Optimal Placement of the Bike Rental Stations and Their Capacities in Olomouc

Zdena Dobešová and Radek Hýbner

Abstract Several towns over the whole world run the network of the station for rent a bike for municipal transport. The town Olomouc has good condition for bike transport. The town is flat, and private transport by bike is very often. There is the opportunity to prepare the network of bike rental station. The rent out the bike is assumed for daily transport of inhabitants or tourists and visitors. The presented study shows the analysis of optimal placement of the rental station in Olomouc. The spatial analysis is based on data about street lines, cycling lines and numbers of inhabitants and others. Extension Network Analyst for ArcGIS was used for location and allocation analyses. Moreover, the suggestion of capacities (number of position for bikes) for each station was calculated. The result is two variants for 3 and 4 min walking time to the rental station.

Keywords Rental station · Cycling · Location analysis · Allocation analysis

1 Introduction

Valencia, Santander, Seville, Barcelona, London, Dublin, Lyon, Paris, Marseille, Luxembourg, Wien and many other cities have the bicycle renting public service. Bike-sharing is becoming more and more frequent mean of transport in the European and World cities. Cycling supplements the public transport in a good way in towns. Cycling fill the gap between walking that is very slow and public transport. In case of traffic jam, the cycling is the quickest way of transport.

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Many case studies and realization (San Francisco, Lisbon, Seattle) exist for several towns [1–3]. The inspiration was the real experience with the system Valenbisi in Valencia [4]. Only one solution exists in the Czech Republic. Bicycle renting public service HOMEPORT PRAHA exists in Prague, municipal part Karlín. Presented solution suggests the placement of stations for the whole city Olomouc. This study did not concern to the economical, technical or operating aspects of bike sharing. The main aim was to analyze spatial situation and conditions for optimal location of bike rental stations in town Olomouc using GIS. The analysis was solved as geoinformatics task. Spatial analyses are very often used for exploration of the urban environment [5].

Several case studies were explored. Midgley [6] mentions four generations of bike sharing. The first solution appeared in Amsterdam (1960), La Rochelle (1976) a Cambridge (1993). Bicycles were for free for inhabitants. The second generation locked the bicycles in the rental stations. The loan of a bicycle was by inserting a coin (Danish towns Farso and Grena in 1991). The third generation started in Copenhagen at 1995. The users paid the annual fee to rent a bicycle. The using of bicycle is free for the first 30 min. It is necessary to pay a small fee when the time is longer than 30 min. Now it is the most realized solution in many towns.

The spatial distribution of rental stations considers some facts in studied case studies. The distance between two of stations is recommended from 300 to 500 m [7]. The study for Paris recommended about 10 rental stations per km^2. Localization of stations must primarily consider the highest moving of inhabitant. The influences are a number of inhabitant on permanent address, commuters to schools and jobs, the closeness to the shops, the cultural and sport facilities (stadiums, theatres, cinemas, museums, concert halls, markets, department stores etc.).

The presented solution is individual solution for Olomouc city. The suggested method is own developed method that is partially inspirited by presented case studies. The method has considered source data and their structure and also their availability for city Olomouc and census in the Czech Republic. The synthesizing solution arose from detail research of case studies over the whole world and detail study of condition in city Olomouc.

2 Step of Analysis

Case study for Olomouc city consists of several steps. The first step was the data collection and the update of street lines and especial bicycle path and bicycle lane. It was assumed to locate the rental station near the bicycle path and line. The second step was the collection data about the number of inhabitants, commuting people to localize source and target area with high citizen motion. These data and data about land use were the base for the creation of “raster of suitable areas”. The raster of suitable areas was the first output of spatial analysis.

Analyses Minimize Facilities and Maximise Coverage from the set of Location-Allocation Analyses were the next step. Task Minimize Facilities determines the minimal number of facilities that cover maximum demand points. This analysis determines the suitable number of the rental station. The address data was input to the location analysis as demand points. The last step was the suggestion of capacity of stations.

3 Raster of Suitable Areas

The first spatial analysis was the creation of suitable areas for location of rental stations. Suitable areas were created as a weighted raster that expressed the high population movement. The pixel size was discussed. The sizes 10 and 20 m were tested. The size 10 m better expresses the situation near the streets in the centre of the town.

