Transport Accessibility of Warsaw: A Case Study

Albina MOŚCICKA and Krzysztof POKONIECZNY, Poland
Anna WILBIK, The Netherlands,
Jakub WABIŃSKI, Poland

Key words: spatial analysis; means of transport; potential accessibility; Warsaw transportation system

SUMMARY

In this study, we detected which means of transportation is beneficial from a travel time perspective in specific districts of Warsaw, Poland. To achieve this goal, we proposed a framework to perform a spatial analysis to describe the AS-IS situation in the city (the state that the situation is in at the present time). The framework contains the following elements: attractiveness analysis, travel time and speed analysis, and potential accessibility analysis. The relationship between the averaged nominal travel speed and the number of residents was also investigated.

The results are presented as maps of travel times, travel speed, and potential accessibility, as well as scatter plots of dependencies between travel speed and number of residents. Unfortunately, public transportation ranks behind car and bike transport in terms of travel time, speed, and potential accessibility. The largest positive influence on effectiveness of traveling by public transportation is the metro and railway system; also, bikes can perfectly complement the public transportation system. The obtained results can be used to indicate directions of changes in the transportation system of Warsaw.

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1. INTRODUCTION

Travel time is one of the most important factor that determine whether or not people use public transit. Presentation of travel time and related topics on a map plays a major role in this determination. The amount of information that can be conveyed via one single map could require several page of text. Understanding an image presented on a map is easy and natural, that is why availability maps have been developed for a long time (Galton, 1881; Paulin, Wright, 1932).

Together with the development of Geographic Information Systems (GIS), as well as spatial analysis maps started to be the main tool to present and visualize the results od spatial data analysis. Most solutions aimed at improving the quality of transport, including urban transport, are also based on data analysis, including spatial data. Moreover, their results can be presented on maps showing different aspects of transport policy, as well as dependencies between factors affecting transport effectiveness.

In this study, we detected which means of transportation is beneficial from a travel time perspective in specific districts of Warsaw, Poland. To achieve this goal, we proposed a framework to perform a spatial analysis to describe the AS-IS situation in the city (the state that the situation is in at the present time). Our research goal was formulated by the following three research questions:

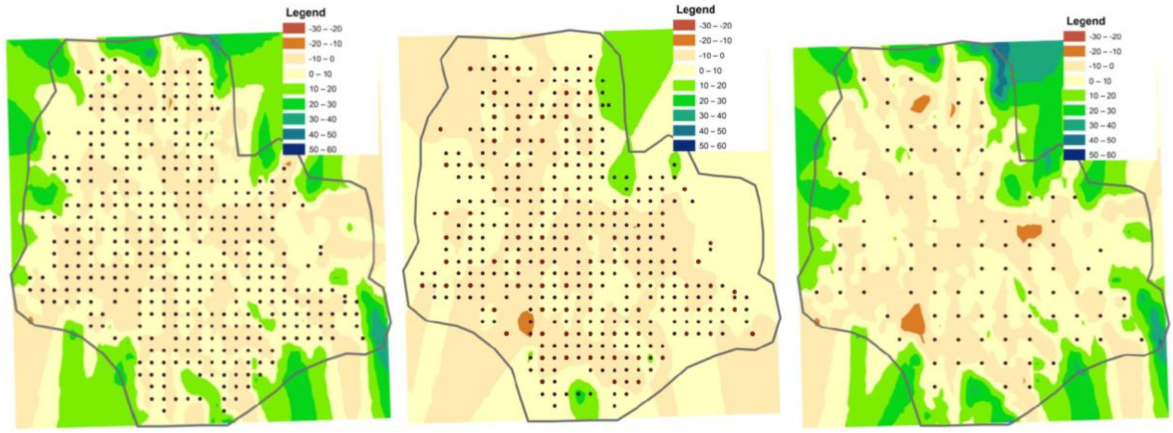
- Which means of transportation is the most efficient for each location in the city?
- Which districts have the best transportation to the most attractive locations in the city?
- Are there such areas in the city where many people live and using a car is better than using public
- transport from a travel time perspective?

2. METHODS

The framework contains the following elements: attractiveness analysis, travel time and speed analysis, and potential accessibility analysis. The relationship between the averaged nominal travel speed and the number of residents was also investigated.

