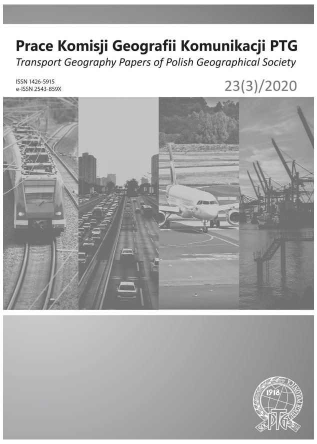

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BIKE-SHARING SYSTEM IN POZNAN – WHAT WILL WEB API DATA TELL US?

System rowerów miejskich w Poznaniu - co nam powiedzą dane z Web API?

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Abstract
Bike-sharing systems, also known as public bicycles, are among the most dynamically developing mobility solutions in contemporary cities. In the past decade, numerous Polish cities hoping to increase the modal share of cycling have also adopted bike-sharing. Such systems continuously register user movements through installed sensors. The resulting database allows a highly detailed representation of this segment of urban mobility. This article illustrates how a database accessed via a Web API (Web Application Programming Interface) could be used to investigate the spatial distribution of trips, using the case study of Poznań, the fifth-largest city in Poland. Using geographical information systems, we identify the hot spots of bike-sharing as well as areas with low usage. The research procedure outlined in the paper provides knowledge that allows better responding to users' needs.

Keywords: Bike-sharing, cycling, mobility, big data, Poznań.

1. Introduction

Bike-sharing systems have been gaining more and more attention in recent years. A significant increase in the number of such systems is observed in many cities around the world (Parkes et al. 2013; Fishman, 2016). The "white bicycle" introduced in Amsterdam in the sixties is considered to be the first public bike-sharing system. This initiative was associated with the activities of the anarchist Provo group and was a reflection of its ideological program, which is why bicycles were left on the streets for public use without any protection. The next generation of bike-sharing systems, functioning, among others in Copenhagen was based on mechanisms that use a coin as a deposit. However, the dynamic spread of city bikes took place later, in the era of the credit cards, the Internet and mobile devices. The current number of city bike systems in the world is difficult to estimate accurately due to the high dynamics of the phenomenon. Every month new city bike systems are created, while some of the functioning systems are closed. Public city bikes are most popular in Europe, the United States and China.

The first bike-sharing system in Poland was established in 2008 in Cracow (Łastowska and Bryniarska, 2015). Over the next decade, there was a dynamic expansion of such systems: in 2016, there were about 20 operating systems (Dębowska-Mróz et al., 2017), while two years later more than 60 (Kwiatkowski, 2018). The majority of bike-sharing systems is localized in the largest cities, but some systems can also be found in smaller urban centers, or municipalities located in suburban areas. Some of the bike-sharing systems, such as those located in Siedlce, Siemianowice Śląskie, Sopot, Świętochłowice or in the Warsaw district of Bemowo had not been successful and were closed (Dębowska-Mróz et al., 2017). In 2019, a unique system based on bicycles with electric assist called Mevo was launched in the Gdańsk agglomeration. However, it functioned only for one season, because the contract with the operator was terminated by the authorities of the metropolitan area. As a result of the action in Gdańsk agglomeration, the operation of a city bike in Cracow was also suspended in January 2020. The largest operator of city bike systems in Poland is the German company Nextbike, operating through its subsidiary Nextbike Polska. This is a common practise, because the global market of bike-sharing systems is dominated by several large entities, such as JCDecaux, Motivate or the already mentioned Nextbike. Other companies operating in Poland are Acro Bike, BikeU, Comdrev or Romet Rental Systems (Dębowska-Mróz et al., 2017).

Despite the several years of history of city bikes in Poland and the dynamic development of this service, little is known about the role they play in urban mobility in Polish cities. On the international level, a number of relevant studies has been provided as the data are constantly available online, e.g. in the form of Web API services (Faghih-Imani et al., 2014; Médard de Chardon and Caruso, 2015; Shen et al. 2018). Obviously, such data sets have their limitations: most often they contain only basic information about the location of the vehicle, without other potentially useful variables, such as socio-demographic characteristics of users. However, their undoubted advantage is the fact that they are widely available, free of charge and provide data for many cities around the world. Open sources of shared mobility data including bicycle, scooter, or car sharing schemes, also pose some risks to privacy, especially when they allow individual users to be identified. However, these threats are minimized if data is anonymized.

In this context, the purpose of this paper is to use a Web API data source to analyze the spatial distribution of bike-sharing trips and to investigate the overall usefulness of this kind of data. These types of analyzes are important because they help us to understand better how the bike-sharing system works under specific local conditions. They can highlight the areas where the system matches better to the needs of residents, as well as those where its potential is still untapped. Consequently, they can help to improve the operation of bike-sharing systems.

The paper is a case study of the Poznań City Bike, created in 2012, which is one of the oldest and largest bike-sharing systems in Poland. From 2012 to 2019, bicycles were rented 4.5 million times in total, and the number of registered users reached 179,000 (Poznań City Bike, 2020). Nextbike Polska has operated the system since the beginning on the basis of an agreement with the City of Poznań, represented by the City Transport Authority.

2. Literature review

Among the pros of introducing city bikes, the most important is the argument to increase the share of cyclists in the structure of trips. Indirectly, this can lead to a reduction in passenger car traffic, and therefore improve air quality and decrease in the level of noise in the city. It can also affect the supply and quality of public space, as well as the safety of urban traffic participants, but the literature also draws attention to the difficulty in accurate measuring of the impact of this mode of transport on air quality and the health of bike-sharing users (Médard de Chardon, 2019; Ricci, 2015). However, bike-sharing systems can also have a beneficial effect on promoting a healthy lifestyle and increasing the physical activity of residents (Woodcock et al., 2014) and tourism (Bieliński et al., 2019). City bikes can be complementary to public transport. In trips connecting different modes of transport, especially on "first and last mile" sections, they can be a more convenient alternative to private bikes, which require parking spaces, are exposed to theft and not always allowed in public transport vehicles (Yao, 2019). Research on the impact of bicycle-sharing systems on private bike users was also conducted (Fishman 2016). On the other hand, in the literature it is pointed out that such transport solutions do not necessarily translate into the promotion of sustainable mobility on a wider scale (Buehler and Pucher, 2017).

