Spatial Analyses Help to Find Movement Barriers for Physically Impaired People in the City Environment - Case Study of Pardubice, Czech Republic

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Abstract: - One of the main aims of the contemporary society is to provide barrier-free environment so all physically impaired people can move safely and without any discomfort. Utilization of GIS and spatial analyses to identify barriers for physically impaired people in the city of Pardubice (Czech Republic) is described in the paper. At first, data had to be collected. Then, database queries, proximity analyses and network analyses were used to analyze them, find barriers and evaluate friendliness of the city environment for people with physical impairment. Proposal for the future work are presented in the paper too.

Key-Words: - physically impaired, GIS, barriers, spatial analyses.

1 Introduction

Spatial information and geographic information systems (GIS) are today very important for many decision-making situations in public administration, commercial companies and private life of people. Taking care of all disabled people is one of all examples of GIS utilization. Information and communication technologies can significantly improve planning and care of all types of disabled people. People can be physically disabled, i.e. they have problems with a physical movement, they have some kind of visual impairment, or they can be psychically disabled.

Aim of the paper is to show how to propose and use suitable spatial analyses to identify barriers for physically impaired people within city environment. The city of Pardubice is used for the provided case study. The paper is organized as follows: in the chapter 2 there is a problem formulated and overview of related work is provided. The chapter 3 describes problem solution and conclusions are provided in the chapter 4.

2 Physically Impaired People and Barriers-Free Environment

Disabled people are people who have some physical or mental impairment. This impairment has substantially and in the long term negative influence on their ability to carry out normal day-to-day activities, like movement.

2.1 Problem Formulation

Lately, a very strong attention is paid to removing barriers which make movement of disabled people more difficult or even impossible.

In the Czech Republic, persons with limited capability of movement and orientation are mentioned by many laws. The definition can be found for example in the in the Building Act. In according to this law, all people with any health impairment, pregnant women, people with a child in a pram and elderly people are understood as people with limited capability of movement [1]. There are several acts valid in the Czech Republic which deal with barrier-free environment. The basic act is Act No. 183/2006 Coll., on Town and Country Planning and Building Code (the Building Act), as amended by subsequent regulations. Technical requirements on a barrier-free environment in urban areas are precisely specified by the Act No. 369/2001 Coll., on General Technical Requirements Assuring the Use of Public Buildings for Persons with Limited Mobility and Orientation, as amended by subsequent regulations.

2.2 Related Work

A very strong attention has been paid to visually impaired people. Navigation system for visually impaired people which can provide dynamic interaction and adaptability to changes was proposed by [15]. Assistive technology based navigation aid with ultrasonic and infrared sensors (ATNAVI) was proposed by [5]. Verbal descriptions and instructions are understood as the best way how to guide blind people, as it was proven by the study [4] but in this case path finding problem was not solved. The system was proposed and tested in a simple and structured urban area and it was based on specific database features and guidance functions (i.e. instructions and spatial information provided at specific places).

Route planning in navigation system is an example of a very difficult task to be solved in the case of all disabled people. There are many algorithms solving the shortest path problem, e.g. Dijkstra algorithm or A* algorithm. Problem of these algorithms is impossibility to select paths in according to several various criteria, e.g. suitability for wheelchair. This is the reason why various personalized navigation systems have been proposed. Austrian Federal Ministry of Transportation, Innovation and Technology supports development of a positioning and navigation system of visually impaired pedestrians in an urban environment which is based on utilization of GPS (Galileo System is supposed), very detailed and precise database and cost function for the route planning algorithm [14]. Navigation system described by Akasaka and Onisawa uses fuzzy measures and integrals [2]. Another navigation system is focused on mobility impaired people. Path finding is based on a specific cost function and enriched geographic data (multimodal data). Data and additional information are associated with predefined user profiles [17]. In Germany, there has been a route planning tool developed which is based on a geo-coding routine and two fuzzy decision systems [9]. Fuzzy approach is a very useful approach which can significantly help to provide more user-friendly query environment [16]. Another system allows users to make comments on accessibility of their environment and provides annotations to the others [6]. In all cases, there is one more problem connected to all applications in the Czech language – special Czech characters have to be taken into account [8].

