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EXPLORING BIKE-SHARING SYSTEMS IN POLAND CO-FINANCED FROM THE EUROPEAN UNION FUNDS

Badanie systemów rowerów miejskich w Polsce dofinansowanych z funduszy Unii Europejskiej

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Abstract: In recent years, numerous Polish cities and municipalities have become involved in the creation of bike-sharing systems. Although the contribution of bike-sharing to creating sustainable transport caused some controversy in the literature, the positive role of cycling in promoting low-emission mobility and a healthy lifestyle is widely acknowledged. As part of the European Union's sustainable transport agenda, some Polish local governments have obtained funding from structural funds for the implementation of bicycle-sharing schemes. This article presents an overview of selected systems, as well as a preliminary analysis of their users' activity based on data obtained through a Web API. Although the scope of the data was limited in time due to the shutdown of the systems caused by the COVID-19 pandemic shortly after their spring reactivation, some patterns could be observed. In particular, users activity was more evenly distributed over time in larger cities (over 300 thousand of residents), whereas in smaller cities alternating periods of high and low activity was observed.

Keywords

Bike sharing, European Union funds, cycling, mobility.

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Introduction

Bike-sharing systems (also known as public bike schemes) are becoming more and more popular in recent years (Parkes et al. 2013; Fishman, 2016). They can increase accessibility to other forms of transport (Jäppinen et al., 2013; Molin et al., 2016), as well as to places related to tourism and recreation (Bieliński et al., 2019). Most bike-sharing systems are found in Europe (Médard de Chardon et al. 2017; Raux, 2017), Asia (Shen et al. 2018; Yao et al., 2019) and North America (Martin, 2014; Winters et al., 2019). Most of them operate commercially, while only a small part is operated on a non-profit basis (Médard de Chardon et al., 2017). In general, bicycle systems operators in Europe receive public support (Fuller et al., 2013). They can also benefit from advertisements on bicycles and stations. Sometimes, bike-sharing systems are sponsored by private companies.

In Poland, the first public bike scheme was created in Kraków in 2008 (Łastowska and Bryniarska, 2015). In 2016, there were already about 20 such schemes in operation (Dębowska-Mróz et al., 2017), while in 2018 there were about 60 (Kwiatkowski, 2018). In March 2020, there were 96 bike-sharing systems functioning in Poland (Ostre hamowanie roweru miejskiego, 2020). The largest number of systems in Poland is operated by the German company Nextbike (Ostre hamowanie roweru miejskiego, 2020). Some public bike schemes are co-financed with funds from the European Union, with the European Regional Development Fund being the main source of funding.

The first purpose of this paper is to explore how Polish bike-sharing systems, financed from the Eu-

ropean Union funds, are used. To achieve this aim we explore data obtained from a web service provided by the system operator. The database contained information on the movements of bicycles and their numbers at individual bike stations. The research used a computer program that retrieved information using the Nextbike dedicated Web API¹. Consequently, the frequency of bike rentals on single days of March 2020 was visualized using a calendar heatmap. The most popular bicycle stations in selected cities were also shown. The second purpose of the work was to provide basic information about projects that supported the financing of city bikes-sharing systems in selected cities. Brief characteristics of the examined systems were also made.

1. Materials and methods

Bike-sharing systems in Poland are typically inactive during winter and resume operation in early spring (Powrót rowerów miejskich Nextbike, 2020). This is usually the beginning of March. In turn, they are usually suspended in the fall. Few systems, such as Wrocławski Rower Miejski and Rowerowe Łódzkie operate throughout the year.

A brief description of bike-sharing systems supported by European Union funds in selected Polish cities is presented in Table 1. Only the systems for which trip data could be obtained were presented.

¹ In this case, a network interface that enabled data transfer in real time directly from the Nextbike database to any computer. This makes it easier to obtain data that is delivered in a database file convenient for further processing.

Tab. 1. List of examined cities and project titles supporting the considered city bike-sharing systems.

The city	Project title and funding information (where available)	Purpose of the system
Grodzisk Mazowiecki	"The system of unmanned bicycle rental as an integrated, innovative tourist product of the Grodzisk Mazowiecki commune". (Mapa dotacji UE, 2020)	Sustainable transport, tourism and recreation
Kołobrzeg	"Intelligent transport systems, bike paths, municipal bike rental and Park & Ride strategic parking lots". (ZIT Kołobrzeg, 2020)	Sustainable transport, tourism and recreation
Koszalin	"Investments in integrated infrastructure related to low-emission transport in Koszalin". The total value of the project: PLN 20,673,719 (EUR 4,698,572). (Inwestycje Koszalina, 2020)	Sustainable transport
Lublin	"European Capital of Bicycle Tourism in Lublin". The total value of the project: PLN 8,596,021 (EUR 1,953,641). Co-financing value: PLN 3,419,293.28 (EUR 777,161). (Lublin – Projekty zrealizowane, 2020)	Sustainable transport, tourism and recreation
Ostrów Wielkopolski	"Modernization of urban transport in Ostrów Wielkopolski along with other low-carbon activities in the Kalisko-Ostrowska agglomeration." The total value of the project was over PLN 39,000,000 (EUR 8,863,636) (Ostrów Wielkopolski – Unowocześnienie transportu miejskiego, 2020)	Sustainable transport

Rowerowe Łódzkie	"Integration of various public transport systems through the development of interchanges in the Lodz region." (Wojewódzki Rower Publiczny, 2020)	Sustainable transport
Szamotuły	"Delivery, installation and commissioning of a city bike system with complete equipment as part of the construction of an integrated transfer node in Szamotuły, Pamiątkowa Baborówek with infrastructure" (Szamotuły Bike, 2020)	Sustainable transport
Tarnów	"Integration of public transport in Tarnów" (BIP Małopolska, 2020)	Sustainable transport

Source: Own elaboration based on data from project websites and pages of public bicycle systems in selected cities. The information on the total cost of the project was not available for some cities.

The investigated schemes were available in cities with various numbers of inhabitants (e.g. Szamotuły – 19000, Kołobrzeg – 45000, Koszalin – 100000, Lublin – 330000). In the case of Łódź inhabited by about 700000 people, the situation was more complicated. The city terminated its bike-sharing scheme in 2019 due to increasing maintenance costs. Instead, it has participated in a regional-scale project "Rowerowe Łódzkie". Thus,

the number of bicycles available in Łódź was small compared to other major cities in Poland.