We used data from a journey planner, as well as land use and population statistics and employed descriptive analytics. As a study area, Warsaw, the capital of Poland, was selected. For the territory of Warsaw, 601 measurement points were defined on a 1000 meters grid. Our research

(Mościcka, Pokonieczny, Tomala, 2016), comparing the results obtained for a mesh of 500m, 1000m and 2000m grid density (Fig. 1), confirmed that 1000 m density is enough to obtain travel time with an accuracy of few minutes.



a) 500 m and 1000 m b) 1000 m and 2000 m c) 500 m and 2000 m

Fig. 1. Visualisation of differences model of the mesh with different density (Mościcka, Pokonieczny, Tomala, 2016),

For each measurement point, the travel times to the other 600 points were calculated along with the distances and speeds. Travel times, by foot, bike, car, and public transport were determined. The travel times for public transportation and driving by car were measured at 2 a.m., 8 a.m., 12 p.m., 5 p.m., and 9 p.m. The travel times for walking and bicycling were measured only at one moment during the day. Population data were acquired from the Main Statistical Office of Poland in a grid with 1x1 km cells (primary fields). As the source of land use, the database of topographic objects (BDOT) was used.

For each 1x1 km cell, we calculated its destination attractiveness in the form of a coefficient of the destination attractiveness, which can be understood as the potential usefulness of the opportunities located in the travel destination. To designate the destination attractiveness, we used feature classes from the the database of topographic objects (BDOT) data set to select different kinds of places where people can travel. Using statistical data, we determined how many people can go to each of these kinds of places and how often they do so. Based on this, we determined the weights of each BDOT feature class in the range of 0–20 (Table 1).

Table 1. The weights of each BDOT feature class (Mościcka et al., 2019)

No.	Object name	Weight	Type
1	Stations and terminals	20	Point
2	Offices	5	Point
2	Commercial and service buildings	5	Area
3	Schools and research institutions	5	Point
4	Hospitals and medical care buildings	5	Area
5	Parking lots	4	Area
6	Museums, libraries, and other cultural places	3	Point

7	Physical culture buildings	3	Point
8	Hotels	2	Point
9	Industrial buildings	2	Area
10	Religious buildings	2	Point
11	Botanical gardens and zoos	2	Point
12	Residential buildings with three or more flats	1	Point
13	Garages	1	Area
14	Swimming pools, stadiums, and other sports places	1	Point
15	Cemeteries, parks, and garden plots	1	Area
16	Historic buildings	0.5	Point
17	Tennis courts	0.5	Point
18	Residential buildings with two flats	0.2	Point
19	Single-family residential buildings	0.1	Point
20	Play and sports grounds	0.1	Point
21	Other	0	Point

The coefficient of the destination attractiveness for each cell was calculated using Equation (1) (Pokonieczny, Mościcka, 2018):

$$CVC_i = \sum_{k=1}^{n} A_k \, I_{A_k} + \sum_{l=1}^{m} P_l I_{P_l} \quad (1)$$

where:

CVC_i - the coefficient of the destination attractiveness of the i^{th} primary field,

A_k - the normalized area of a polygon object (located within the *i* primary field) of the *k* BDOT polygon feature class,

I_{Ak} - the normalized attractiveness of the *k* BDOT feature class,

P_l - the normalized number of point objects (located within the *i* primary field) of the *m* BDOT point feature class,

I_{Pl} - the normalized attractiveness of the *m* BDOT feature class.

Based on the coefficient of the destination attractiveness potential accessibility was calculated for each primary field and for each transportation means with the use of Equation (2) (Komornicki, Śleszyński. Rosik, 2009):

$$A_i = M_i exp\,(-\beta c_{ii}) + \sum_{i=1}^{j} CVC_j \exp\,(-\beta c_{ij}) \quad (2)$$

where:

A_i - the accessibility of the i^{th} primary field,

M_i - the number of residents in the i^{th} primary field,

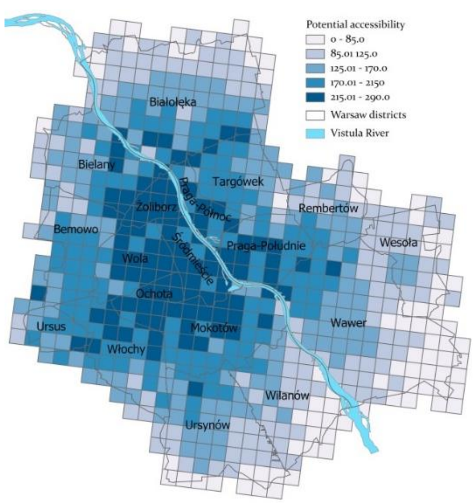
CVC_j - the coefficient of the destination attractiveness of the j^{th} primary field,