Input data for the raster were vector data: street lines, bicycle lane/path, station of public transport and railway stations. All these data were actualized and verified in summer 2012 [8]. Stations of public transport and railway stations are important. The continuation of bus transport with cycling is supposed [7]. Buffer zones (50 m) of these points and the line vector data were converted to the rasters. In addition, another data were considered. Data about commuters were taken from the Czech Statistical Office. Commuters are supposed to be a client of rental stations. Number of commuters was originally assigned to the street lines. Accommodation facilities and their capacities were multiplied by 0.29. The occupation of hotels is 29 % in average. All these data and address points with the number of inhabitants were converted to the separate rasters. The last input data was vector polygon theme—land use that was also converted to the raster [9]. The building block areas and water had value 0. All rasters were reclassified.

Using tool Raster Calculator from Map Algebra toolset was created the final raster of suitable areas. The scale of weight was from 0 to 9. The weight 0 means "unsuitable area", the weight 1–3 means "not much suitable area", the weight 4–6 means "suitable area" and the weight 7–9 means "the most suitable area". The detail part of raster of suitable areas is in Fig. 1. The first step of analysis—calculation of raster of suitable areas was tested for two municipal parts of town. One part was from the centre of town, and the second one was neighbourhood municipal part.

Finally, the weights of suitability from raster were assigned to the address points. These address points were the input for next network analyses as potential places of self-service stations.

The steps of input data preparing and next spatial processing were assumed to record as a model (data flow diagram) in ModelBuilder. The advantage would be an automatic batch processing and repetitive using of model [10, 11]. The idea was not realized due to the necessity of manual setting of class in reclassifying process.

Fig. 1 Part of the raster of suitable areas

4 Network Analyses

Extension Network Analyst for ArcGIS was used for the next steps of analysis. The data structure—Network dataset was based on feature class street line (contains also pavements). Network dataset is necessary for next network analyses.

4.1 Minimize Facilities Analysis

Analysis Minimize Facilities solves the minimal number of stations. The principle is to localize facilities to allocate to them the maximum of demand points in specified distance. Address points with the weight in interval 5–9 were taken as candidate points. Weight was taken from raster of suitable areas. The interval was a crucial decision. There were only 15 address points in interval 7–9 (the most suitable area) and 263 points in interval 6–9. Small number of candidate points produces all points as result facilities [12]. The better choice was interval 5–9. Total number of candidate points was 1,663 address points. Search tolerance was set to 200 m [8]. The input parameter is also impedance in minutes. Two values were set: 3 and 4 min for two runs of analysis. The result was only the number of station, not their localisation. Quantities were 87 stations for 3 min and 43 for 4 min. The quantities are very different in case of small change of time.

4.2 Maximize Coverage

Subsequently, the localization of stations was solved by function Maximize Coverage. This function needs as input parameter the number of facilities. The results of previous analysis Minimize Facilities were used. This analysis tries to place the limited number of points to maximize the covered area. The amount of candidate points was taken bigger than in the previous analysis. Points with weight 4 were also considered. Total number of candidate points was 4,645. Output of that analysis was lines that connected demand points with their localized facilities (rental stations). Finally, the polygons belonging to localized facilities were obtained by analysis Service Area. The polygons were solved as not overlapping polygons. For both versions (3 and 4 min) service areas were determinated.

5 Proposal of Capacities for Stations

Final step was a suggestion of capacity for each station. Capacity means the number of position (stands) for bicycles in station. Base information was the service area of each station. The area, that was covered by station, was determined by tool Service Area from extension Network Analyst for ArcGIS. For each 78 stations were determined 78 polygons of service areas (Fig. 2). The polygon features class was joined with the point layer of address points with the number of inhabitants. Total number of inhabitants that belong to each service area was calculated (Fig. 3).