2.3 Levels and Ways of Utilization of Geoinformation Technologies in the Framework of the Project

In general, geographic information systems (GIS) can be used in many different ways. Utilization of geographic information systems in the project can be split into three main types.

At first, GIS is used as a kind of an integrative tool for proposal of data models, input and output data management and treatment.

Next, GIS is used as an analytical tool to run various spatial analyses. In this moment, given tasks and problems are solved and resulting recommendations are proposed.

Finally, results should be presented in an understandable and reasonable way. GIS can be used as an cartographic tool to create output digital (and consequently printed) maps showing results of analyses and proposed recommendations.

Today, remote sensing data constitute a significant part of input data for GIS. Remote sensing methods and data are used to update existing vector data layers and to make more illustrative outputs, e.g. maps.

Next important technology is global positioning systems technology (GPS). This technology allows to measure location on the Earth's surface in a real time with a high level of precision. This function cause a nowadays widespread utilization of GPS. Connection of GPS and GIS can bring significant benefits. In the project, GPS is used to map thematic features.

3 Movement Barriers for Physically Impaired People in the City Environment – Case of Pardubice

As it was mentioned previously, the aim of the paper is to propose a way how to run a complex analysis of the city environment to identify movement barriers for physically impaired people by means of GIS.

The city of Pardubice, Czech Republic was selected for the case study. Pardubice is located at the confluence of the Elbe and Chrudimka Rivers. Area of the city is approximately 82.7 km^2. The city has approximately 90,000 inhabitants and it is divided into 8 administrative parts. The city is a regional centre (county town). The city is situated in a very flat land at an altitude of between 215 and 237 metres above sea level [3]. One of the problems is that the hospital is located on the top of a small mound and there is a barrier-free bus stop only in one direction. There are many non-governmental organizations which deal with disabled people in the Pardubice region.

As the first step, data had to be collected, processed or updated when needed. Topographical and thematic data used for the analyses were in scale 1 : 10 000. Additionally, information about barrier-free access and toilet were added. Some information was provided by the Municipality of Pardubice, some information had to be primarily collected or verified in terrain. Data layer describing public transportation stops including barrier-free stops was created too. All data were kept in the Czech coordinate system S-JTSK. Sources of data: Central European Data Agency, Municipality of Pardubice and own measurements.

Used software: ArcGIS Desktop (ArcInfo) r. 9.2, MS Excel 2003 and MS Access 2003.

In the following chapters, all steps of the case study are described.

3.1 Method and Phases of Work

Less attention is paid to other spatial analyses to run a deep and complex analysis of an urban environment. Geographic information system as a software tool provides various spatial analyses to analyses data connected to some location. In general, GIS can provide many types of analyses, e.g. [10, 12]:

- Database queries
- Spatial overlays
- Proximity analyses
- Network analyses
- Patterns analyses
- Geostatistical analyses
- Modelling and simulations
- Remote sensing and image processing
- Modelling and analyses of terrain

Available analyses depend on particular software so software tools can significantly vary from each other.