c_{ii} - the time of an internal trip within the i^{th} primary field,

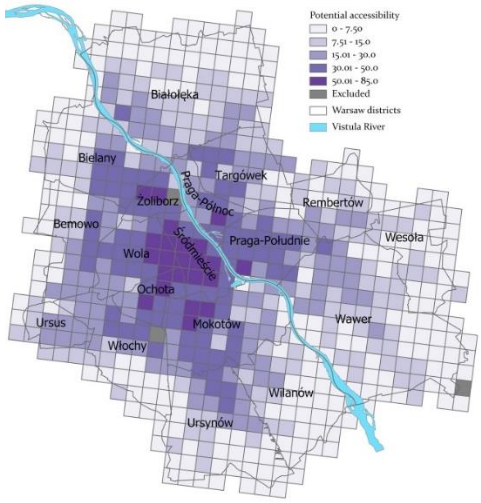
c_{ij} - the travel time between i and j primary fields.

3. RESULTS

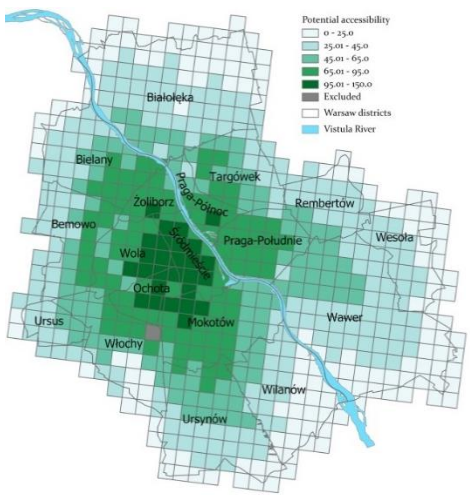
The results are presented as maps of travel times, travel speed, and potential accessibility (Fig 2), as well as scatter plots of dependencies between travel speed and number of residents. Differences of potential accessibility between different means of transportation was also analyzed (Fig. 3).



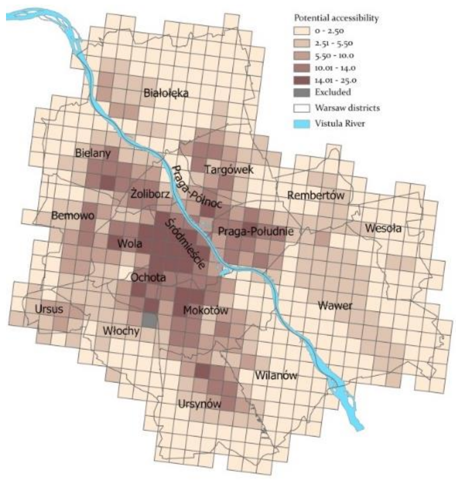
a) car



b) public transport



c) bicycle



d) walking

Fig. 2. Potential accessibility (Mościcka et al., 2019)

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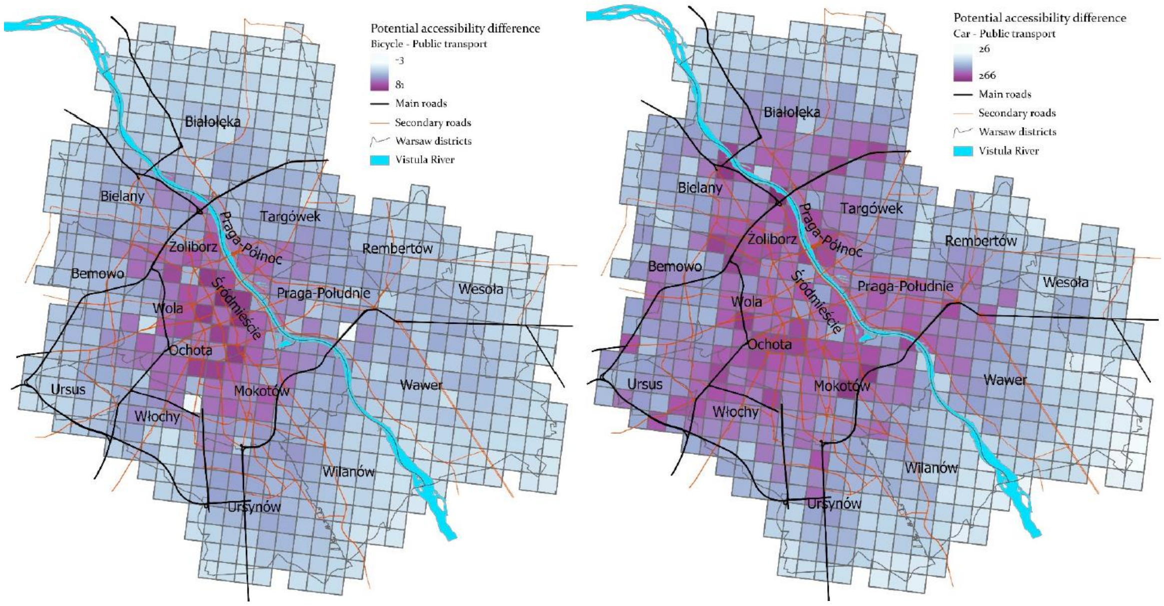