Although the technical realisation did not propose, the sizes of stations were suggested in that case study. The modules from 10 up to 40 positions were considered (modules with 10, 15, 20, 25, 30, 35 and 40 stands). The inspiration was taken from other cities. Table 1 shows the situation in some European cities. The rental services have more stand than bicycles to guarantee space for parking. The ration is about 10. The number of bicycles and stands per 1,000 inhabitants very vary in cities. The redistribution of bicycles between stations is sometimes necessary. It happens especially in the morning when commuters arrive at the main railway station, and bike rental station is empty very quickly. Inverse situation is in the afternoon.

The limits for the number of inhabitants for modular rental station were experimentally suggested achieving average number of 6.85 stands per 1,000 inhabitants (Table 2).

According to calculated number of inhabitants in each service area the size of capacity was manually assigned to the rental stations. Final localization of rental stations and their capacities are on the map in Fig. 4. Each station is labelled by the suggested capacity.

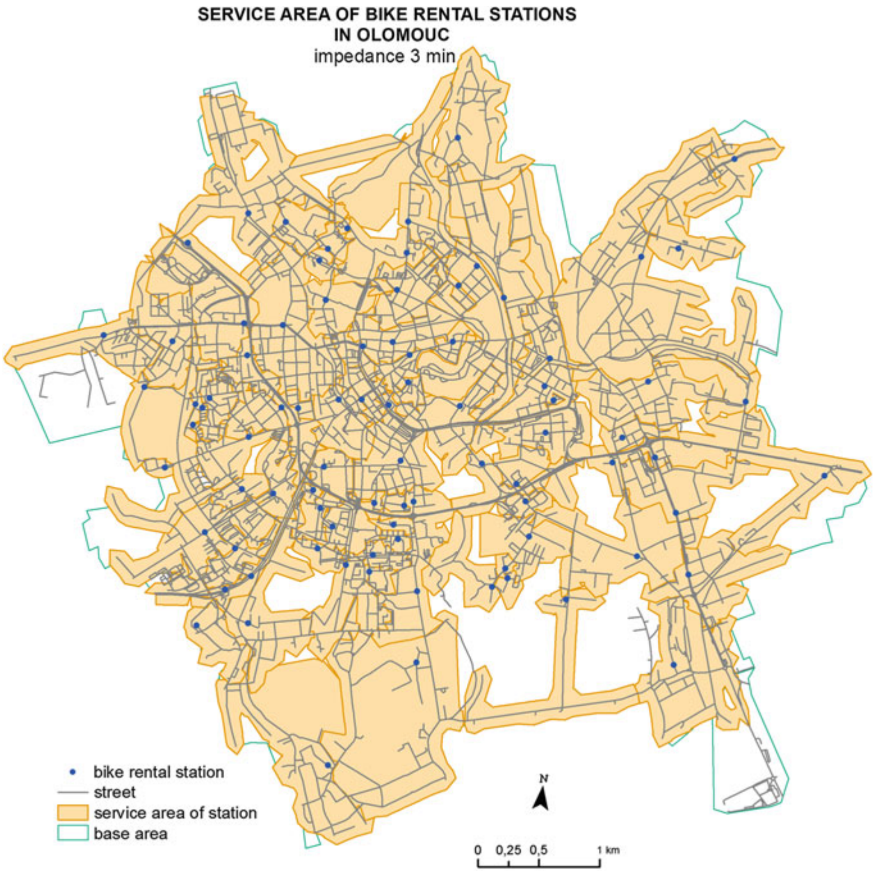

Fig. 2 Service area of bike rental stations in Olomouc [8]

6 Results

The case study has two possible solutions. The first one is for maximum 3 min walking to the station. In that case, the number of the bike rental station is 87. When the maximum walking time is 4 min the number of stations is 43. The first solution is preferred (Fig. 4). When the station is empty and no bicycle is here, the person has to go to the next station. Total time is 6 min in the first solution or 8 min in the second solution. The 6 min are limitation that be practically accepted by cyclists. Comparison of results is Table 3.

The real location of station must consider the traffic situation, owner condition in realisation. Local condition must be verified. A small shift up to 50–100 m can be accepted. The optimal distance between stations is from 300 to 500 m [7]. Very often the station occupies one or two parking places that is owned by municipality.

