in throughput. Additionally, they showed that snowfall reduces the value of traffic volume.

In the case of non-working days, the impact of public holidays on the occurrence of road incidents was investigated [12]. The research presented by S. Anowar et al. [12] shows that the occurrence of a traffic incident in public holidays is influenced by factors other than the occurrence of traffic incidents on non-holiday weekends. The impact of public holidays on the occurrence of a road accident due to alcohol consumption was examined in the study of S. Foster et al. [13]. The results show that non-working days increase the probability of a road accident due to alcohol consumption. In turn, M. Cools et al. [5] indicate that public holidays should be taken into account in assessing the daily behavior of travelers. The impact of non-working days on the value of traffic volumes was examined e.g. by Z. Liu and S. Sharma [14], M. Cools et al. [15], and Y. Bao et al. [16]. The results of these studies allowed for the conclusion that the values of traffic intensity in non-working days differ compared to working days.

This article aims to analyze the variability of the distribution of traffic volumes on public holidays and working days on select elements of transport infrastructure. Moreover, the influence of public holidays on the traffic volume on days before and after public holidays was determined. The nonparametric hypothesis testing method was used to investigate changes in the traffic volume patterns caused by public holidays. The analysis was performed for selected intersections located in the city of Gliwice.

This paper consists of five sections. After the introduction, in the second section, the characteristics of the research area and the characteristics of the conducted research are presented. Section three presents the analysis of the traffic volume on public holidays and working days at selected intersections in the city of Gliwice and an analysis of the significance of differences in the values of traffic volume on the days before and after Corpus Christi. In order to check the statistical significance of the obtained results, the analysis in terms of differences in traffic distribution was additionally carried out for the paid parking zone that had dynamic passenger information. This paper ends with the discussion and conclusions section.

2. CHARACTERISTICS OF THE RESEARCH AREA AND THE CONDUCTED RESEARCH

Five four-inlet intersections with traffic lights located in the city of Gliwice were selected for the analysis (Fig. 1): (1) Andersa - Okulickiego, (2) Kozielska - Okulickiego, (3) Orlickiego - Portowa - Śliwki, (4) Chorzowska - Knurowska - Wolności - DK88,
and (5) Chorzowska - Zabrska - Dąbrowskiego. All intersections are located on important roads leading and discharging traffic flows to and from the city center. These intersections are also important communication junctions in the city, serving significant proportions of traffic volume by the day. They are equipped with vehicle detection and traffic control systems, video detection cameras, and induction loops, which are part of the intelligent traffic control system in the city of Gliwice (ITS Gliwice).

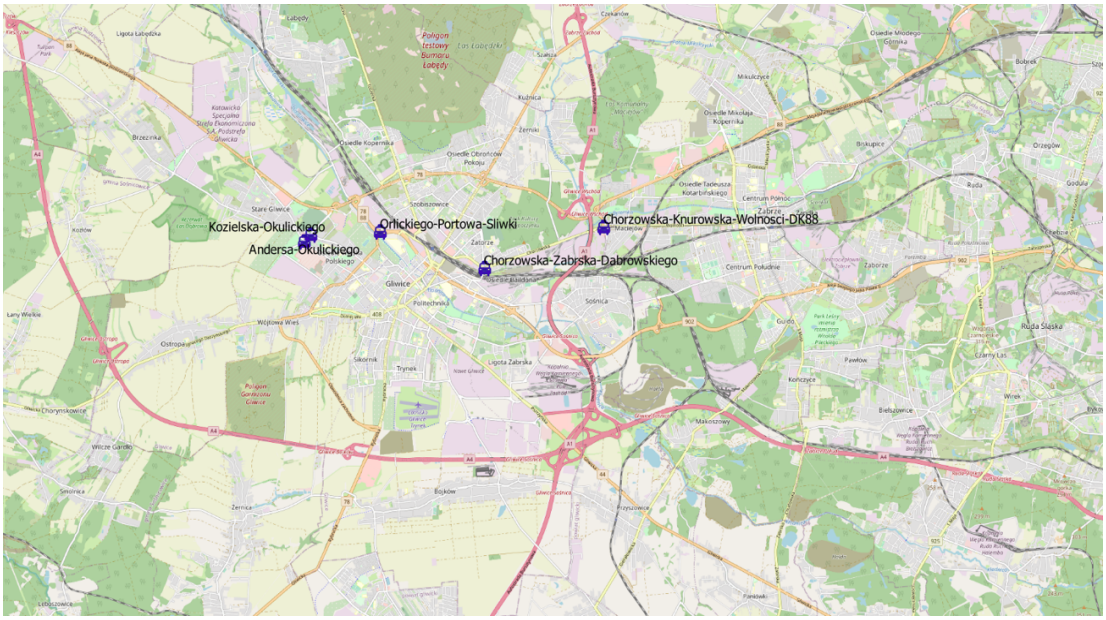

Fig. 1. Research area - intersections located in Gliwice (Poland)