a) bicycle versus public transport, b) car versus public transport

Fig. 3. Differences of potential accessibility between different means of transportation [6]

Unfortunately, public transportation ranks behind car and bike transport in terms of travel time, speed, and potential accessibility. The largest positive influence on effectiveness of traveling by public transportation is the metro and railway system; also, bikes can perfectly complement the public transportation system.

4. SUMMARY

Using the concept of potential accessibility in transport analysis has many advantages. Potential accessibility takes into account the relationship between the land use and the transport components. In addition, it requires less data than methods that consider an individual component (i.e., accessibility measured in time geography or maximization of utility). Potential accessibility is a relatively easy approach in calculations and is often used at both national and international levels, including the European level.

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BIOGRAPHICAL NOTES

Albina MOŚCICKA is an Associate Professor at the Faculty of Civil Engineering and Geodesy, Military University of Technology in Warsaw (Poland). She gained research experience during the internships at the Stanford University (USA) and University in Stuttgart (Germany), as well as during European Union projects at Dushanbe (Tajikistan). Her research interest focuses on spatial analysis as well as on the use of GIS and cartography in historical research and cultural heritage access, management and dissemination.

Krzysztof POKONIECZNY is an Assistant Professor at the Faculty of Civil Engineering and Geodesy, Military University of Technology in Warsaw (Poland). For 8 years he served in the Military Geographic Center, where was responsible for military projects related to geoinformatics. The main research program focuses on geostatistics services and machine processing algorithms, special in military GIS applications.

Anna WILBIK is an Assistant Professor in the Information Systems Group of the Department of Industrial Engineering and Innovation Sciences at Eindhoven University of Technology (TU/e). Her areas of expertise include artificial intelligence, information systems and databases, business intelligence, data mining, and machine learning. Anna's research interests are focused especially on linguistic summaries and computing with words. Data analysis methods use numbers, figures or mathematical equations to show data, decision recommendations and patterns.

Jakub WABIŃSKI is a PhD student at the Faculty of Civil Engineering and Geodesy, Military University of Technology in Warsaw (Poland). Scholarship holder of the Fulbright Junior Research Award (Oregon USA) and Erasmus + program (Dublin, Ireland). Deals with the issue of automation of the typhlomap development process, the use of 3D printing technology in cartography and modern cartographic presentation methods.

CONTACTS

Albina Mościcka
Military University of Technology
2, Gen. Kaliskiego Str.
Warsaw
POLAND
Tel. +48 261-83-90-76
Email: albina.moscicka@wat.edu.pl
Web site: www.wat.edu.pl

Krzysztof Pokonieczny
Military University of Technology
2, Gen. Kaliskiego Str.
Warsaw
POLAND
Tel. +48 261-83-90-76
Email: krzysztof.pokonieczny@wat.edu.pl
Web site: www.wat.edu.pl

Anna Wilbik
Eindhoven University of Technology
De Zaale
Eindhoven
THE NETHERLANDS
Tel. + 31 40 247 2183
Email: a.m.wilbik@tue.nl
Web site: www.tue.nl

Jakub Wabiński
Military University of Technology
2, Gen. Kaliskiego Str.
Warsaw
POLAND
Tel. +48 261-83-90-76
Email: jakub.wabiński@wat.edu.pl
Web site: www.wat.edu.pl