The available detailed statistics of city bike users indicate that the majority of trip fall on a small group of users (Winters et al., 2019). Young men with a fairly high socioeconomic status are the majority of regular bike-sharing users, while only few users are at risk of transport exclusion. The way the system is organized, including station placement, as well as actions undertaken by the operator (i.e. related to rebalancing), may favor the most mobile users at the expense of others (Médard de Chardon, 2019). However, it is difficult to generalize, because a lot depends on local conditions, such as the terms of cooperation between the local transport administration and the bike-sharing operator. Yet another issue is the dialogue with cycling NGOs and other interested parties.

The current mobility research on bike-sharing is based on various data sources, such as databases provided by the operator, downloaded from the websites of operators or cities, Web Application Programming Interfaces (Web API) services, or user surveys (tab. 1). We would like to pay special attention to Web API, which allows to access large amounts of data in real-time. Thanks to this, researchers are able to analyze processes that until now were poorly understood. In addition, it is also possible to take a closer look at phenomena which had been overlooked due to lack of data (Romanillos et al. 2016). Open access to large data resources in real time promotes transparency in research. Researchers are able to access raw data rather than a data package that might have been manipulated. Of course, despite the already mentioned issues, the potential threats of users' privacy must be taken into account.

Tab. 1. Data sources and the purpose of their use in research on city bikes.

Data type	Research aim
Data provided by the operator	Analysis of the relationship between traffic generated by city bikes and the metro (Zhang et al., 2018)
Data provided by the operator	Analysis of the profile of people using the city bike system over a three-year period (Goodman and Cheshire, 2014)
Data provided by the operator	Research on spatio-temporal patterns generated by the users of 4th generation bicycles (Du et al., 2019)
Data provided by the operator	Determining the benefits of city bikes in smaller urban centers (Caulfield et al., 2017)
Data provided by the operator	Analysis of the network structure of the city bike systems (Yao et al., 2019)
Data provided by the operator	To show that bicycles now compete with the car in terms of speed in downtown of Lyon (Jensen et al., 2010)
Data downloaded from the operator's website (open data)	Study on the impact of cycling infrastructure, the built environment and public transport on the behavior of city bike users (Wang and Akar, 2019)
Data downloaded from the operator's website (open data)	Identifying factors that encourage or discourage cycling, and study on the attractiveness of bike stations (Sun et al., 2018)
Web API (own script for data collection)	Estimating the effectiveness of the city bike-sharing system (Médard de Chardon and Caruso, 2015)
Web API (own script for data collection)	Classification of city bike stations (Jiménez et al., 2016)
Web API (own script for data collection)	Research on the effects of weather, infrastructure and the built-up environment on city bike traffic (Faghih-Imani et al., 2014)
Web API (own script for data collection)	Analysis of the use of fourth generation bicycles (Shen et al. 2018)
Survey	Study of the relationship between public transport and city bikes (Martin and Shaheen, 2014)
Survey	Defining the socio-demographic profile of city bike users (Raux et al. 2017)
Survey	Defining factors that impact the behavior of fourth generation bicycle users (Du and Cheng, 2018)
Survey and data obtained from the system operator	Determining the demographic profile of "super users" of city bikes (Winters et al., 2019)

Source: Own elaboration based on literature.

There is a diverse range of data on bike-sharing that can be obtained from various sources. Some works use data on the number of bicycle rentals at specific stations (O'Brien et al. 2014). This type of information can be used to study the impact of the built environment on bike-sharing e rentals (Faghih-Imani et al., 2014). It may also help to guide decisions regarding the size and location of bike-sharing stations. Interesting information can also be obtained by tracking changes in bicycle locations over time. Bicycles equipped with GPS transmitters provide the geographical coordinates with a certain accuracy in a given time (Fishman, 2016). During each trip, the operator receives information such as time, bike number, bike type and geographical coordinates of the station. Such bicycles are commonly used in dockless systems. During each trip, the operator receives information about bicycles available at a specific station. This type of information is useful for the process of rebalancing of bicycles between stations (Médard de Chardon et al., 2016), which involves the operator relocating bikes from overcrowded stations to less crowded ones. Data obtained from GPS transmitters also allows for the detection of spatial patterns generated by cyclists (Shen et al. 2018). Large amount of data are also used to check and calibrate models for cycling (Giot and Cherrier, 2014).

Research on city bikes often use data on the popularity of individual stations and bicycle trips. This type of information can sometimes be obtained from the system operator or downloaded from the operator's website (e.g. Citi Bike in New York or Pronto in Seattle). In some cases, it is also possible download data from a Web API using a script written in a programming language. This type of data allows, among others, to estimate the daily number of trips from a specific station (Médard de Chardon and Caruso, 2015). In addition, some researchers make use of questionnaire surveys. They are often applied to analyze the socio-demographic profile of users and to characterize factors affecting their behavior. It is also interesting to combine survey data with information on bike movements obtained from the system operator. This type of analysis allowed to determine the demographic profile of "super users" of city bikes in Vancouver (Winters et al., 2019).

3. Research methods

In 2019, the Poznań City Bike consisted of 107 stations with bicycle racks (docked stations) and 32 stations without racks (called "zones" or dockless stations). The latter had been introduced before the start of the 2019 season. Dockless stations are intended for the fourth-generation bicycles, which can also be left outside the regular stations (docked or dockless) with an additional charge. The locations of the bike-sharing stations in Poznań are presented in fig. 1.