The registration and archiving of traffic volumes at intersections and roads in Gliwice covered by the area traffic control system have been taking place continuously since 2013. The database created in this way enables the analysis of data on traffic volumes with an accuracy of 5 minutes. From the Traffic Control Center (in Polish: CSR) in Gliwice, data were obtained on traffic volumes for the analysis of the road traffic volume distribution in public holidays and workdays on selected intersections. The data included each day in 2019 divided into 15-minute intervals, taking into account the direction and structure of traffic, along with the accuracy of the traffic lane. For January and February 2019, the data on traffic volumes were incomplete due to the ongoing modernization of the system. Hence, the data for these months were not included in further analysis. Public holidays were

chosen, occurring from March to December 2019, which were taken into account in further analysis based on the Act on public holidays in Poland [17] (Table 1).

On public holidays, lower daily traffic volumes are usually observed than on working days. The measure M was introduced to assess the share of traffic volume on a public holiday to the traffic volume on a working day. M reflects the share of traffic volume on a public holiday to the average value of traffic volume on the corresponding working day in a given month. This measure takes the following form:

$$M = \frac{Q_p}{\overline{Q_p}} \cdot 100\% \quad [\%] \tag{1}$$

where Q_p - traffic volume on a public holiday [Veh./24 hours] and $\overline{Q_p}$ - the average traffic volume on working days [Veh./24 hours].

Table 1

Public holidays from April to December in 2019 in Poland

L.p.	Public holiday	Month	Day	Day of the week
1.	Easter	April	22th	Monday
2.	Labour Day	May	1st	Wednesday
3.	Constitution Day	May	3rd	Friday
4.	Corpus Christi	June	20th	Thursday
5.	Armed Forces Day	August	15th	Thursday
6.	All Saints' Day	November	1st	Friday
7.	Independence Day	November	11th	Monday
8.	Christmas Day	December	25th	Wednesday
9.	Second Day of Christmas	December	26th	Thursday

The differences between the traffic volume on public holidays and the traffic volume on working days were analyzed for the intersections studied. This analysis included determination of the following:

- variability of the daily distribution (profiles) of traffic volumes on working days,
- variability of the daily distribution (profiles) of traffic volumes on public holidays,
- measurements of the share of traffic volumes on public holidays to the average values of traffic volumes on the corresponding working days in a given month (M),
- the impact (or no impact) of the occurrence of public holidays on the traffic volume on days before and after the public holiday. This study was conducted for an average working day in June and the day before and after the Corpus Christi holiday for 2019 and 2020 using Friedman test statistics.

3. ANALYSIS OF THE ROAD TRAFFIC VOLUME DISTRIBUTION ON HOLIDAYS AND WORKDAYS AT THE SELECTED INTERSECTIONS IN THE CITY OF GLIWICE

Table 2 presents the values of traffic volume on public holidays, the average daily traffic volume on the corresponding days of the week, and the values of the M measure for the analyzed intersections for 2019. The smallest decrease in the value of traffic volume occurred on 1st November for all analyzed intersections. This fact is reflected in reality, because on this day, many people visit the graves of their relatives, often traveling on the transport network to several cemeteries in one day. In the case of the following intersections: Andersa-Okulickiego, Kozielska-Okulickiego, Chorzowska-Knurowska-Wolności-DK88, and Chorzowska-Zabrska-Dąbrowskiego, the greatest decrease in traffic was recorded on 3rd May and 25th and 26th December (from 27.24% to 35.67%). At the Orlickiego-Portowa-Śliwki intersection, the greatest decrease in the traffic volume was observed on 1st May (4.52%).

A graph of hourly traffic fluctuations (also called the daily route line or daily distribution) is usually used to characterize the variability of the traffic volume during the day. The share of hourly traffic volumes in all-day traffic is calculated to obtain a graph of average daily traffic fluctuations. The standardized graph obtained in this way is characterized by low sensitivity to random changes in traffic volume.