Fig. 3 Bike rental station in Valencia [4]

Table 1 Comparison of the number of bicycles and stands per 1,000 inhabitants in European cities [6]

City	Number of bicycles/ 1,000 inhabitants	Number of stands/ 1,000 inhabitants
Paris	9.6	13.9
Lyon	6.1	8.8
Rennes	4.8	7.0
Copenhagen	4.0	5.8
Stockholm	4.0	5.8
Barcelona	3.7	5.4
Brussels	1.1	1.6
Frankfurt	1.1	1.6
Oslo	0.5	0.7
Wien	0.4	0.6

Table 2 Suggested category of capacities for impedance 3 min [8]

Capacity	Limit number of inhabitants	Number of stands/1,000 inhabitants
10	1,000	10
15	2,000	7.5
20	3,000	6.67
25	4,000	6.25
30	5,000	6
35	6,000	5.86
40	7,000	5.71

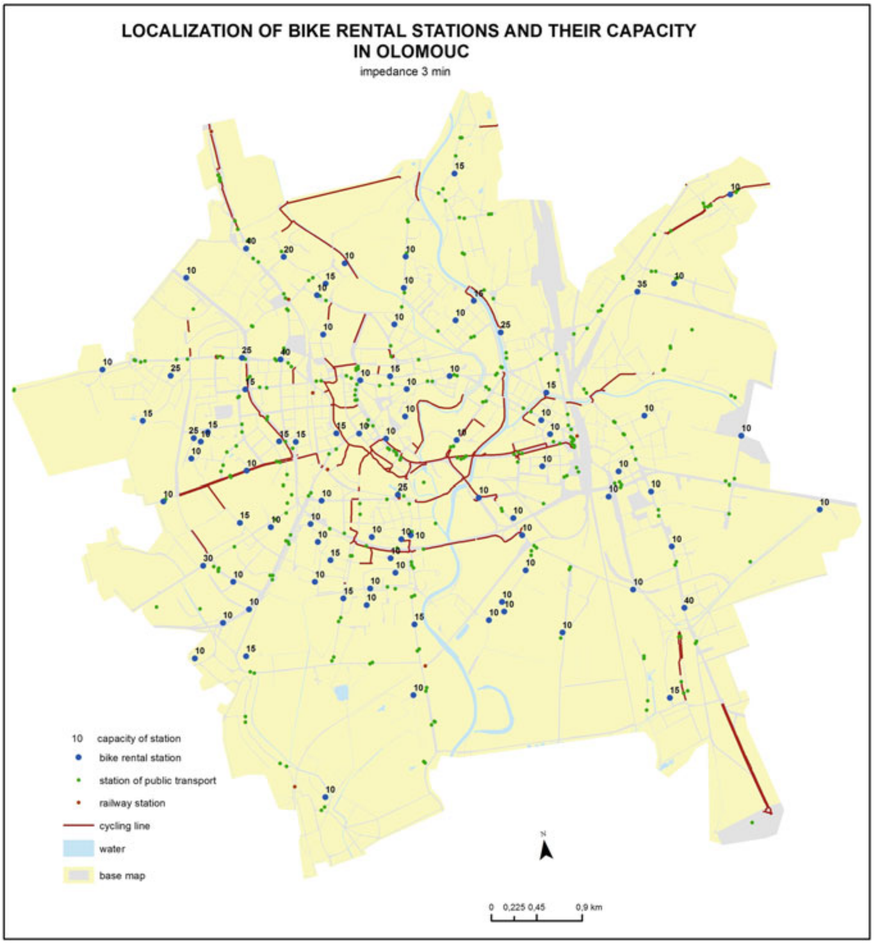

Fig. 4 Localization of bike rental stations and their capacity [8]

Table 3 Comparison of two solutions [8]

Impedance	3 min	4 min
Total number of stations	87	43
Number of covered inhabitants	90,408	90,322
Total capacity of stations	1,175	755
Average number of inhabitants per one stand	76.9	199.6
Average number of stands per 1,000 inhabitants	13	8.4
Number of bicycles in flotilla	646	415

The terrain investigation, discussion and refining must be used before final realisation of the network of bike rental station. This theoretical output produced by network analyses was handed to municipal government of Olomouc city to consider it in new cycling strategy for the city.

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