An accessibility analysis shows that 71% of the city's population aged 15 to 65 had access to one of the stations within a walking distance of up to 500 meters (fig. 2). They were mostly residents of downtown, districts created in the pre-war period, and large housing estates. On the other hand, most residents of suburban areas with a predominance of single-family housing were out of reach to the station, although their situation slightly improved as a result of the network expansion carried out in 2019. Further expansion of the bike network, improving the availability of stations in the suburbs, was introduced in 2020.

Data used in the paper have been obtained using the Nextbike API (Nextbike Web API). This application shows current information about the positions of bikes and the use of bicycle stations. A script written in Python was used to download the data directly. This high-level programming language is widely used in the data mining process (Demsar et al., 2013). The script was connected to the website and downloaded information to the database. Detailed information on the downloaded parameters of the stations and bikes is presented in fig. 3. Data were initially collected every 2 minutes, but due to their large capacity, it was decided to take a 10-minute interval, which is also used and acceptable in these types of studies (e.g. Médard de Chardon et al., 2017). The script downloaded data from May 23, 2019 to October 20, 2019. During this time, over 19,240,000 GPS locations of city bikes were collected. For 4th generation bikes, which are equipped with GPS transmitters, the coordinates of the bike were collected.

Based on the locations database, a bicycle movements database was created. From the spatial points data set (locations), a spatial lines dataset (trajectories) was created. A separate trajectory has been assigned to each bike characterized by a unique identifier. Then, the trajectories were cut into sections corresponding to the movements in the given time intervals. The displacement associated with the relocation of bicycles by the operator (so-called rebalancing) has not been filtered. Such displacements typically account for less than 10% of the total traffic (Faghih-Imani et al., 2017). It can be assumed that they did not have a significant impact on the overall spatial distribution of trips. The total number of movements (both incoming and outgoing) was calculated for each station, followed by the daily average number of displacements.

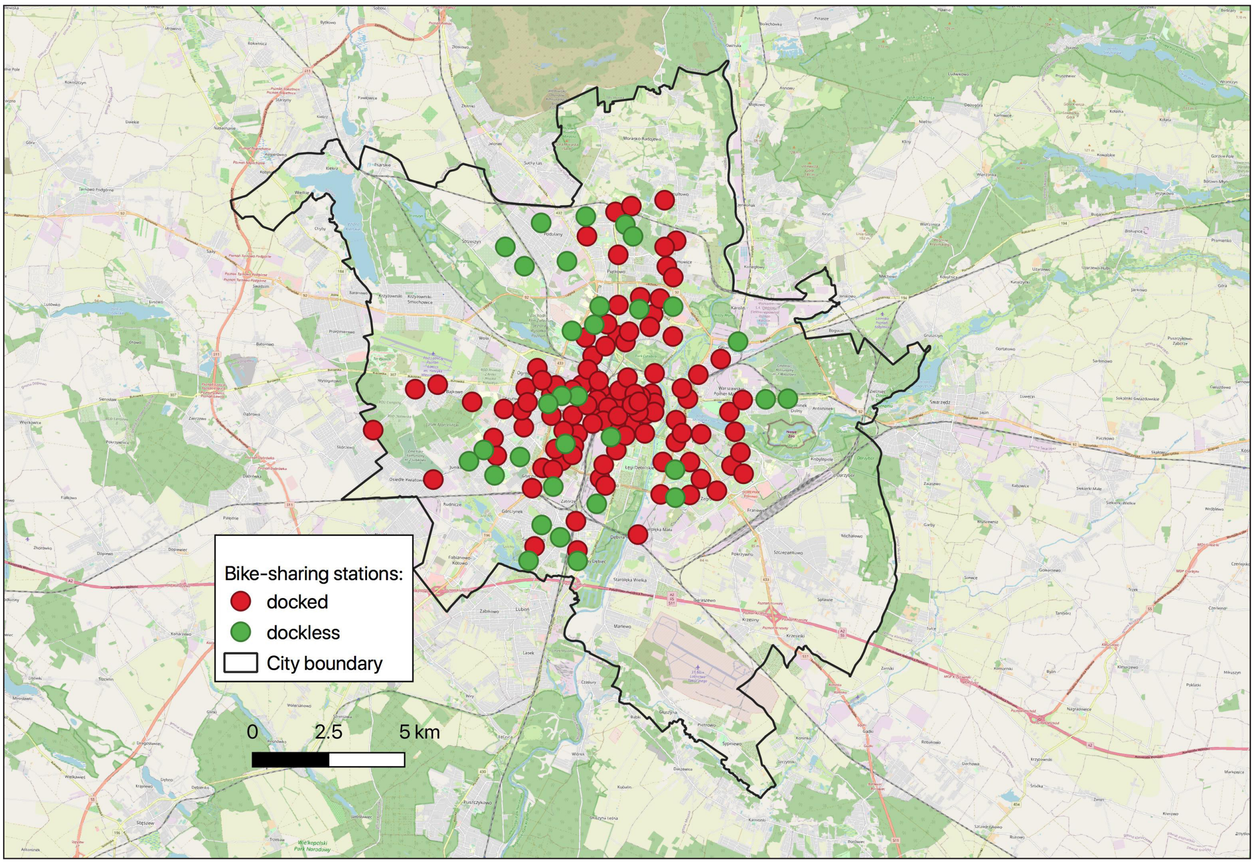

Fig 1. Spatial distribution of Poznan City Bike stations.

Source: Own elaboration based on Web API data.