Table 2

Traffic volume at the intersections on public holidays, average traffic volume on the corresponding days of the week, and value of the measures in 2019

Intersection --- Public holidays	(1)		(2)		(3)		(4)		(5)	
	$\overline{Q_p}$ [Veh./ 24 hours]	M [%]	$\overline{Q_p}$ [Veh./ 24 hours]	M [%]	$\overline{Q_p}$ [Veh./ 24 hours]	M [%]	$\overline{Q_p}$ [Veh./ 24 hours]	M [%]	$\overline{Q_p}$ [Veh./ 24 hours]	M [%]
22th of April	11805	42.85	8512	38.44	10773	39.15	9862	53.08	11622	41.36
Average Monday in April	27552		22144		27516		18581		28101	
1st of May	12298	46.18	7524	36.00	1204	4.52	6944	39.55	11612	42.70
Average Wednesday in May	26629		20899		26639		17559		27192	
3rd of May	8753	31.88	6215	27.24	9561	33.25	6482	35.67	9716	33.07
Average Friday in May	27452		22817		28751		18171		29377	
20th of June	10542	37.71	7961	35.78	10783	39.92	9337	39.26	10724	39.03
Average Thursday in June	27952		22248		27011		23783		27479	
15th of August	11191	46.99	8329	41.40	11161	44.76	8897	41.53	10661	43.63
Average Thursday in August	23816		20116		24935		21425		24435	
1st of November	17027	63.15	8885	41.36	22451	63.81	15842	61.92	20544	72.55
Average Friday in November	26962		21485		35187		25585		28316	
11th of November	10238	40.31	8304	42.07	17673	52.37	10125	42.59	11397	46.83
Average Monday of November	25398		19737		33744		23774		24335	
25th of December	7715	30.34	5556	28.01	16010	45.57	8366	34.12	8231	31.43
Average Wednesday in December	25426		19835		35135		24522		26187	
26th of December	8243	29.61	5888	27.77	15333	41.56	8691	32.86	9028	32.94
Average Thursday in December	27838		21201		36889		26446		27411	

Fig. 2 shows the daily distribution of traffic volume at the analyzed intersections on public holidays and the average values of the traffic volume on the corresponding days of the week in a given month for 2019.

The figures show that on all working days, the nature of the daily traffic volume distribution is similar and is typical for working days. The highest values of traffic volumes are obtained in the afternoon and morning rush hours. The morning rush hour at all intersections is between 06:00 and 08:00. On the other hand, the afternoon rush hours for particular intersections are slightly spaced in time relative to each other. At the Andersa-Okulickiego intersection, the afternoon peak hours are from 13:00 to 17:00 for the Kozielska-Okulickiego intersection, from 15:00 to 17:00 for the Chorzowska-Zabrska-Dąbrowskiego-DK88 intersections, from 15:00 to 18:00 in the case of the Orlickiego-Portowa-Śliwki intersection, and from 14:00 to 17:00 for the Chorzowska-Knurowska-Wolności intersection.

A feature that characterizes the daily distribution of traffic volumes on public holidays is low traffic volumes in the early morning and morning hours until 09:00 and the distinctly higher traffic volumes from the afternoon (from 13:00) to the evening hours (until 21:00). At the Orlickiego - Portowa - Śliwki intersection, on public holidays, more traffic volume can be observed during the night hours from 00:00 to 04:00. This intersection is located near the city center and allows access to the provincial road (in Polish: DTŚ). High traffic volumes during these hours may indicate travel related to social and family life.

The Friedman test was carried out to test the differences in the values of traffic volumes on an average working day and the day before and after it. In 2019, the May holidays (1st and 3rd May), Easter (22th April), and Christmas (25th and 26th December) last more than one day and for a longer period before and after. The Polish Armed Forces Day falls during the holiday period, and the traffic intensity in this period is different compared to other months. On the other hand, All Saints (1st November) was on a Friday in 2019; thus, the following day was Saturday. This day was characterized by varying traffic volumes compared to the other days of the week. It was similar in the case of Independence Day, which fell on a Monday in 2019; thus, the day before was Sunday, which was characterized by different traffic volumes compared to the other days of the week. In terms of the above, it was decided to present an analysis of the significance of the differences in the traffic volume values on an average Thursday in June and the day before and after Corpus Christi (in 2019, Corpus Christi was on a Thursday).

Friedman's test is a non-parametric test [18, 19]. The results of the measurements are assigned ranks for each sample [20]. The following hypotheses were formulated:

H_0: There are no differences in the values of traffic volumes on an average Thursday in June and the day before and after Corpus Christi.

The alternative hypothesis was as follows:

H_1: There are differences in the values of traffic volumes on an average Thursday in June and the day before and after Corpus Christi.

The Friedman test statistic takes the following form:

$$\chi^2 = \frac{12}{a \cdot l \cdot (l+1)} \sum_{i=1}^{l} R_i^2 - 3 \cdot a \cdot (l+1) \tag{2}$$

where l is the number of groups (treatments), a is the number of subjects, and R_i is the sum of the ranks for the i-th group.