Most of the investigated bike-sharing systems have been established after 2017. Two exceptions are Grodzisk Mazowiecki and Lublin, which were created in 2014. The number of inhabitants of selected cities, the number of available public bicycles, and the cost of renting are presented in Table 2.

Tab. 2. Basic information about the presented city bike systems. Poland currency – PLN (1 PLN ~ 0,25 USD).

The city	Number of inhabitants	Number of bikes	Number of station	Launch date	The cost of renting a bike
Grodzisk Mazowiecki	30 000	92	12	2014	1 – 20 minutes – 0 PLN. 21 – 60 minutes – PLN 1 61-120 minutes – 1 PLN. 121 – 180 minutes – PLN 1 181 minutes and each subsequent hour – 5 PLN. (Grodziski Rower Miejski – Cennik, 2020)
Kołobrzeg	45 000	135	13	2017	1-20 minutes – PLN 0. 21-60 minutes – 2 PLN. 61-120 minutes – 3 PLN. 121 minutes and another hour – 10 PLN. (Kołobrzegi Rower Miejski – Cennik, 2020)
Koszalin	100 000	100	10	2018	1-20 minutes – PLN 0. 21-60 minutes – PLN 1 61 minutes and another hour – 2 PLN. (Koszaliński Rower Miejski – Cennik, 2020)
Lublin (and Świdnik)	370 000	961	98	2014	1 – 20 minutes – 0 PLN. 21 – 60 minutes – PLN 1 61-120 minutes – 3 PLN. 121 minutes and each subsequent hour – PLN 4. (Lubelski Rower Miejski – Cennik, 2020)
Ostrów Wielkopolski	72 000	81	10	2017	1 – 240 minutes – 0 PLN. 241 minutes and each subsequent hour – 10 PLN. (Ostrowski Rower Miejski – Cennik, 2020)
Rowerowe Łódzkie (Koluszki, Kutno, Łask, Łowicz, Łódź, Pabianice, Sieradz, Skierniewice, Zduńska Wola, Zgierz)	900 000 (all cities in total)	1000	125	2018	1 – 20 minutes – 0 PLN. 21 – 60 minutes – PLN 1 61-120 minutes – 3 PLN. 121 minutes and each subsequent hour – 5 PLN. (Rowerowe Łódzkie – Cennik, 2020)
Szamotuły	19 000	60	7	2017	1 – 180 minutes – 0 PLN. 181 minutes and each subsequent hour – 10 PLN. (Szamotuły Bike – Cennik, 2020)
Tarnów	100 000	110	10	2018	1 – 20 minutes – 0 PLN. 21 – 60 minutes – PLN 1 61 minutes and each subsequent hour – PLN 2. (Tarnowski Rower Miejski – Cennik, 2020)

Source: Own elaboration based on data from project websites and pages of public bicycle systems in selected cities.

Among the investigated systems, Lublin has got the largest number of available bicycles 961, which seems to be much for a city with 330000 residents. It is also worth noting that Grodzisk Mazowiecki – a city with a population of 30000 – had a decent number of 92 bicycles. On average, there were around 10 bikes per bicycle station in the studied cities. Usually, users can rent the bicycles for free for about 20 minutes. However, in Ostrów Wielkopolski up to 4 hours of riding are free. Similarly, in Szamotuły bicycles could be freely used for up to 3 hours.

Data on the number of rentals on individual days were obtained using a dedicated Web API of the op-

two CSV databases³: one with the geographic coordinates of bike stations and another with the coordinates of bicycles. The databases also contained the names of bike stations and UNIX timestamps⁴ that were converted to common date/time format. The databases were then cleaned of outliers – the geographical coordinates of bikes/stations that did not match the area of a given city⁵. Consequently, in the next step, only the bicycles that changed their geographical position within the city limits were picked up for further consideration. Finally, the R script produced calendar heatmaps as well as frequency bar plots for the given city. Descriptive

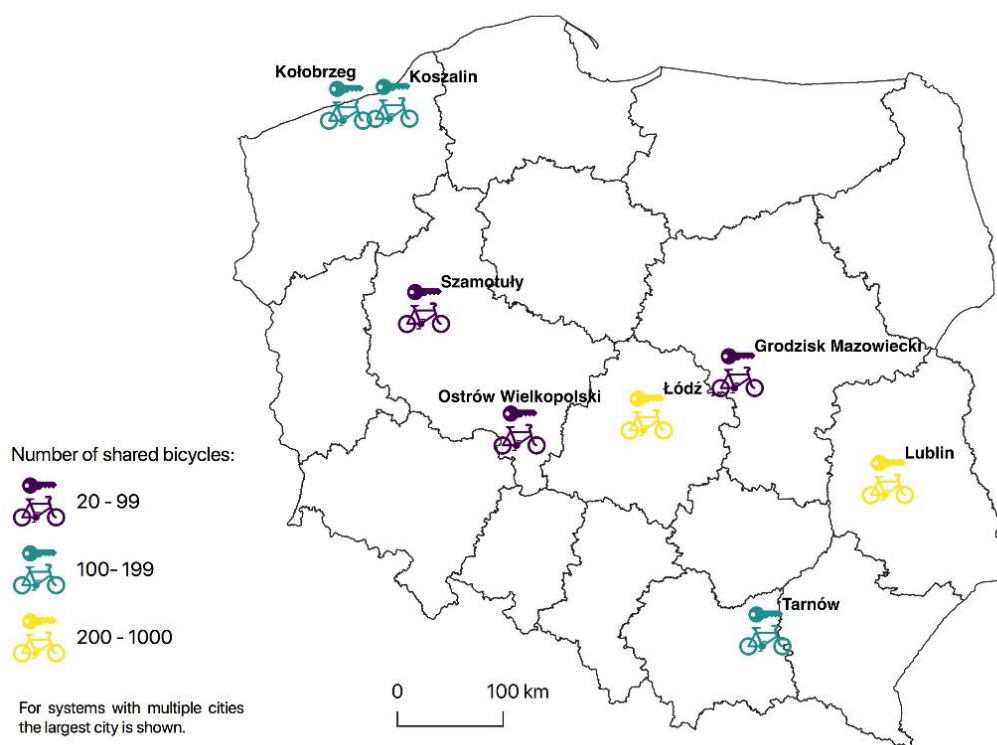


Fig. 1. Spatial distribution of selected city bike systems, co-financed from the EU funds.