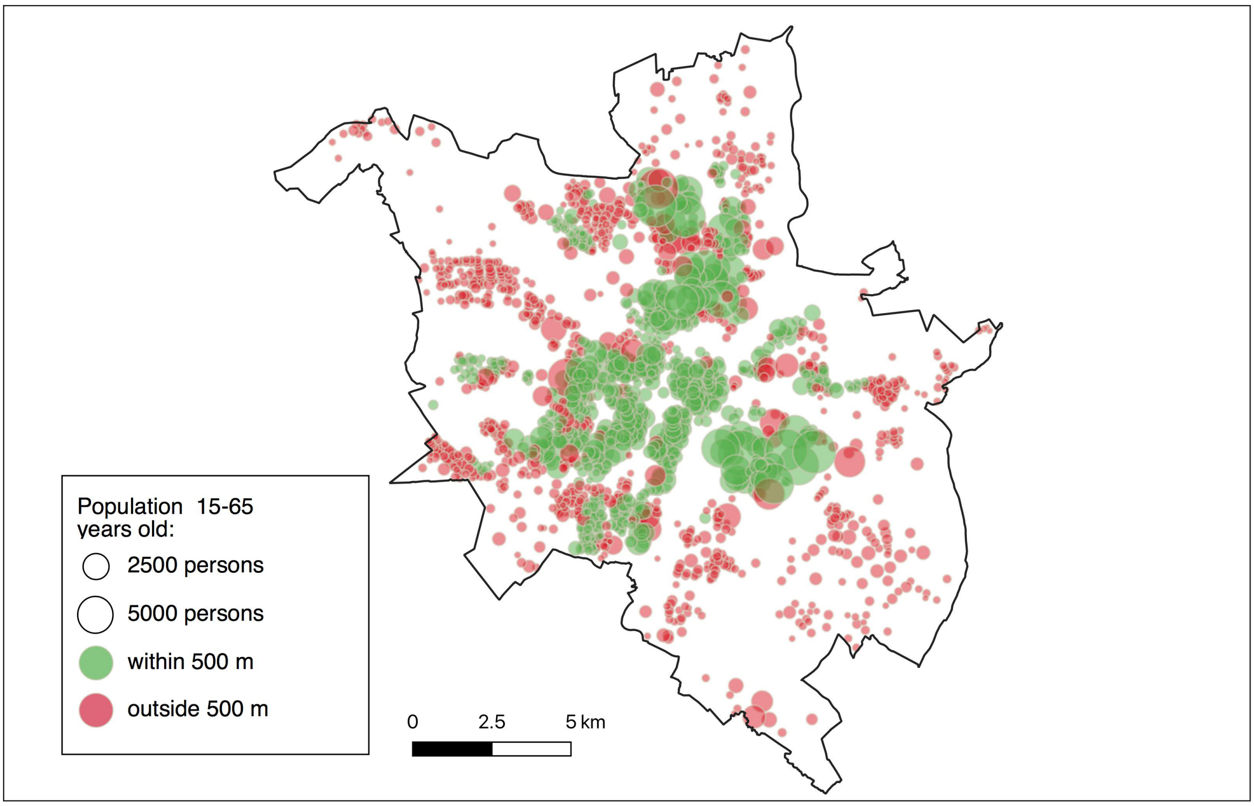

Fig. 2. Accessibility of the Poznań City Bike stations.

Source: own elaboration based on Web API data.

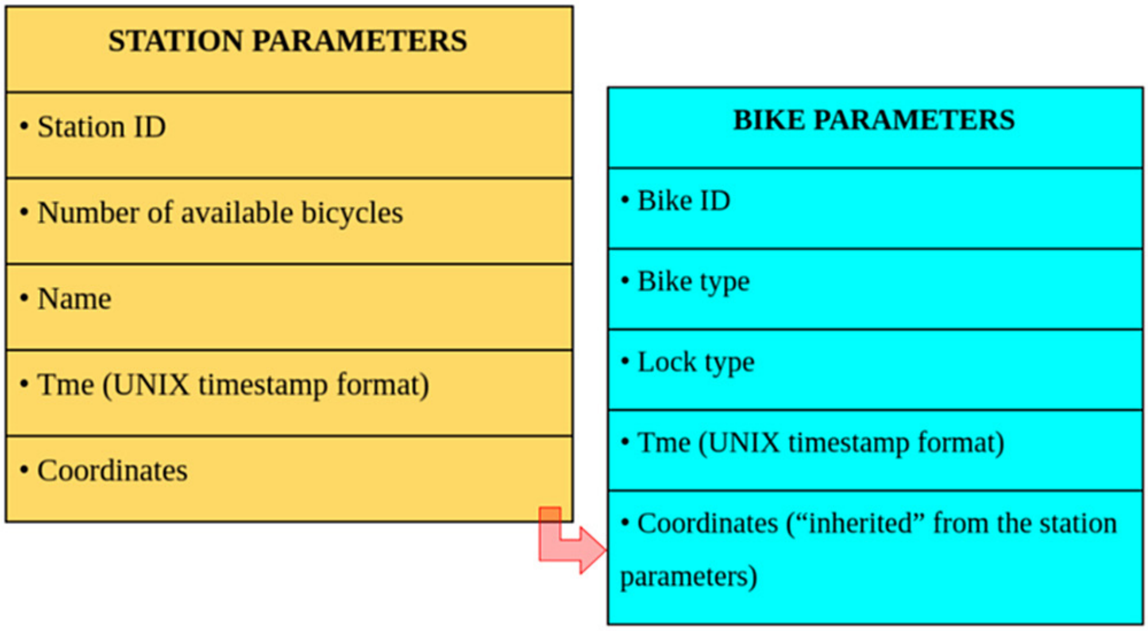

Fig. 3. Information about the station and bike parameters that were collected by the Python script used in the data gathering process. The bike coordinates were merged with the destination stations (marked with an arrow).

Source: Own elaboration based on Web API data.

4. City bikes itinerary

The collected data set indicates that the activity of city bike users in Poznań had a strongly asymmetrical spatial distribution. Despite the expansion of the stations' network in the suburbs, the vast majority of trips were located in the city center and adjacent areas (fig. 4). A large number of trips in this area can be associated on the one hand with a large number of potential users (residents, commuters, tourists), and on the other with the higher density of stations. Most city bike trips took place over short distances. About two-thirds of the trips took place over distances not exceeding 2,500 m (measured as a straight line), and about 90% of the journey did not exceed the distance of 5,000 m (fig. 4).