Table 3 shows the Friedman test results for the day before and after Corpus Christi and an average Thursday in June for the analyzed intersections. The aim was to verify whether there are differences in the values of traffic volume on an average Thursday in June and the day before and after Corpus Christi. The ranks were calculated and then added up for each day. The highest values of the sum of ranks occur on the day before the public holiday, while the lowest values of the sum of ranks occur on the day after the public holiday. This means that on the day before Corpus Christi, more traffic volume can be observed than on an average Thursday in June. This may be due to shopping trips as shops are closed on the day off. These trips can also be related to recreation, tourism, or family gatherings. On

the day after Corpus Christi, less traffic volume can be observed than on an average Thursday in June. This may be due to the extension of the weekend and trips outside the city.

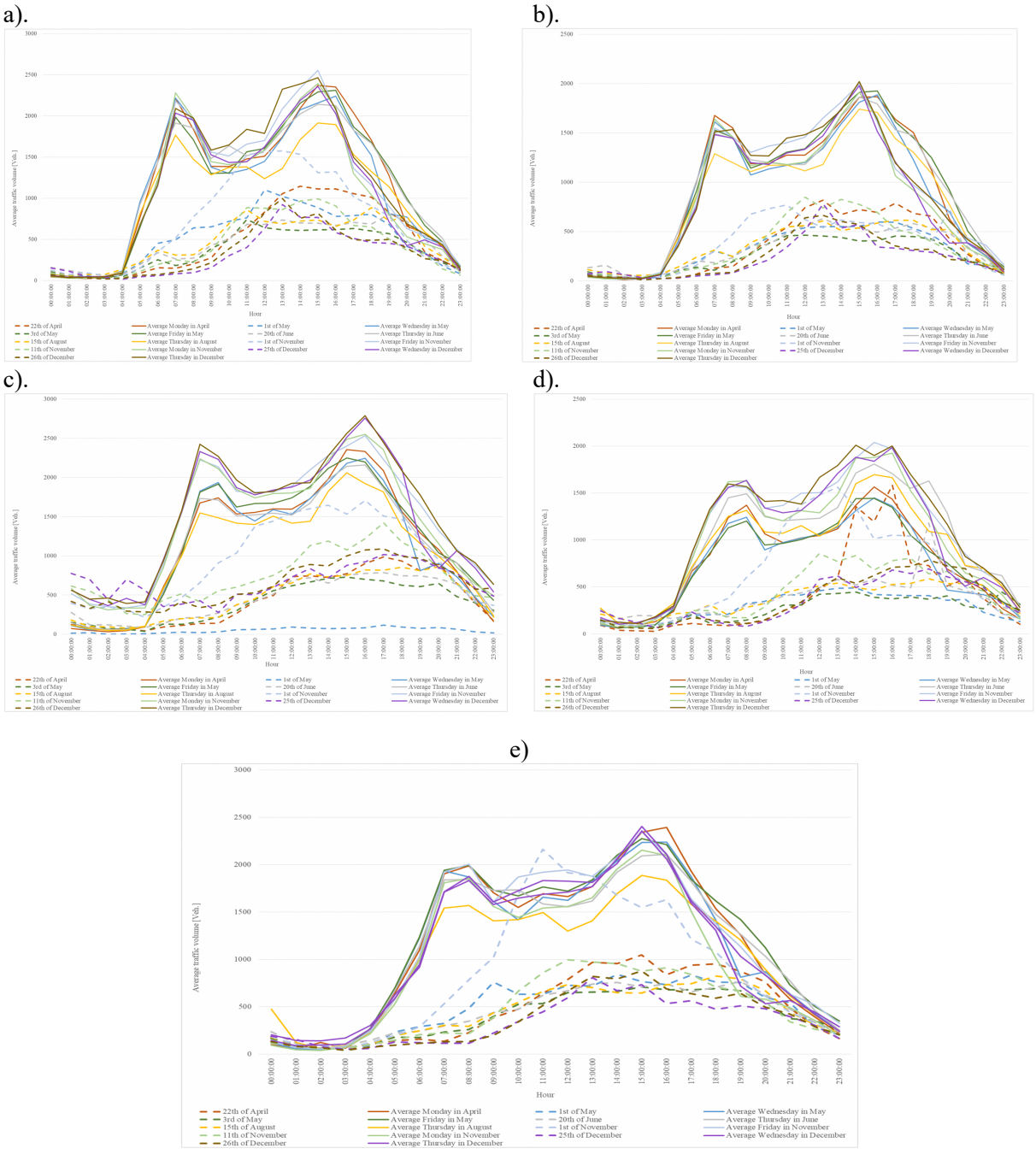

Fig. 2. Daily distribution of traffic volumes on public holidays and the corresponding average working day in 2019 at the following intersections: (a) Andersa-Okulickiego, (b) Kozielska-Okulickiego, (c) Okulickiego-Portowa-Śliwki, (d) Chorzowska-Knurowska-Wolności-DK88, and (e) Chorzowska--Zabrska-Dąbrowskiego

Fig. 3 shows the box plot for an average Thursday in June, the day before and after Corpus Christi, and for an average Thursday in June for the analyzed intersections. The box plots presented in Fig. 3 show the mean, standard deviation, and standard error. It can be observed that the values of the standard error and standard deviation are the greatest in the case of an average Thursday in June, the

day before and after the Corpus Christi, then on Corpus Christi. This means that Corpus Christi is characterized by smaller differences in the traffic volumes during the day compared to an average Thursday in June, the day before and after, based on the box plots.