Source: own elaborations based on Nextbike Polska (2020).

erator Nextbike. A script written in Python was used to download the data. Data related to bikes and stations (identifier, name, location, the current number of bikes, and time) were acquired. Data were collected every 10 minutes, 24 hours a day, 7 days a week.

Subsequently, for the purposes of data analysis we developed eight scripts written in R programming language² (one script per city). The script worked with

statistics of data used in our analysis are presented in Table 3.

² The following R libraries were used: “plm”, “ggplot2”, “ggTimeSeries”, “data.table” – see Croissant and Millo (2018); Dowle and Srinivasan (2019); Kothari (2018); Wickham (2016) for further details.

³ The CSV databases were extracted from real-time data feed SQLite databases.

⁴ Unix time is a system for describing a point in time. It is the number of seconds that have elapsed since 00:00:00 UTC on 1 January 1970 (so-called the Unix Epoch) (Neil and Stones (2008)).

⁵ Biased coordinates may be the result of read errors of GPS positioning devices installed in bikes/stations. They constitute the promil of all observations.

Tab. 3. Descriptive statistics of data used in analysis.

The city	Time range of data	Mean number of rentals	Maximum number of rentals	Minimum number of rentals	Standard deviation
Grodzisk Mazowiecki	1.03-2.04	5	19 rentals (3.03)	0 rentals (14-15 and 25-26.03)	5
Kołobrzeg	1-30.03	8	17 rentals (22.03)	2 rentals (3, 8 and 29.03)	10
Koszalin	3.03-2.04	8	21 rentals (11.03)	0 rentals (15.03)	5
Lublin	19-31.03	63	247 rentals (29.03)	3 rentals (19 and 20.03)	64
Łódź (within: Łódzkie voivodeship bike system)	5.03-2.04	22	40 rentals (23.03)	11 rentals (29.03)	7
Ostrów Wielkopolski	1.03-13.03	6	25 rentals (11.03)	1 rentals (12.03)	6
Szamotuły	1-23.03	4	14 rentals (4.03)	0 rentals (18 and 20.03)	3
Tarnów	1-31.03	3	7 rentals (29.03)	0 rentals (12-19.03)	2

Source: own elaborations based on Nextbike data.

2. Usage analysis of bike-sharing systems in selected cities

2.1. Koszalin

The Koszalin City Bike was established in 2018. There are 100 bicycles and 10 bike stations in the city. In 2019, the bikes were used over 52000 times. There are over 13000 registered users in the system (over 10% of city residents). The operator's data show that the largest group are users aged 30-39 (28% of all registered customers). Almost equally active are people aged 18-25 (25% of users). Most rentals (86%) were made using the Nextbike mobile application. The

average duration of a single rental was 30 minutes and 16 seconds. The largest number of rentals (16.7%) took place between 6 pm and 8 pm (Koszaliński Rowler Miejski – Podsumowanie 2019 roku).

According to our data, the most popular days in terms of rentals were March 8 and 11 (Fig. 2A). After March 17, the number of rentals decreased and some days with no bicycle rentals occurred (e.g. March 18 and 31). Stations located relatively close to the city center were most popular, as well as these located in close proximity to schools and universities (Budowlanka, Politechnika) (Fig. 2B). Other popular stations were located in the very downtown (Zielona, Ratusz).

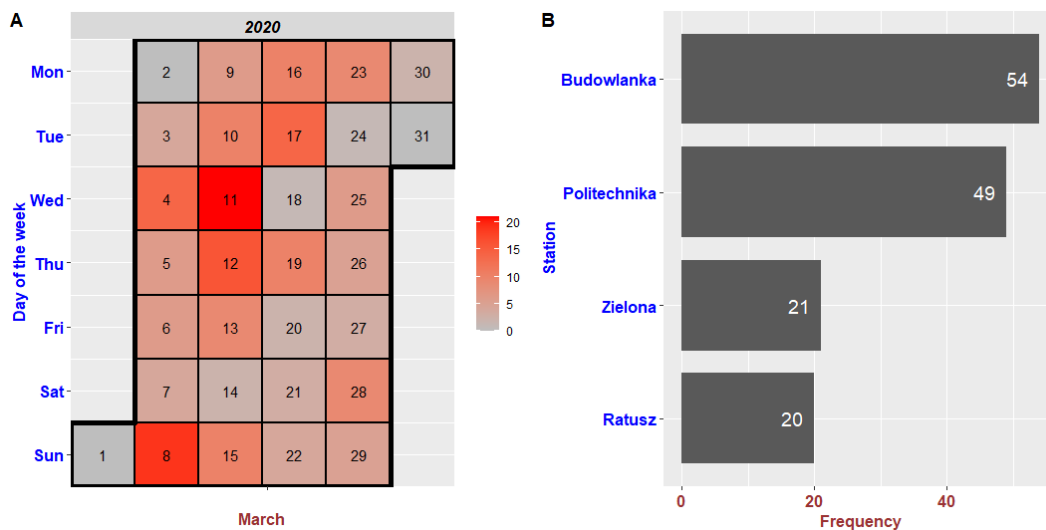


Fig. 2. The frequency of city bike rentals (A) and the most popular stations (B) in Koszalin on individual days of March 2020.

Source: own elaborations based on Nextbike data.

2.2. Kołobrzeg

The Kołobrzeg bike-sharing system was created in 2017. In the third season of operation, the system offered 135 bicycles located at 13 stations. In 2019, bicycles were rented over 88000. times. Residents and tourists staying in Kołobrzeg most often used the bikes between 3 pm and 7 pm, when there were over 33% of all rentals. There are about 24500 registered users of the system, corresponding to about 50% of the city's population, but many registered users were likely tourists due to Kołobrzeg being a popular sea resort. In March, the distribution of rentals was very evenly distributed, however, most rentals were recorded on Saturdays (17.6%). Bicycles were most often used from June to August, with Almost 60% of all trips taking place during this period. Over 18500 trips occurred in July alone (Kołobrzeki Rower Miejski – Podsumowanie 2019 roku).

Our results show that the most popular day in terms of the number of rentals was March 22 (Saturday). The overall frequency of city bike rentals in March in Kołobrzeg was illustrated in Fig. 3A. In turn, the most popular bike stations were those located in the city center (Słowińców, Fredry, railway station), and nearby recreational areas (ul. Fredry) – Fig 3B.