The most popular stations in terms of average daily number of trips were: Kórnicka, Półwiejska and Rondo Rataje (fig. 5). Many popular stations are located near important transportation hubs, such as the main train station and Rondo Kaponiera, whereas the most frequented station - Kórnicka - is located next to a large shopping center. Stations located near universities neighboring the city center were also popular: Uni-

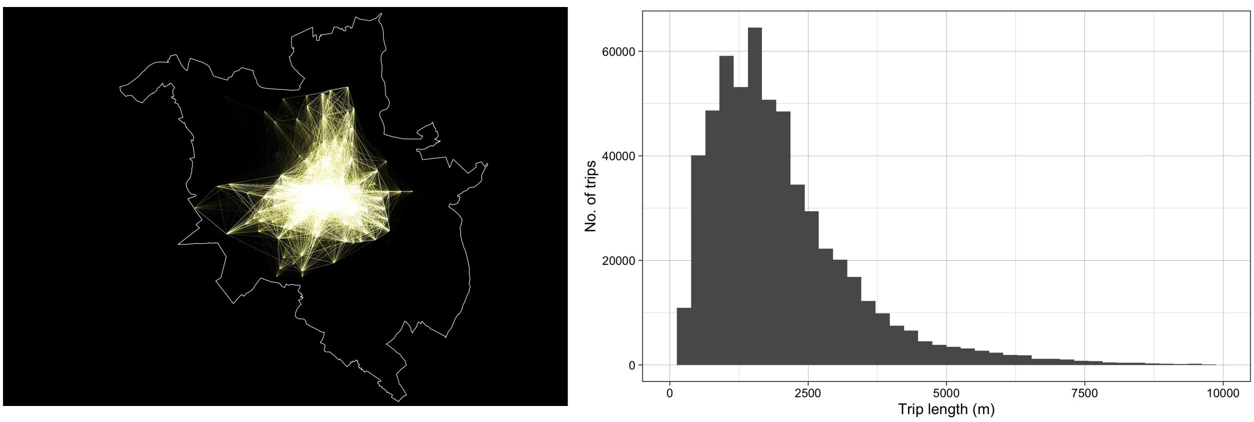

Fig. 4. Intensity (left side) and lengths of travels histogram (right side) between Poznań City Bike stations.

Source: Own elaboration based on Web API data.

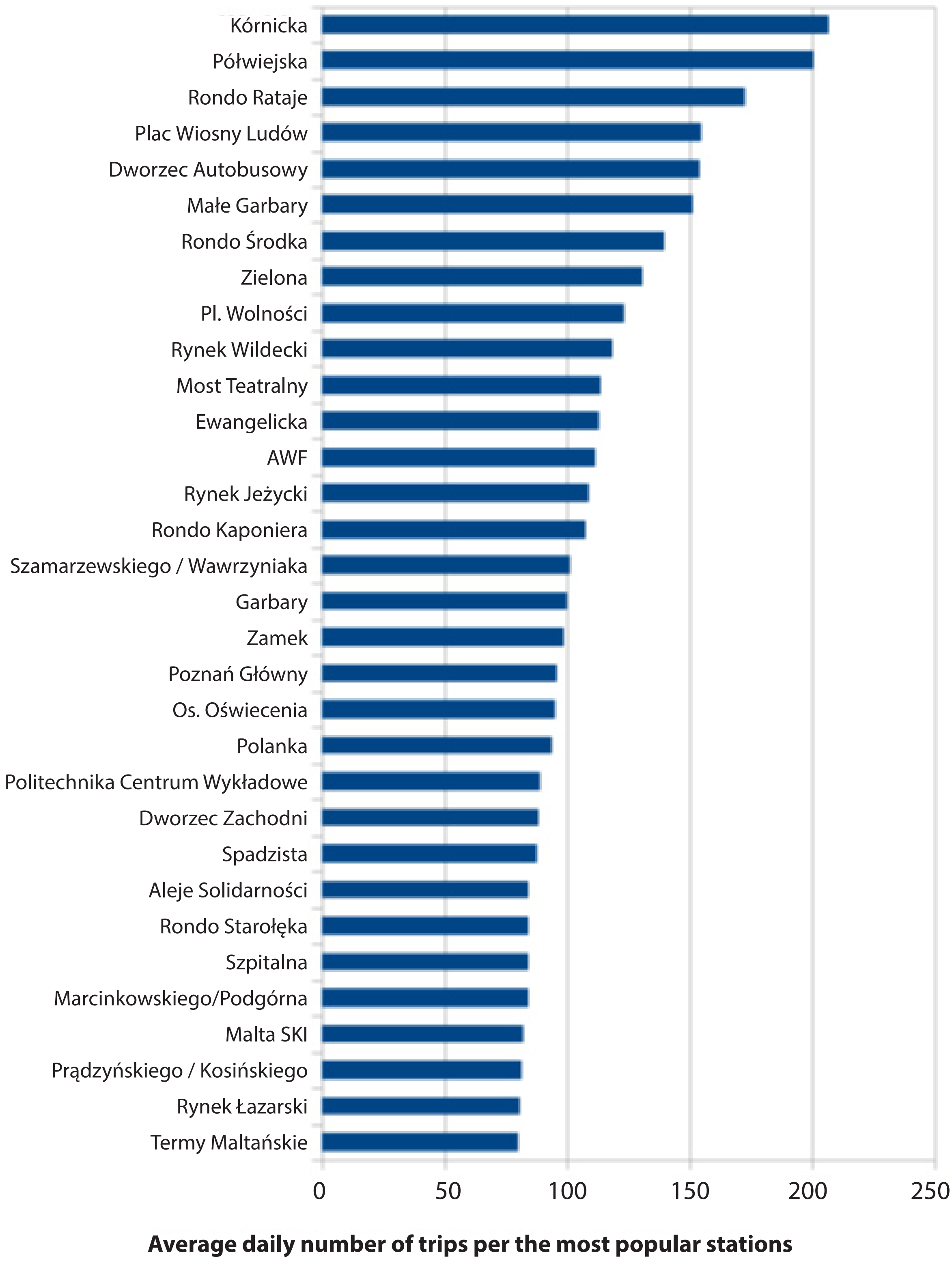

Fig 5. The most popular city bike stations in Poznań from May 23 to October 20, 2019 (with an average number of daily trips over 80).