Table 3

Friedman test results (2019)

Intersection	Day	Average rank	Sum of ranks	Average	Standard deviation
1	Before	2.63	63	1228	791
	Average	2.23	53	1165	762
	After	1.15	27	933	619
2	Before	2.63	63	1038	691
	Average	1.92	46	927	629
	After	1.46	35	813	561
3	Before	2.46	59	1200	775
	Average	1.96	47	1125	721
	After	1.58	38	952	613
4	Before	2.50	60	982	576
	Average	2.46	59	991	575
	After	1.04	25	753	432
5	Before	2.63	63	1231	779
	Average	2.04	49	1145	728
	After	1.33	32	987	617

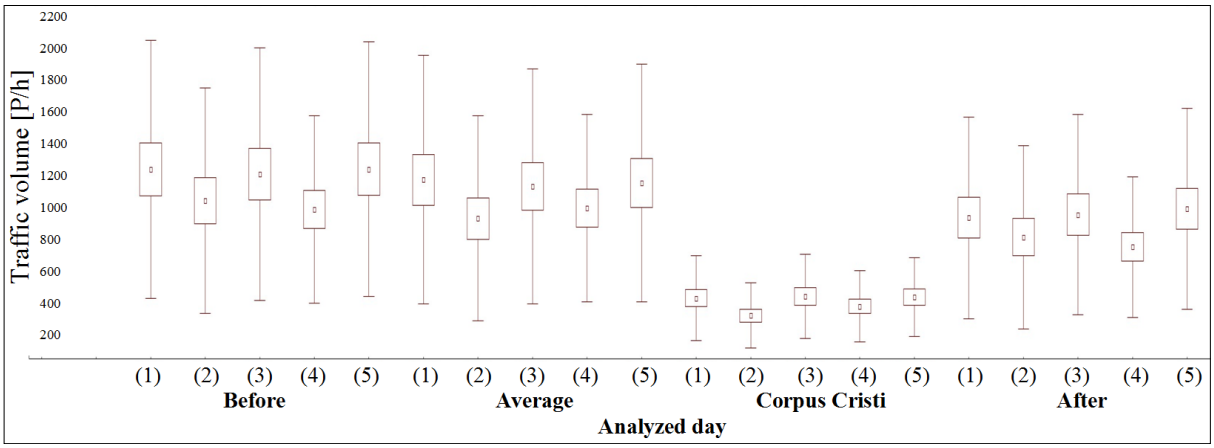

Fig. 3. Box plot for Corpus Christi, the day before and after Corpus Christi, and for an average Thursday in June for all analyzed intersections in 2019

Table 4 shows the statistics of the Friedman test according to formula (2) for the analyzed intersections. χ^2_{cri} for $\alpha = 0.05$ and $l = 1$ is 3.48. Table 4 shows that all values $\chi^2 > \chi^2_{cri}$. Therefore, in the case of all intersections, the null hypothesis is rejected and an alternative hypothesis is accepted. This allows concluding that there are differences in the values of traffic volumes on an average Thursday in June and the day before and after Corpus Christi.

In order to confirm the existence (or lack of existence) of a similar regular trend in 2020, the Friedman test was performed again. Table 5 shows the Friedman test results for the day before and after Corpus Christi and an average Thursday in June for the analyzed intersections in 2020; meanwhile, the calculated Friedman test statistics are presented in Table 6. Table 6 shows that all values $\chi^2 > \chi^2_{cri}$. Therefore, in the case of all intersections, the null hypothesis is again rejected and an alternative hypothesis is accepted. This allows concluding that there are also differences in the

values of traffic volumes on an average Thursday in June and the day before and after Corpus Christi in 2020.