In addition, there are a number of non-governmental organizations and informal groups active in the promotion of cycling. Cyclists can currently use 961 shared bikes, located at 98 self-service stations in Lublin and the nearby city of Świdnik. In 2019, the bicycle system was used more than 658000 times, and the number of users exceeded 112000 (over 30% of the city's population). According to the Nextbike report (2019), the largest number of rentals (17%) took place between 3 pm and 5 pm, which suggests high usage for returns from work. The most numerous group – 45% of all registered users – were people between 18-25 (about 50800 persons). In turn, inhabitants of Lublin and Świdnik aged 30 to 39 constituted almost 20% of all users (22400). By contrast, seniors were a relatively small group of about 1350 active users of city bikes (1,2%).

In 2020, in Lublin, the bike-sharing system was not launched until 19 March, and data were collected until 31 March. In this short period, 29 March (Sunday) was by far the most popular day with a record number of 247 rentals. In turn, cyclists rarely made use of the system on March 19, 20, and 31, when the number of rentals fell to just 3 (Fig. 4A).

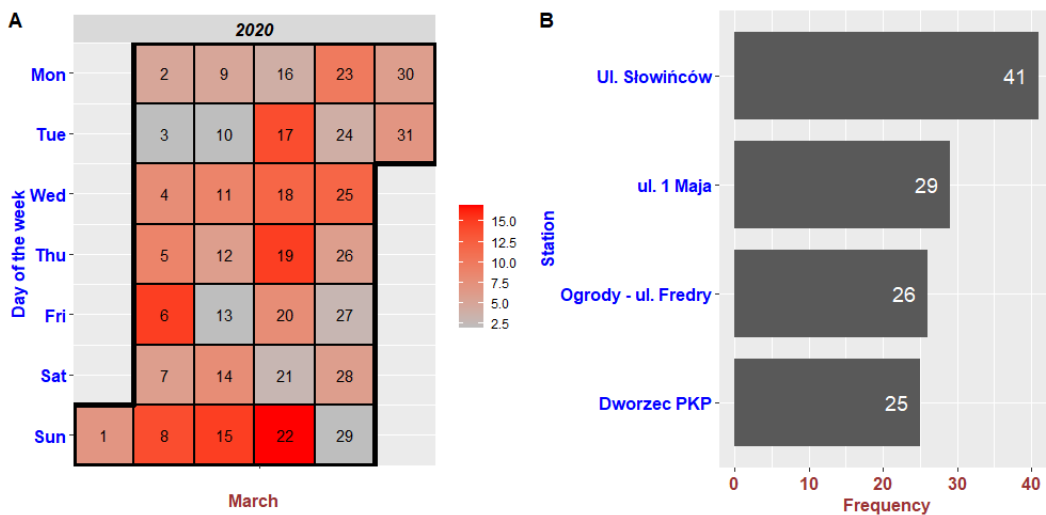


Fig 3. The frequency of city bike rentals (A) and the most popular stations (B) in Kołobrzeg on individual days of March 2020.

Source: own elaborations based on Nextbike data.

2.3. Lublin

The Lublin City Bike was established in 2014. In 2019 there was about 170 km of bicycle routes in Lublin, partly due to support from the European Union funds. The city has also adopted strategic documents regarding the development of bicycle

Stations located close to housing estates (Kraśnicka, Judyma), academic campuses (Czwartaków), as well as around the city center were the most popular. Finally, those located near the recreation areas (Zamojska Street, Piłsudskiego Street) also enjoyed considerable popularity (Fig 4B).

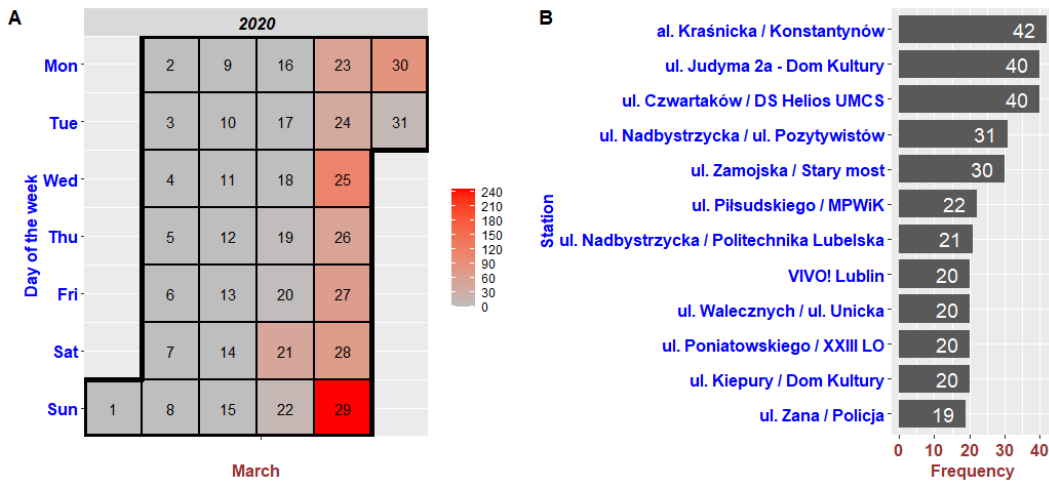


Fig 4. The frequency of city bike rentals (A) and the most popular stations (B) in Lublin on individual days of March 2020. Source: own elaborations based on Nextbike data.

2.4. Tarnów

Tarnów City Bike was established in 2018. It consists of 10 self-service stations and 110 bikes (including bikes for children). In 2019, the system recorded 21500 rentals (Tarnowski Rower Miejski – Podsumowanie 2019 roku). The number of users was over 5,000 (about 5% of the city’s population).

According to data, the bike system in Tarnów in 2020 was launched on March 1. There were no rentals during the week between March 12 and March 19. It is possible that maintenance work was done

in Tarnów was only 2, and the system was the most popular on March 29 (7 rentals). The number of city bike rentals in Tarnów, including individual days of system operation, is presented in Fig. 5A. The most frequented stations were located near sports and recreation facilities as well as transport hubs (Fig. 5B).