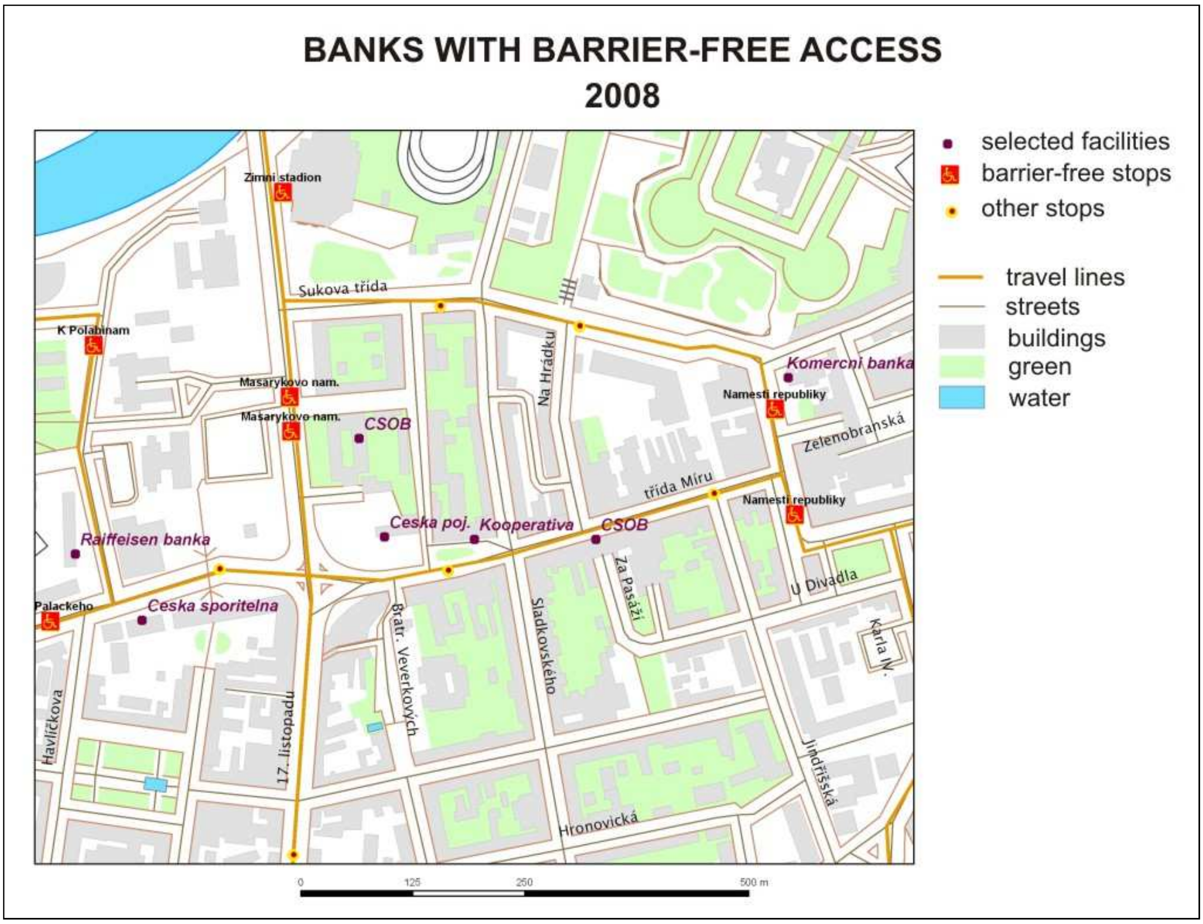

Fig. 1 – Facilities providing banking services with barrier-free access (source: authors, based on [13])

For the purpose of the case study the following **phases** were proposed and passed:

- **Conceptual level model** – text formulation of aims of analyses, target group of users and needed data; overview of limitations
- **Choice of spatial analyses** which can meet requirements given in the previous steps
- **Choice of spatial data representation and their quality attributes** – raster or vector data can be used and at least two most important quality attributes have to be considered: precision (scale) and age of data
- **Logical level model** – this level allows to transform conceptual model into more detailed technological model which allows to involve implementation issues, e.g. relational or object-oriented databases principles
- **Physical level model** – proposal of a physical data model
- **Carrying out spatial analyses and interpretation of their results**
- **Creating outputs representing results**, mostly cartographical outputs will be used

3.2 Aims of Study and Models

At the **conceptual level**, aim of the study was defined. The aim is to identify barriers for physically impaired people within the city of Pardubice. In some cases, people with a child in a pram and cyclists can be taken into account too because they have several similar limitations as people using wheel-chairs. Visually impaired people belong neither to the focus group nor to the target group of users of study results (especially map outputs, so no tactile maps were planned as results). Classical maps in a printed or digital form are expected so there is no need to take into account proposal of a proper user interface of an on-line application [7]. The city environment was introduced above. The following entities will be taken into account: buildings including information about barrier-free access and WC, public transportation stops including information about barrier-free access, accommodation facilities including information about barrier-free access.