Table 4

Friedman test statistics for the analyzed intersections (2019)

Intersection	1	2	3	4	5
χ^2	28.44	16.58	9.25	33.08	20.08

Table 5

Friedman test results (2020)

Intersection	Day	Average rank	Sum of ranks	Average	Standard deviation
1	Before	2.54	61	1103	749
	Average	2.15	52	1049	709
	After	1.31	32	782	565
2	Before	2.56	62	897	614
	Average	1.96	47	832	575
	After	1.48	36	567	550
3	Before	2.83	68	1270	760
	Average	1.33	32	972	643
	After	1.83	44	1000	557
4	Before	2.50	60	990	560
	Average	2.50	60	980	542
	After	1.00	24	704	441
5	Before	2.67	64	991	619
	Average	1.92	46	955	598
	After	1.42	34	816	491

Table 6

Friedman test statistics for the analyzed intersections (2020)

Intersection	1	2	3	4	5
χ^2	19.09	14.29	28.00	36.00	19.00

Fig. 4 shows the box plot for an average Thursday in June, the day before and after Corpus Christi, and Corpus Christi for analyzed intersections in 2020. The box plots presented in Figure 4 show the mean, standard deviation, and standard error. It can be observed again that the values of the standard error and standard deviation are the greatest in the case of an average Thursday in June, the day before and after Corpus Christi than on Corpus Christi. This means that Corpus Christi is characterized by smaller differences in the traffic volumes during the day compared to an average Thursday in June, the day before and after Corpus Christi, based on the box plots.

In order to check whether the occurrence of a public holiday affects communication behavior, the Friedman test was carried out for parking spaces covered by the Paid Parking Zone (PPZ) and Dynamic Parking Information (DPI) in Gliwice in 2019. A total of 791 parking spaces covered by PPZ and DPI in Gliwice are equipped with sensors detecting the presence of vehicles. The data were obtained from the Municipal Roads Authority in Gliwice and included the parking usage and rotation rate in parking spaces. Table 7 shows the Friedman test results for the day before and after Corpus Christi and an average Thursday in June for the analyzed parking spaces in 2019; meanwhile, the calculated Friedman test statistics are presented in Table 8. Table 8 shows that both values $\chi^2 > \chi^2_{cri}$. Therefore, in the case of analyzed parking spaces, the null hypothesis is again rejected and an alternative hypothesis is accepted. This allows concluding that there are also differences in the values

of traffic volumes on an average Thursday in June and the day before and after Corpus Christi for analyzed parking spaces.

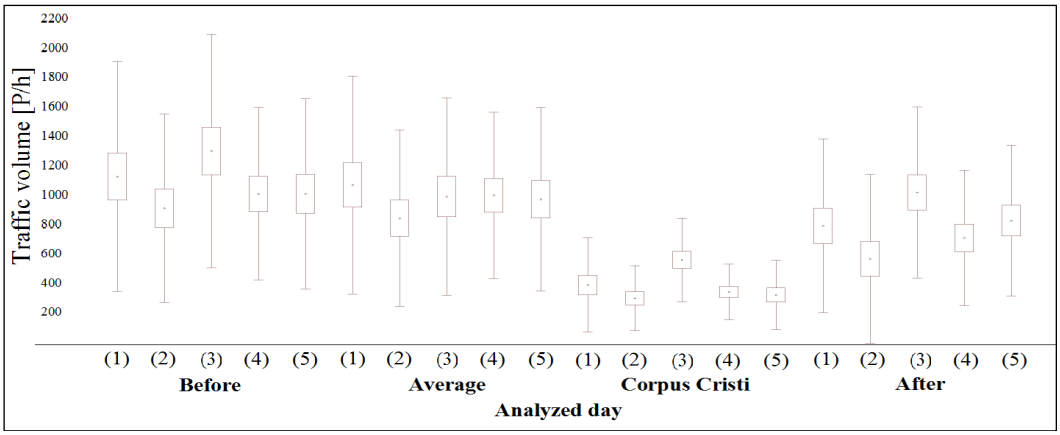

Fig. 4. Box plot for Corpus Christi, the day before and after Corpus Christi, and for an average Thursday in June for all analyzed intersections in 2020

Table 7

Friedman test results (Paid Parking Zone)

Parking characteristics	Day	Average rank	Sum of ranks	Average	Standard deviation
Parking usage (U)	Before	2.42	58	53	17
	Average	2.46	59	54	20
	After	1.13	27	47	16
Rotation rate (R)	Before	2.08	50	0.25	0.18
	Average	2.46	59	0.25	0.18
	After	1.46	35	0.19	0.15

Table 8

Friedman test statistics for the Paid Parking Zone

Parking characteristics	U	R
χ^2	27.25	12.25

Figure 5 presents the box plots for an average Thursday in June, the day before and after Corpus Christi, and for Corpus Christi for parking usage and rotation rate for analyzed parking spaces in 2019. The box plots presented in Figure 5 show the mean, standard deviation, and standard error. In the case of parking usage, an average Thursday in June is characterized by the highest value of standard deviation, while the lowest value of standard deviation is for Corpus Christi. However, the value of the standard deviation of the rotation rate for an average Thursday in June and the day before and after Corpus Christi is at a similar level. The smallest value of the standard deviation in the case of the rotation rate occurs in Corpus Christi.