2.5. Łódź

The “Rowerowe Łódzkie” project is a very interesting initiative, which is an example of a so-called Bike-Train-Bike system. It aims to facilitate cycling trips

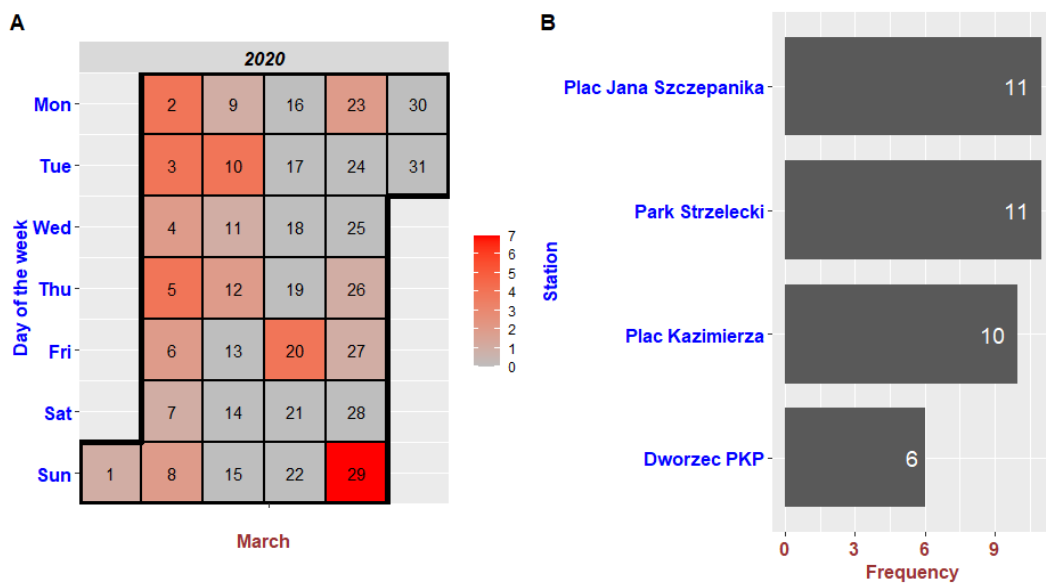


Fig. 5. The frequency of city bike rentals (A) and the most popular stations (B) in Tarnów on individual days of March 2020. Source: own elaborations based on Nextbike data.

at that time, but we could not find any information confirming this. The average daily number of rentals

to railway stations within the Łódzkie voivodeship. It was launched in 2018 with 125 city bike stations

being made available in 10 cities of the Łódź voivodeship, including Koluszki, Kutno, Łask, Łowicz, Łódź, Pabianice, Sieradz, Skierniewice, Zduńska Wola and Zgierz. In total, about 1000 bikes are available to the users. Among them are also 4th generation bicycles with GPS modules that can be left outside the bike stations.

The database obtained by the authors for Łódź covers the period from 5 to 31 March. At that time, the most popular days in terms of rentals were March 20 and 23. On the other hand, the 14th and 29th day of the month recorded the lowest traffic. Many rentals in Łódź took place outside of the stations. Thus, rentals recorded at the stations seem to be relatively low (Fig. 6A). The popularity of bicycle stations is closely related to the functioning of the Łódź Voivodeship Railway. The most popular bicycle stations are therefore located in the immediate vicinity of the railway stations (Łódź Marysin, Łódź Fabryczna, Łódź Radogoszcz, Łódź Chojny) – Fig. 6B.

Data for Grodzisk Mazowiecki were collected between March 1 and March 31, 2020. It can be noted that after 12 March, the frequency of rentals dropped substantially with some days with no recorded rentals at all (e.g. 14-15 March). By far the most popular period was the beginning of the month, when the number of rentals reached 20 per day (March 3) – Fig. 7A. The most frequently used stations are located near sports facilities, as well as those settled in the immediate vicinity of the railway station (Park im. hr. Skarbków, PKP Deptak) – Fig. 7B.

2.7. Ostrów Wielkopolski

The Ostrów bike-sharing system was created in 2017 and currently offers 10 stations and 81 bikes. In 2018, there were 2000 users registered in the system (about 3% of the city's inhabitants), and at the same time bikes were rented 10000 times (Ostrowski Rower Miejski – Podsumowanie 2018 roku). Interestingly, the

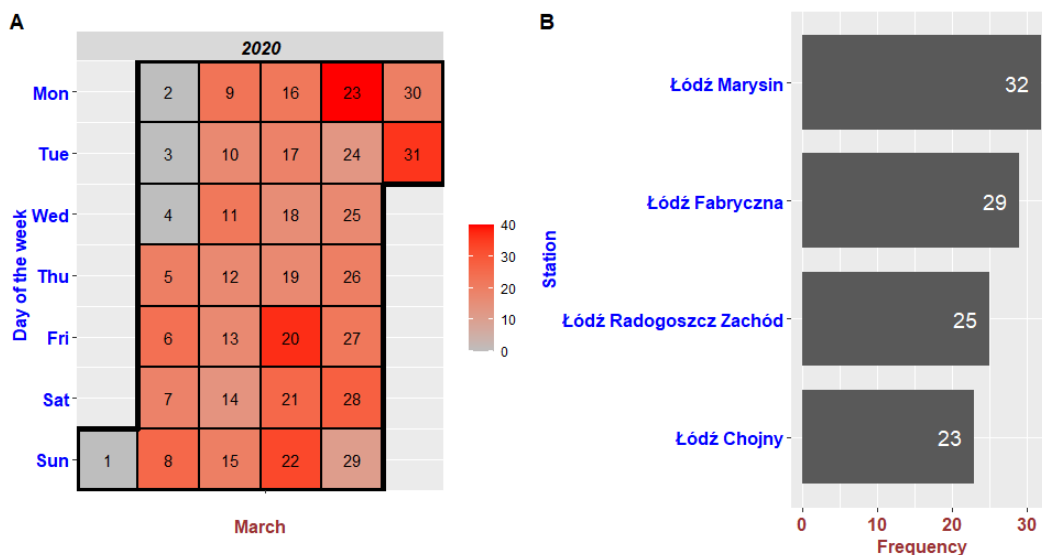


Fig. 6. The frequency of city bike rentals (A) and the most popular stations (B) in Łódź on individual days of March 2020. Source: own elaborations based on Nextbike data.