For the purpose of this study, database queries (e.g. searching for facilities meeting several given criteria), proximity analyses, topological overlays and network analyses (route optimization) were chosen as **suitable spatial analyses**.

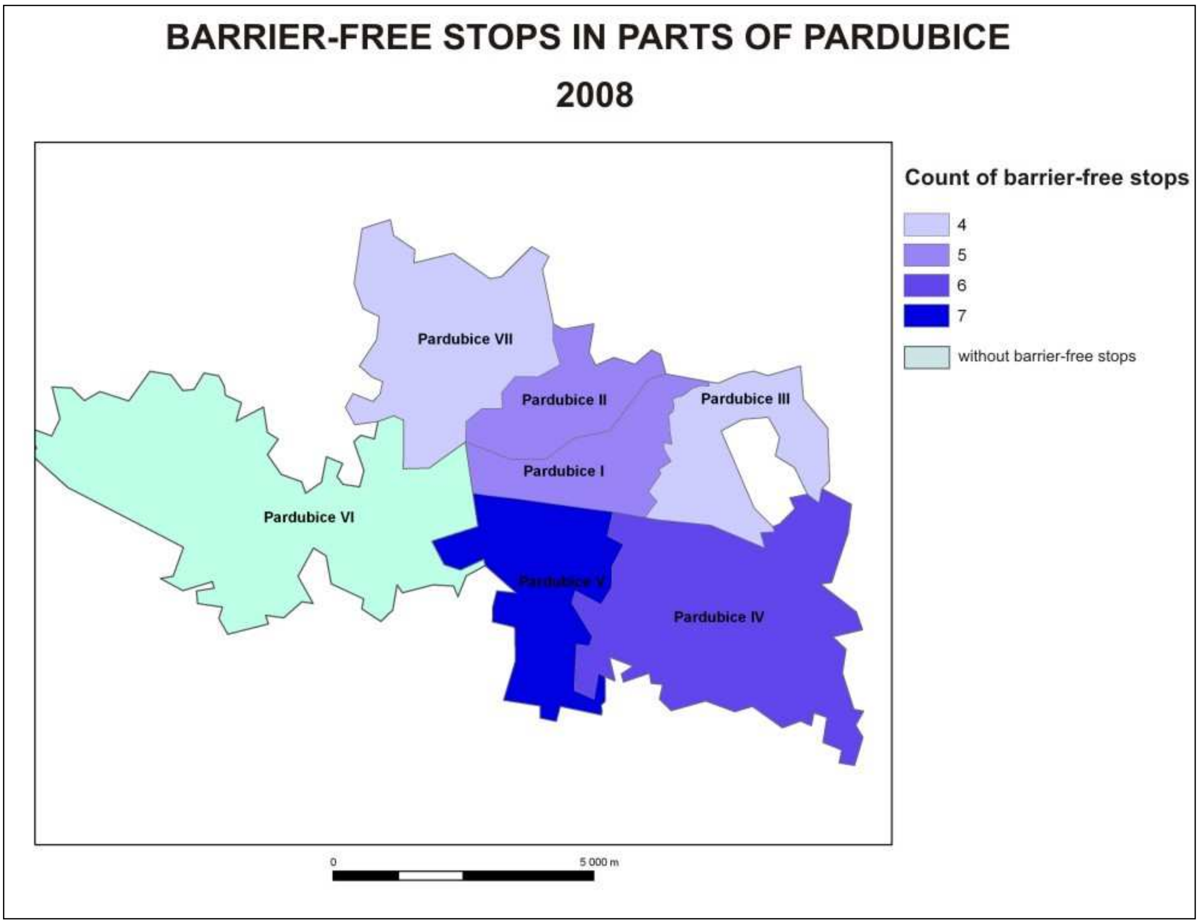

Fig. 2 – Number of barrier-free stops in parts of Pardubice (source: authors, based on [13])

The selected spatial analyses significantly influence **suitability of data**. In this case, vector data are more appropriate because they allow storing and analysing more attributes for each feature (object). In comparison with raster data, they are suitable for network analyses because they store topological information.