4. CONCLUSIONS

This article aimed to analyze the variability of the distribution of traffic volumes on public holidays and working days on selected elements of transport infrastructure. It made it possible to define communication behaviors on public holidays and working days at these intersections. Information on the distribution of daily traffic volumes on public holidays can be used for more effective traffic management. All analyzed intersections are intersections equipped with signaling devices operating in a variable time mode. In the case of this kind of traffic lights, it is possible to adapt the traffic light programs to the variable values of traffic volume. This translates into the improvement of traffic

conditions and improvement of traffic flow in the area of the intersection and may also contribute to the reduction of the operating costs of traffic lights. Based on the analyses carried out in this article, the following conclusions were arrived at:

- on public holidays, there was less traffic volume compared to working days. The greatest decrease in the value of traffic volume occurred on such public holidays as 3rd May, and 25th and 26th December. This decrease ranged from 27.24% to 35.67%. It can be noticed that for all analyzed intersections, the smallest differences in the values of traffic volumes between a public holiday and a working day occurred on 1st November.
- The daily distribution of traffic volume on a public holiday differs from the distribution of traffic volume on a working day. On a public holiday, the highest traffic volumes are in the afternoon and evening hours. However, on working days, there are two peak hours: morning and afternoon.
- Friedman's test results show and confirm that there are differences in traffic volumes on the day before and after Corpus Christi and an average Thursday in June. The analysis showed that these differences are statistically significant for both years 2019 and 2020.
- Friedman test results for the value of parking usage and the rotation rate for analyzed parking in 2019 also confirm the difference in communication behavior on an average Thursday in June and the day before and after Corpus Christi.
- Corpus Christi is characterized by smaller differences in traffic volumes during the day compared to the day before and after and an average Thursday in June based on the box plots.

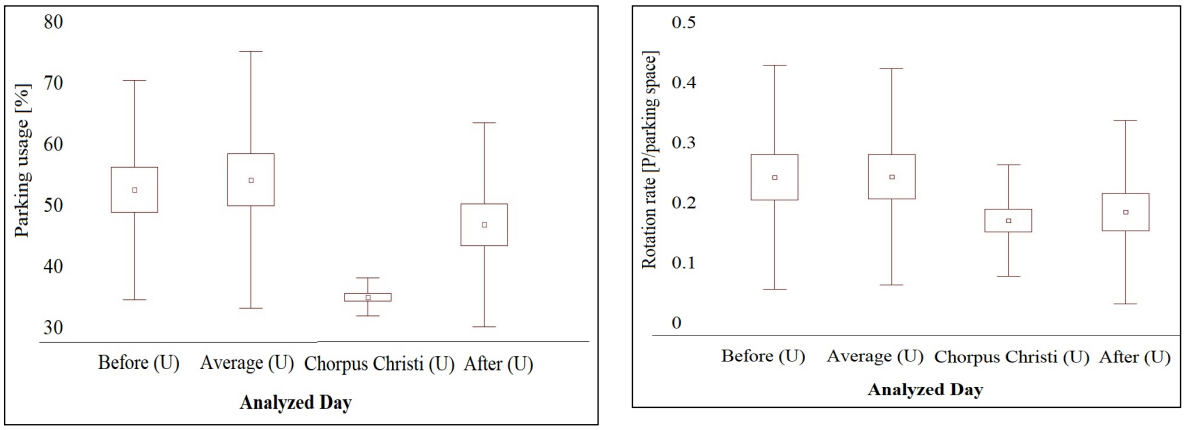

Fig. 5. Box plots for Corpus Christi, the day before and after Corpus Christi, and for an average Thursday in June in 2019 for (a) parking usage and (b) rotation rate for analyzed parking spaces

The results presented in this paper can contribute to the literature on the methodology of identifying road traffic volume variations on the intersections between holidays and working days using a non-parametric method. Meanwhile, the presented research could be useful when using more advanced non-parametric models in the assessment of traffic volume changes in various settings in future research.

References

1. Thomas, T. & Weijermars, W. & van Berkum, E. Variations in urban traffic volumes. *European Journal of Transport and Infrastructure Research*. 2008. Vol. 8. No. 3. P. 251-263.
2. Macioszek, E. Changes in values of traffic volume - case study based on general traffic measurements in Opolskie Voivodeship (Poland). In: E. Macioszek, G. Sierpiński (eds.) *Directions of Development of Transport Networks and Traffic Engineering. Lecture Notes in Networks and Systems*. Switzerland: Springer International Publishing. 2019. P. 66-76.