2.6. Grodzisk Mazowiecki

The city bike system in Grodzisk Mazowiecki is one of the oldest in Poland, as it has been functioning since 2014. It consists of 12 stations and 92 bicycles. About 25000 people used the system in 2018. The number of registered users is over 5000, and they represent over 15% of city residents. (Grodziski Rower Miejski – Podsumowanie 2019 roku). Grodzisk bike-sharing system is an example of a public bike scheme operating outside of the largest cities. Interestingly, the system also offers bicycles equipped with child seats.

system offers free journeys up to the first 4 hours. After exceeding the free 4-hour rental, cyclists must pay PLN 10 for each hour started, whereas exceeding 12 hours of rental is penalised with a fine of PLN 200. The bike-sharing system was suspended on March 14 to limit the transmission of SARS-CoV-2. Thus, the time range of the collected data covers only the first two weeks of March. During this period, the most popular day was Tuesday, March 11, when 25 rentals were made – Fig. 8A. On other days the number of rentals oscillated around 5-15. The most popular stations in Ostrów Wielkopolski were Olimpijska (located near sports and recreational facilities), Targowisko, Transfer Center (transport hub), and Rynek (the city center) – Fig. 8B.

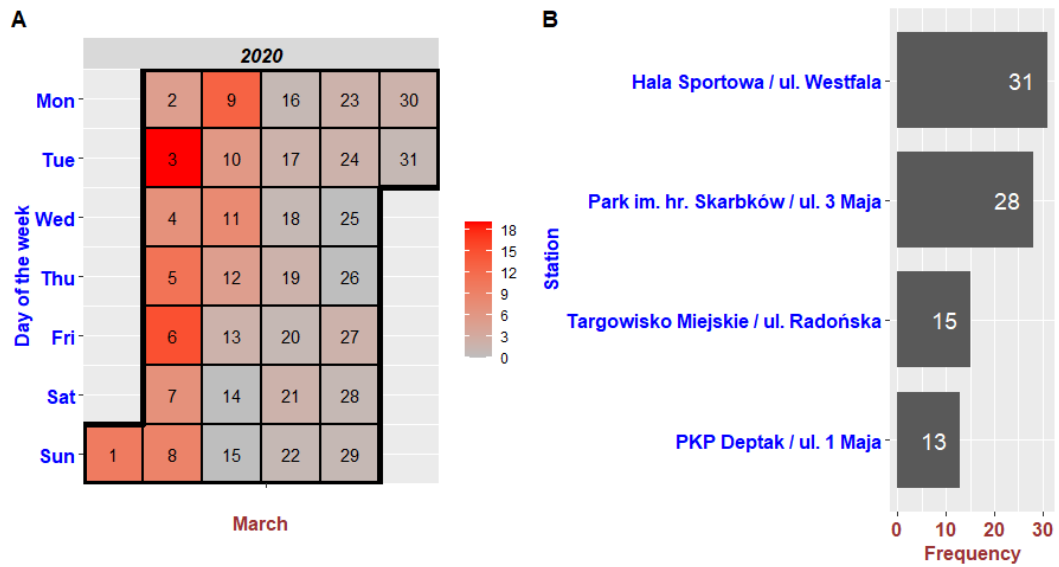


Fig. 7. The frequency of city bike rentals (A) and the most popular stations (B) in Grodzisk Mazowiecki on individual days of March 2020.

Source: own elaborations based on Nextbike data.

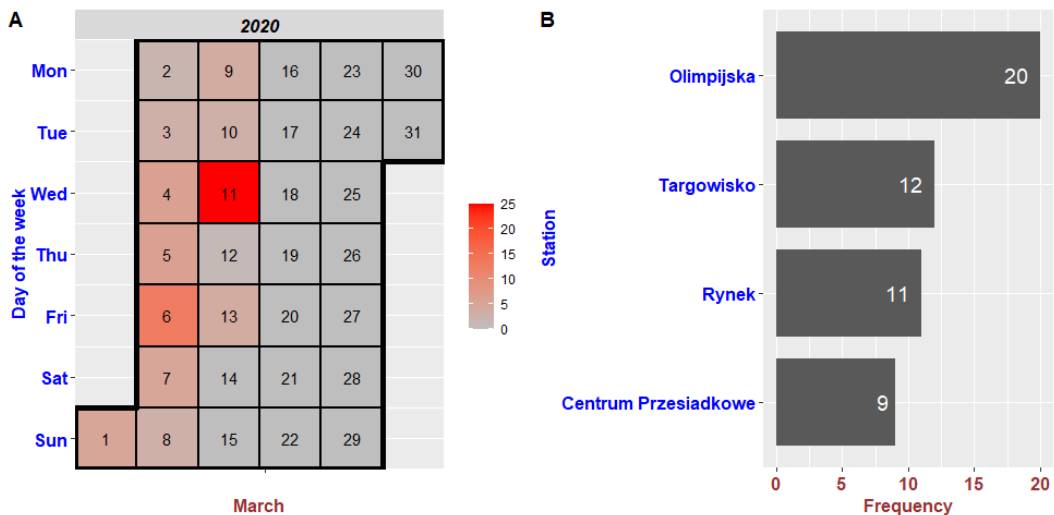


Fig. 8. The frequency of city bike rentals (A) and the most popular stations (B) in Ostrów Wielkopolski on individual days of March 2020.

Source: own elaborations based on Nextbike data.

2.8. Szamotuły

The bike-sharing system in Szamotuły has been operating since 2017. Residents have at their disposal 5 stations and 50 bicycles. In 2018, the system was utilized more than 22000 times, and the average rental time was over 37 minutes (Szamotulski Rower Miejski – Podsumowanie 2019 roku). Similarly as in Ostrów Wielkopolski, the system can be used for free for an exceptionally long time – up to the first 3 hours.

In 2020, the system was launched on March 1. However, due to the risk of spreading the SARS-CoV-2

virus, the city authorities suspended the system on March 23). At this time, the most popular day was March 4 (Wednesday) with 17 rentals. In turn, on March 18 and 20, no rentals were recorded (Fig. 9A). By far the most popular bike station in Szamotuły was located at the railway station. This may suggest the use of a system for commuting to work or school within the limits of Poznań agglomeration. Next in terms of popularity are stations located in the city center (Mickiewiczza, Rynek), as well as the facility near the Sport Center (ul. Sportowa) – Fig. 9B.