At the **logical level**, it was decided to use principle of relational database to store data. This decision was made with respect to the planned utilization of ArcGIS.

At the **physical level**, all data were stored in a shapefile (ArcGIS data format) – list of selected attributes is in the Table 1. As it was mentioned before, scale of data was 1 : 10 000, coordinate system: S-JTSK. Some information was provided by the Municipality of Pardubice, some information was obtained from Web pages of particular objects. Then, measurement in terrain was used to collect and verify information.

Table 1 – Selected attributes of observed entities (source: authors)

Entity	**Type of geometry**	**Attributes**
Public administration authorities' buildings	Point	Name of a authority Barrier-free access Barrier-free WC
Accommodation facilities	Point	Name Barrier-free access
Public transportation stops	Point	Name Barrier-free access Part of the city
Points of interests	Point	Name Barrier-free access
Banks with ATM	Point	Name of a bank Barrier-free access
Street network	Line	Name of a street
Barriers	Point	Type of a barrier

3.3 Spatial Analyses

In this chapter, all used spatial analyses and their results are described in more detail.

3.3.1 Database queries

Database queries belong to the most basic spatial analyses provided by GIS. They allow both spatial and attribute queries to find features which meet given criteria.

The first criterion can be name of an object and then whether an object has or does not have a barrier-free entrance.

The case study: East Bohemian Theatre is the point of interest (POI) which can be found by the simple attribute database query in according to its name. The second query can provide information whether barrier-free access and toilet are available.

Barrier-free public administration authorities' buildings represent very important issue for many people too. It was found that 8 buildings of them provide barrier-free access into building and 4 of them can provide barrier-free toilet as well.

Next example is retrieval of a list of barrier-free accommodation facilities in the city. In total, there are 45 hotels and hostels in the city. Only 17 of them have a barrier-free access. If someone wants to stay close to the castle and old city, there are only two barrier-free accommodation facilities where restaurant is available as well [11].