3. Macioszek, E. The passenger car equivalent factors for heavy vehicles on turbo roundabouts. *Frontiers in Built Environment. Section Transportation and Transit Systems*. 2019. Vol. 5. Article 68. P. 1-13.
4. Macioszek, E. Analysis of driver behaviour at roundabouts in Tokyo and the Tokyo surroundings. In: E. Macioszek, G. Sierpiński (eds.) *Modern Traffic Engineering in the System Approach to the Development of Traffic Networks. Advances in Intelligent Systems and Computing.* Switzerland: Springer International Publishing. Springer Nature. 2020. P. 216-22.
5. Cools, M. & Moons, E. & Wets, G. Assessing the impact of weather on traffic intensity. *Weather, Climate, and Society*. 2010. Vol. 2. No. 1. P. 60-68.
6. Roh, H.J. & Sahu, P.K. & Sharma, S. & Datla, S. & Mehran, B. Statistical investigations of snowfall and temperature with passenger car and truck traffic on primary highway in Canada. *ASCE Journal of Cold Regions Engineering*. 2016. Vol. 30. No 2. Article ID 04015006. P. 04015006-1-04015006-16.
7. Roh, H.J. Spatial transferability testing of dummy variable winter-weather model using traffic data collected from five geographically dispersed weigh-in-motion sites in Alberta Highway Networks. *ASCE Journal of Transportation Engineering, Part A: Systems*. 2020. Vol. 146. No. 11. Article ID 04020128, P. 04020128-1- 04020128-20.
8. Roh, H.J. Development and performance assessment of winter climate hazard models on traffic volume with four model structure types. *ASCE Natural Hazards Review.* 2020. Vol. 21. No 3. Article ID 04020023. P. 04020023-1- 04020023-12.
9. Roh, H.J. Developing Cold Region Winter-Weather Traffic Models and Testing Their Temporal Transferability and Model Specification. *ASCE Journal of Cold Region Engineering*. 2019. Vol. 33. No. 3. Article ID 04019009. P. 04019009-1- 04019009-13.
10. Agarwal, M. & Maze, T.H. & Souleyrette, R. Impacts of weather on urban freeway traffic flow characteristics and facility capacity. In: *Proceedings of the 2005 Mid-Continent Transportation Research Symposium*. 2005. P. 18-19.
11. Akin, D. & Sisiopiku, V.P. & Skabardonis, A. Impacts of weather on traffic flow characteristics of urban freeways in Istanbul. *Procedia-Social and Behavioral Sciences*. 2011. Vol. 16. P. 89-99.
12. Anowar, S. & Yasmin, S. & Tay, R. Comparison of crashes during public holidays and regular weekends. *Accident Analysis & Prevention*. 2013. Vol. 51. P. 93-97.
13. Foster, S. & Gmel, G. & Estévez, N. & Bähler, C. & et al. Temporal patterns of alcohol consumption and alcohol-related road accidents in young Swiss men: seasonal, weekday and public holiday effects. *Alcohol and Alcoholism*. 2015. Vol. 50. No. 5. P. 565-572.
14. Liu, Z. & Sharma, S. Statistical investigations of statutory holiday effects on traffic volumes. *Transportation Research Record*. 2006. Vol. 1945. No. 1. P. 40-48.
15. Cools, M. & Moons, E. & Wets, G. Investigating effect of holidays on daily traffic counts: time series approach. *Transportation Research Record*. 2007. Vol. 2019. No. 1. P. 22-31.
16. Bao, Y. & Xiao, F.& Gao & et al, Investigation of the traffic congestion during public holiday and the impact of the toll-exemption policy. *Transportation Research Part B: Methodological*. 2017. Vol. 104. P. 58-81.
17. Ustawa z dnia 18 stycznia 1951 r. w dniach wolnych od pracy. [In Polish: The Act of 18 January 1951 on non-working days].
18. Cleophas, T.J. & Zwinderman, A.H. Non-parametric tests for three or more samples (Friedman and Kruskal-Wallis). In: *Clinical Data Analysis on a Pocket Calculator.* Springer, Cham. 2106. P. 193-197.
19. Sheldon, M.R. & Fillyaw, M.J. & Thompson, W.D. The use and interpretation of the Friedman test in the analysis of ordinal scale data in repeated measures designs. *Physiotherapy Research International*. 1996. Vol. 1. No. 4. P. 221-228.
20. Liu, Z. & Sharma, S. Nonparametric method to examine changes in traffic volume pattern during holiday periods. *Transportation Research Record*. 2008. Vol. 1. No. 4. P. 45-53.

Received 21.07.2019; accepted in revised form 24.02.2021