Source: Own elaboration based on Web API data.

versity of Physical Education (AWF) (112 trips per day), Szamarzewskiego / Wawrzyniaka (101.7 trips per day), University of Technology Lecture Center (89 trips per day). This may suggest that the users of bike-sharing are mainly young people (Winters et al., 2019) The least popular stations include the following stations: Szarych Szeregów (4.3 trips per day), Puszkina (4.1 trips per day) and Niestachowska / Wojska Polskiego (2.6 trips per day). Most dockless stations, which had been added in 2019, were among the least frequented stations.

In total, 7392 different routes between city bike stations were observed (excluding trips that had a starting or ending point outside the station). However, many of routes referred to rare or even sporadic travels (1296 routes with just a single recorded trip). On the other hand, the top one hundred most popular routes generated 45,000 trips, or 26% of the total number of trips between stations. Most popular routes were located mostly in the city center and adjacent districts (fig. 6). A concentration of frequented routes in the right-bank site of the city is also noticeable, with the main junction at the Kórnicka station.

The largest number of movements (1784) was recorded between Kórnicka station and the nearby Polanka station. Interestingly, none of the most popular routes ran through the Półwiejska station, one of the most frequently used bike-sharing stations in Poznań, that is located in the shopping and services zone of the strict city center. This suggests that the traffic structure connected with this station was more dispersed. Some popular routes also ran outside the city center towards the northern (Winogrady, Piątkowo, Naramowice), western (Junikowo) and southern (Dębina) districts. Almost all popular routes formed a coherent network. The exception was a route in the northern part of the city connecting the bus station at Osiedle Sobieskiego and the final station of Poznań Fast Tram with the Adam Mickiewicz University campus. This route can be an example of using a city bike as a substitute for hardly accessible public transport.

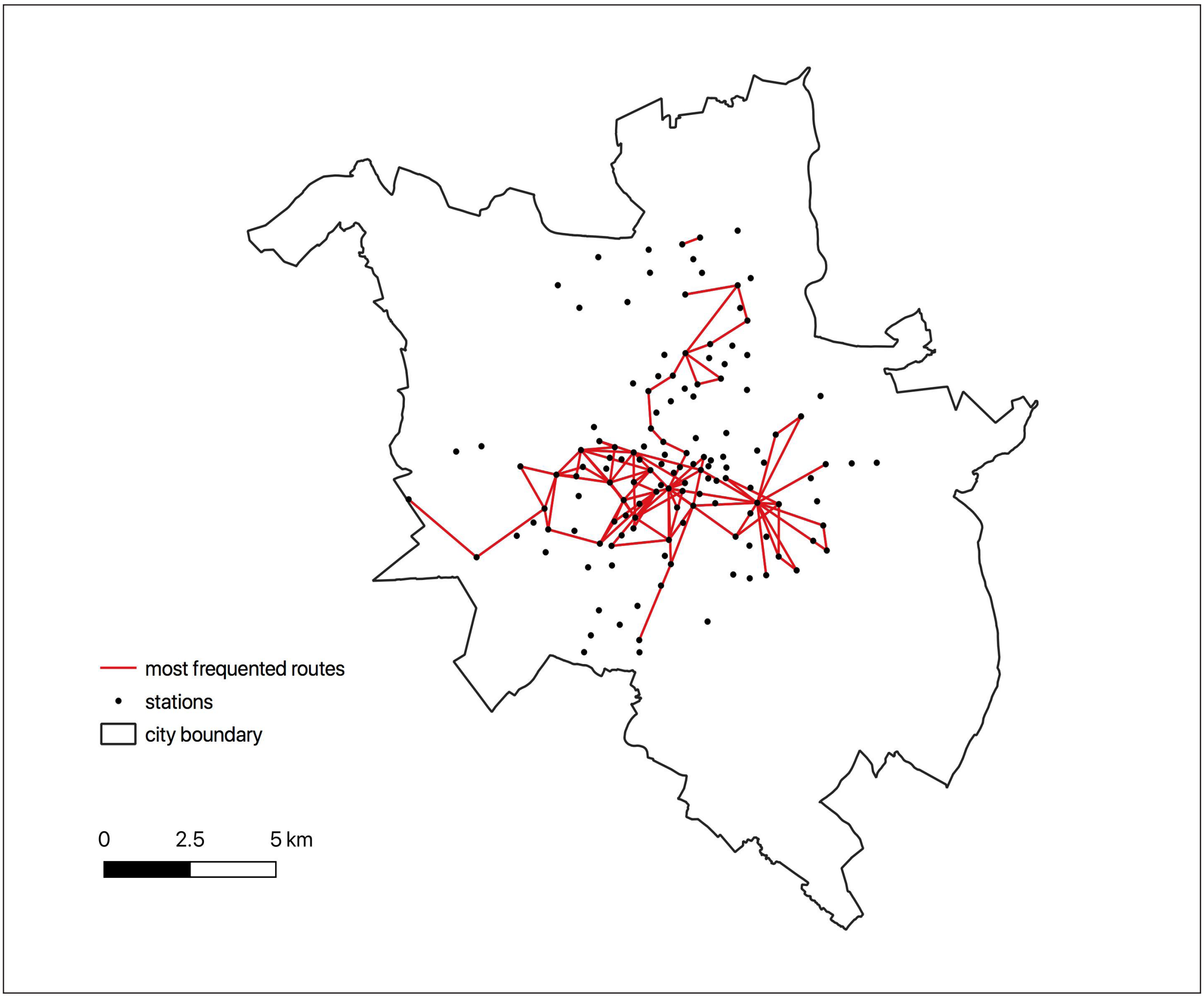

Fig 6. 100 most popular city bike routes in Poznan from May 23 to October 20, 2019.