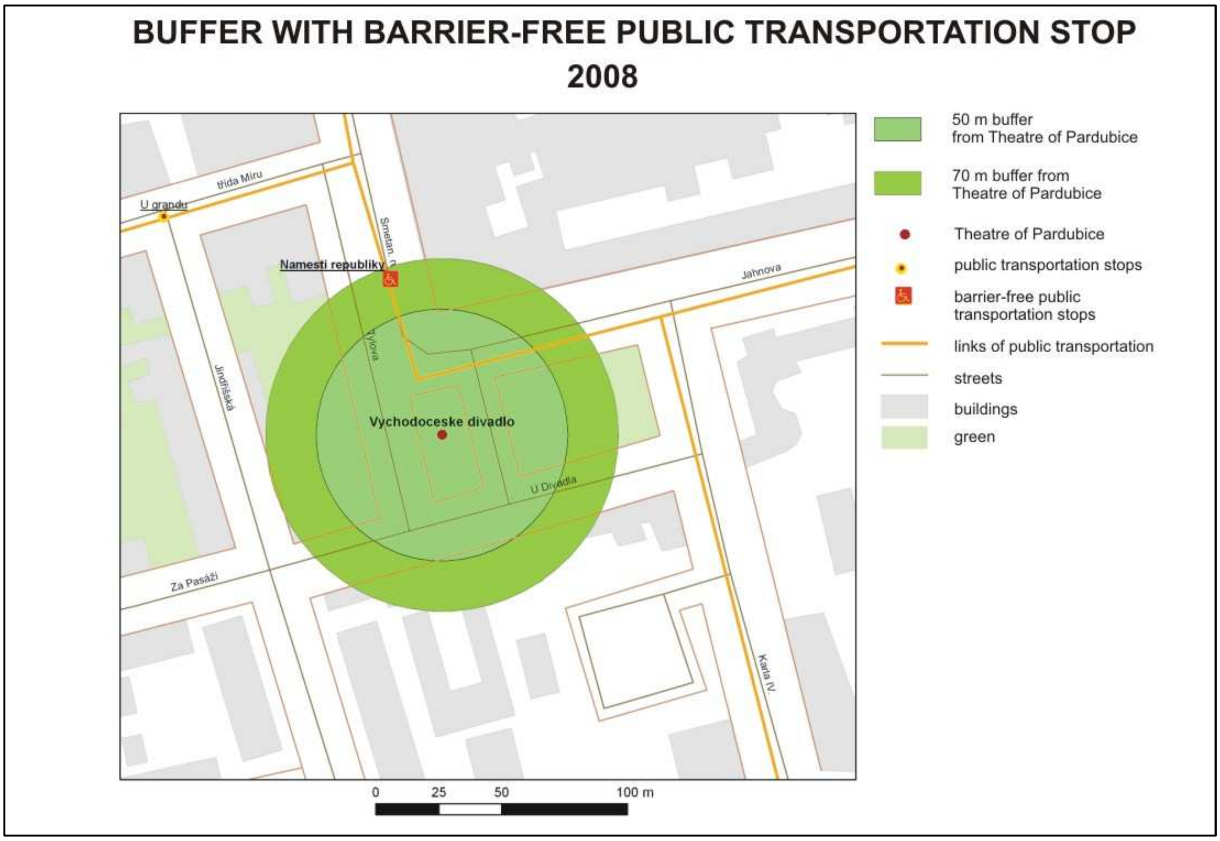

Fig. 3 – 70 m buffer from the East Bohemian Theatre with barrier-free public transportation stop (source: authors, based on [13])

3.3.2 Proximity analyses and spatial overlays

Proximity analyses are based on measuring distance between features. Measuring can be based on several metrics, Euclidean and Manhattan belong to the most well-known of them. These analyses can be combined with database queries.

The case study: to get an overview, buffer can be used to identify the barrier-free public transportation stops and parking places within a given distance from the POI. At first, buffer polygon was created to 50 m from the POI but no stop was situated inside the polygon. Then, the distance of 70 m was used to create buffer zone. One bus stop is located within this buffer (Fig. 3) but for the opposite direction there is still no stop available – distance of this stop is 190 m.

Bank services are today very important to all people. So, the next analysis was focused on identification of barrier-free banks (for the results see Fig. 1). Then, barrier-free ATM machines were identified (7 in the city). As the last step ATM machines which are at most 120 m far from barrier-free public transportation stop were identified. In total, only 4 ATM machines are close to the stop.

An example of combination of a database query with a proximity analysis and topological overlay is identifying number of barrier-free stops in each part of the city – for the results see Table 2 and Figure 2. Pardubice I is the historical part of the city and its surrounding. Parts Pardubice IV – VII partly contain formerly independent villages, part Pardubice VIII is another formerly independent village.