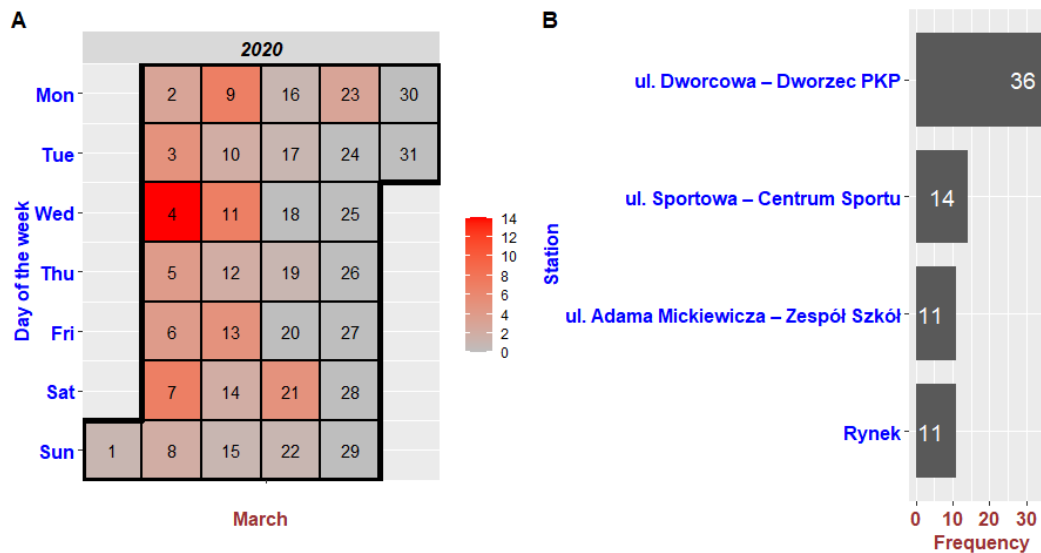


Fig. 9. The frequency of city bike rentals (A) and the most popular stations (B) in Szamotuły on individual days of March 2020.

Source: own elaborations based on Nextbike data.

Conclusions

The paper presented some information about projects that supported the development of bike-sharing systems in selected cities in Poland. The source of co-financing was the EU funds, mainly the European Regional Development Fund. The number of stations and bicycles, as well as the costs of rentals in each city, were also presented. In addition, the number of bicycle rentals, the number of registered users and the hours with the most rentals were also shown for year 2019. The ratio of the number of registered users to the number of residents of particular cities was also presented. The highest values of the indicator were obtained in cities attractive for tourists such as Kołobrzeg (over 50% of the city population) or Lublin (about 30% of the city population). In those cases, it is highly likely that a significant share of the users were tourists.

On a basis of collected raw data, an analysis of the frequency of bicycle rentals in selected cities was also carried out in particular days of March 2020. Data clearly shows that in larger cities (such as Łódź or Lublin) the rentals were more evenly distributed over the different days of the month. In turn, in smaller towns, such as Tarnów or Ostrów Wielkopolski, “islands” appeared, i.e. single days on which the number of rentals temporarily increases. In general, rentals were mostly concentrated in city centers, residential or recreational areas. Again, the exception was large cities or agglomeration areas, where rentals seem to be related to the operation of other means of transport (primarily railways, e.g. Łódź, Szamotuły). This

suggests that bike-sharing systems in these areas are linked to the daily commuting of city residents to work and school. It is consistent with the purposes of the financing projects as in this way, low-emission transport is supported. It should be noted that the observed frequency of rentals may have been substantially affected by mobility restrictions related to the COVID-19 pandemic, especially in the second half of March when nationwide mobility restrictions were enacted.

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Literature

- Bieliński T., Kwapisz A., Ważna A., 2019. Bike-Sharing Systems in Poland, *Sustainability* 11, 2458. (DOI 10.3390/su11092458)
- Croissant Y., Milla G., 2018. *Panel Data Econometrics with R: the plm package*, Wiley, UK.
- Dębowska-Mróż M., Lis P., Szymanek A., Zawisza T., 2017. Rower miejski jako element systemu transportowego w miastach, *Autobusy*, 6, 1173-1182.
- Dowle M., Srinivasan A., 2019. data.table: *Extension of `data.frame`*. R package version 1.12.8. <https://CRAN.R-project.org/package=data.table>

- Fishman E., 2016. Bikeshare: A Review of Recent Literature. *Transport Reviews* 36, 92–113. (DOI 10.1080/01441647.2015.1033036)
- Fuller D., Gauvin L., Kestens Y., Daniel M., Fournier M., Morency P., Drouin L., 2013. Impact Evaluation of a Public Bicycle Share Program on Cycling: A Case Example of BIXI in Montreal, Quebec. *American Journal of Public Health* 103, e85–e92. (DOI: 10.2105/AJPH.2012.300917)
- Jäppinen S., Toivonen T., Salonen M. 2013. Modelling the potential effect of shared bicycles on public transport travel times in Greater Helsinki: An open data approach. *Applied Geography*, 13–24. (DOI: 10.1016/j.apgeog.2013.05.010)
- Kothari A., 2018. *ggTimeSeries: Time Series Visualisations Using the Grammar of Graphics*. R package version 1.0.1. <https://CRAN.R-project.org/package=ggTimeSeries>
- Kwiatkowski M.A., 2018. Bike-sharing-boom – rozwój nowych form zrównoważonego transportu w Polsce na przykładzie roweru publicznego, *Prace Komisji Geografii Komunikacji PTG*, 21(3), 60–69. (DOI: 10.4467/2543859XPKG.18.017.10142)
- Łastowska A., Bryniarska Z., 2015. Analiza funkcjonowania wypożyczalni rowerów miejskich w Krakowie, *Transport Miejski i Regionalny*, 03, 30–35.
- Martin E. W., Shaheen S. A. 2014. Evaluating public transit modal shift dynamics in response to bikesharing: a tale of two U.S. cities. *Journal of Transport Geography*, 41, 315–324. (DOI: 10.1016/j.jtrangeo.2014.06.026)
- Médard de Chardon C., Caruso G., Thomas I., 2017. Bicycle sharing system ‘success’ determinants. *Transportation Research Part A: Policy and Practice*, 100, 202–214. (DOI 10.1016/j.tra.2017.04.020)
- Molin E., Mokhtarian P., Kroesen M., 2016. Multimodal travel groups and attitudes: A latent class cluster analysis of Dutch travelers. *Transportation Research Part A: Policy and Practice*, 83, 14–29. (DOI: 10.1016/j.tra.2015.11.001)
- Neil M., Stones R. 2008. *The Linux Environment. Beginning Linux Programming*. Wiley, Indiana, US.
- Parkes S.D., Marsden G., Shaheen S.A., Cohen A.P., 2013. Understanding the diffusion of public bikesharing systems: evidence from Europe and North America. *Journal of Transport Geography* 31, 94–103. (DOI 10.1016/j.jtrangeo.2013.06.003)
- Raux C., Zoubir A., Geyik M., 2017. Who are bike sharing schemes members and do they travel differently? The case of Lyon’s “Velo’v” scheme. *Transportation Research Part A: Policy and Practice* 106, 350–363. (DOI 10.1016/j.tra.2017.10.010)
- Shen Y., Zhang X., Zhao J., 2018. Understanding the usage of dockless bike sharing in Singapore. *International Journal of Sustainable Transportation* 12, 686–700. (DOI 10.1080/15568318.2018.1429696)
- Winters M., Hosford K., Javaheri S., 2019. Who are the ‘super-users’ of public bike share? An analysis of public bike share members in Vancouver, BC. *Preventive Medicine Reports* 15, 100946. (DOI 10.1016/j.pmedr.2019.100946)
- Wickham H., 2016. *ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag New York, US.
- Yao Y., Zhang Y., Tian L., Zhou N., Li Z., Wang, M., 2019. Analysis of Network Structure of Urban Bike-Sharing System: A Case Study Based on Real-Time Data of a Public Bicycle System. *Sustainability* 11, 5425. (DOI 10.3390/su11195425)