Source: own elaboration based on Web API data.

Data obtained from the Web API also allow us to take a closer look at the structure of bike connections at the level of individual stations. Fig. 7 shows the structure of displacements for the most frequented city bike station (Kórnicka). Also for a single station, the regularity of the whole network was visible: the few routes were the most popular, while the majority of them were characterized by the low frequency of travels. Among the most frequent were the movements to nearby stations, including the aforementioned Polanka station, as well as to the Osiedle Rusa / Chartowo, Inflancka, Krańcowa, and Osiedle Piastowskie stations (over 700 moves for each of the mentioned stations).

The displacement networks presented above are graphs, i.e. they are some simplifications of the real network. Understandably, actual displacements do not occur in a straight line, but using the available infrastructure. Although the Web API data does not contain information on the actual routes of city bike users, at least a partial reconstruction is possible using services such as the Openrouteservice API. This service allows to calculate a route for point or line data, using various means of transport (Heidelberg Institute for Geoinformation Technology). Fig. 8 shows the actual reconstructed routes for the most frequented city bike station (Kórnicka).

Despite the flexibility of the bike-sharing system, not all destinations desired by users were equipped with bike stations. This does not mean, however, that there were no trips, or only occasional trips, to places outside the station network. Lack of stations was not an obstacle for some users arriving in potentially attractive destinations. This is well illustrated by the example of Strzeszyńskie Lake, one of the most popular leisure destinations among the inhabitants of Poznań. Despite the lack of stations, 119 trips to Strzeszyńskie Lake were recorded in the analyzed period, mostly from the center, western and northern districts, although longer trips also occurred (fig. 8).

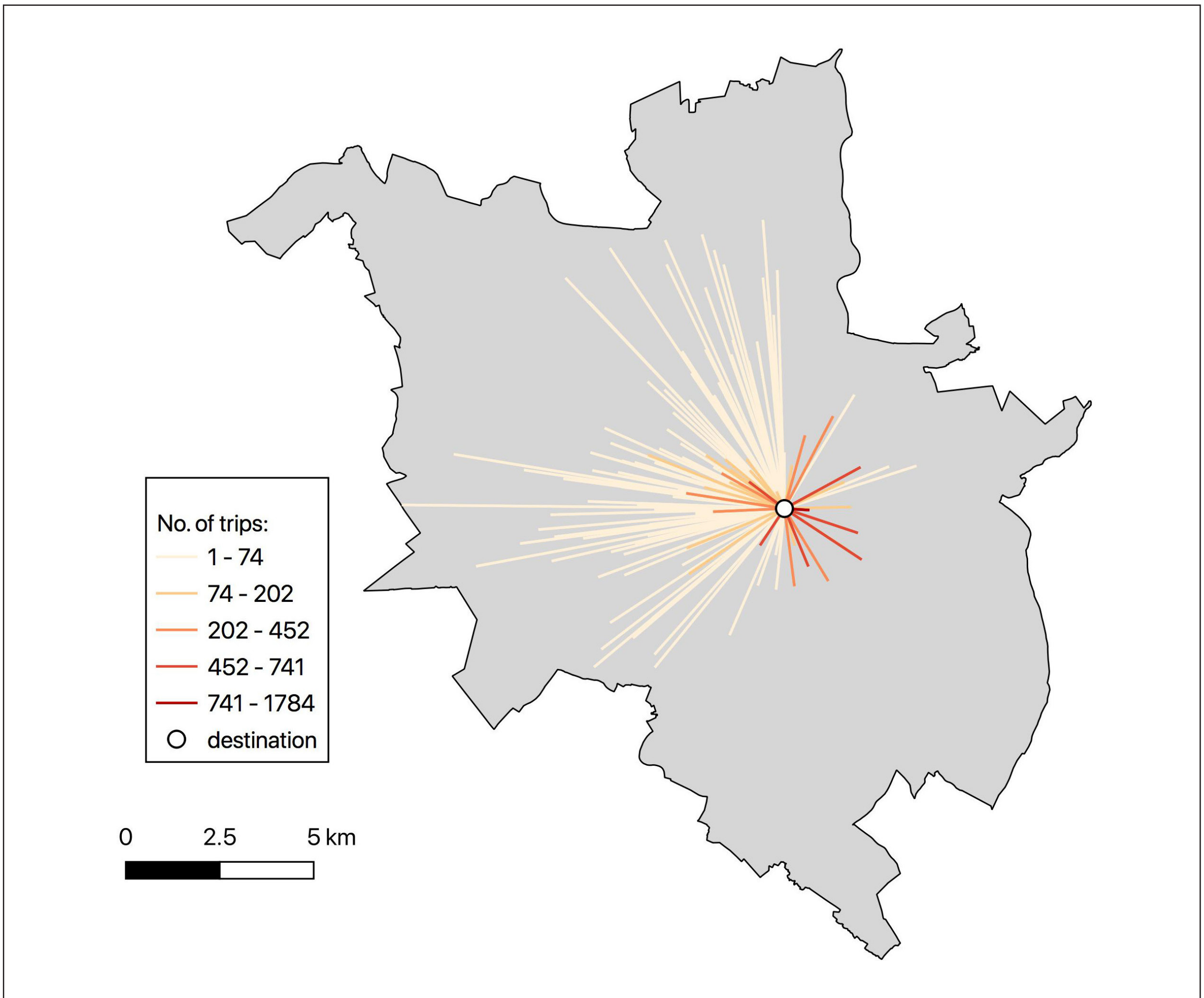

Fig. 7. City bikes intinerary for the Kórnicka station according to the number of movements.