Internet sources:

- BIP Małopolska – Cennik <https://bip.malopolska.pl/zdik,a,1423531,dostawa-systemu-roweru-miejskiego-miasta-tarnowa-realizowana-w-ramach-projektu-integracja-transportu.html> [21.06.2020]
- Grodziski Rower Miejski – Cennik <https://rowery.grodzisk.pl/cennik/> [21.06.2020]
- Grodziski Rower Miejski – Podsumowanie 2018 roku <https://rowery.grodzisk.pl/news/rekordowy-sezon-rowerowy-w-grodzisku-mazowieckim/> [04.04.2020]
- Inwestycje Koszalina <https://www.koszalin.pl/pl/content/inwestycje-w-zintegrowana-infrastruktura-zwiazana-z-transportem-niskoemisyjnym-na-terenie> [21.06.2020]
- Kołobrzeski Rower Miejski – Cennik <https://kolobrzekirower.pl/cennik/> [21.06.2020]
- Kołobrzeski Rower Miejski – Podsumowanie 2019 roku <https://kolobrzekirower.pl/koniec-sezonu-rowerowego-w-kolobrzegu/> [04.04.2020]
- Koszaliński Rower Miejski – Cennik <https://koszalinrowermiejski.pl/cennik/> [21.06.2020]
- Koszaliński Rower Miejski – Podsumowanie 2019 roku <https://koszalinrowermiejski.pl/ostatni-tydzien-z-koszalinskim-rowerem-miejskim/> [04.04.2020]
- Lubelski Rower Miejski – Cennik <https://lubelskirower.pl/cennik/> [21.06.2020]
- Lubelski Rower Miejski – Podsumowanie 2019 roku <https://lubelskirower.pl/news/szesty-sezon-rowerowy-w-lublinie-dobiega-konca-popularnosc-jednosladownie-slabnie/> [04.04.2020]
- Lublin – Projekty zrealizowane <https://lublin.eu/lublin/lublin-w-ue/projekty-inwestycyjne/projekty-gminy-w-latach-2007-2013/uni-aeuropejska/sport-i-rekreacja/projekty-zrealizowane/> [21.06.2020]
- Mapa dotacji UE <https://mapadotacji.gov.pl/projekty/722779/> [21.06.2020]
- Nextbike Polska <https://nextbike.pl/> [21.06.2020]
- Ostrowski Rower Miejski – Cennik <https://ostrowskirowermiejski.pl/cennik/> [21.06.2020]
- Ostrowski Rower Miejski – Podsumowanie 2018 roku <https://ostrowskirowermiejski.pl/rower-miejski-znika-na-zimowa-przerwe/> [04.04.2020]

Ostrów Wielkopolski – Unowocześnienie transportu miejskiego

<https://umostrow.pl/unowoczesnienie-transportu-miejskiego-wraz-z-innymi-dzialaniami-niskoemisyjnymi.html> [21.06.2020]

Powrót rowerów miejskich Nextbike

<https://nextbike.pl/powrot-rowerow-miejskich-nextbike/> [21.06.2020]

Raport „Ostre hamowanie roweru miejskiego” – Mobilne Miasto http://mobilne-miasto.org/wp-content/uploads/2020/03/Mobilne_Miasto_raport_bikesharing_final.pdf [04.04.2020]

Rowerowe Łódzkie – Cennik <https://rowerowelodzkie.pl/cennik/> [21.06.2020]

Szamotuly Bike <https://szamotuly.bike/szamotuly-bike-juzdziala/> [21.06.2020]

Szamotuly Bike – Cennik <https://szamotuly.bike/cennik/> [21.06.2020]

Szamotuly Bike – Podsumowanie 2018 roku <https://szamotuly.bike/rekordy-wypozycczen-rowerow-miejskich-w-poznaniu-i-szamotulach/> [04.04.2020]

Tarnowski Rower Miejski – Cennik <https://rower.tarnow.pl/cennik/> [21.06.2020]

Tarnowski Rower Miejski – Podsumowanie 2019 roku <https://rower.tarnow.pl/13-milionow-miejskich-podrozy-z-nextbike-w-2019-roku/> [04.04.2020]

Wojewódzki Rower Miejski <https://uml.lodz.pl/komunikacja-i-transport/rowerzysta/wojewodzki-rower-publiczny/> [21.06.2020]

ZIT Kołobrzeg <http://www.rpo.wzp.pl/o-programie/zintegrowane-inwestycje-terytorialne/zit-koszalinsko-kolobrzescsko-bialogardzkiego-obszaru-funkcjonalnego> [21.06.2020]