Source: Own elaboration based on Web API data.

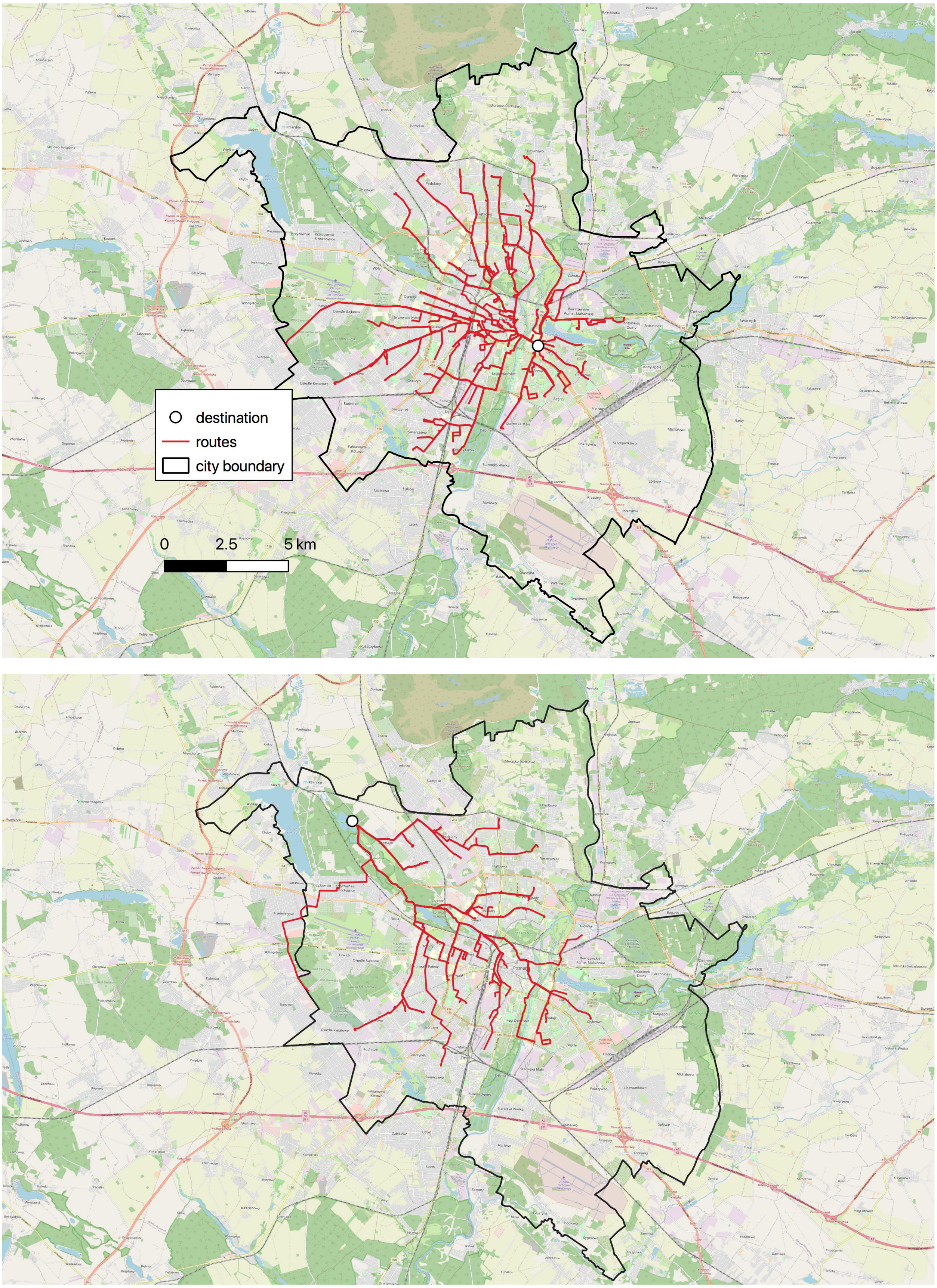

Fig. 8. Reconstruction of the actual bike routes for the Kórnicka station (left side) and to Lake Strzeszyńskie (right side).

Source: Own elaboration based on Web API data.

Conclusions

Public bicycles have been present in Poland for several years, and recently have become a noticeable element of the transport system in many cities. So far, however, they have rarely been the subject of interest of Polish researchers, even though there is a dynamic increase in publications on bike-sharings in international literature. At the same time, databases regarding this mean of transport are becoming increasingly widespread and create new and interesting research perspectives. This article used a Web API data source to analyze the spatial distribution of city bikes travels. The focus was on the Poznań City Bike, one of the oldest and most extensive bike sharing systems in Poland.

Research results indicate that the activity of bike-sharing users in Poznań had a strongly asymmetrical spatial distribution. Stations located in the city center and adjacent areas were used most often, which corroborates findings from previous research in other countries. Short trips (up to 2,500 m in a straight line) dominated, and around 90% of trips did not exceed the distance of 5,000 m. The specification of the data allowed us to analyze the frequency of travels at individual bike stations, and also allowed for the reconstruction of actual bike routes.

The research procedure presented in the article can be replicated in the analysis of other Polish cities. In future research, it is worth trying to compare systems operating in different cities. Also, in the case of collecting data for a longer time, the evolution of bike-sharing mobility could be better understood. An interesting research direction also seems to be a comparison of data obtained from sources such as Web API with socio-economic statistical data, or concerning the built environment or weather. Such analysis can help to better understand the importance of bicycles for urban mobility in Polish cities and their relationship with other elements of the transport system such as public transport. It can also have a significant role in investigating the travel needs of users at risk of transportation exclusion.

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