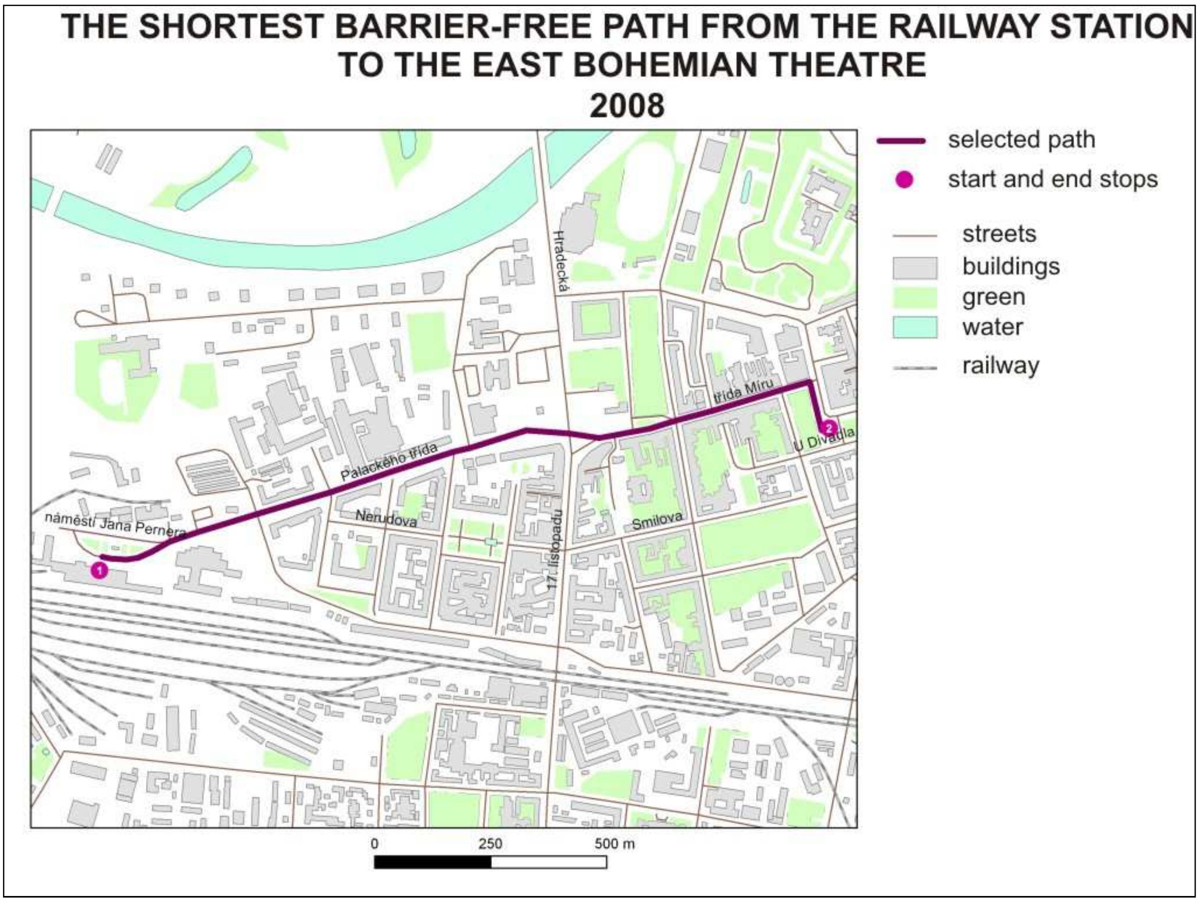

Fig. 4 – An optimum path from the railway station to the East Bohemian Theatre (source: authors, based on [13])

Table 2 – Barrier-free public transportation stops in each part of the city (source: authors; partly based on [3])

Part of the city	Area [km^2]	No. of stops
Pardubice I	5.72	5
Pardubice II	4.58	5
Pardubice III	6.52	4
Pardubice IV	17.58	6
Pardubice V	7.85	7
Pardubice VI	23.75	0
Pardubice VII	11.68	4
Pardubice VIII	4.95	0

More complex analysis can show if it is possible to use several services close to each other and at the same time if it is possible to reach them by public transportation. Required services were: health centre, restaurant and bank within reasonable distance from each other. At first, all facilities providing barrier-free access were selected by an attribute query. Then, buffers at 50, 100 and 200 m respectively were created. After overlaying all buffers it was figured out that maximum distance of all objects is 400 m and distance of the stop is at maximum 100 m from all other objects.

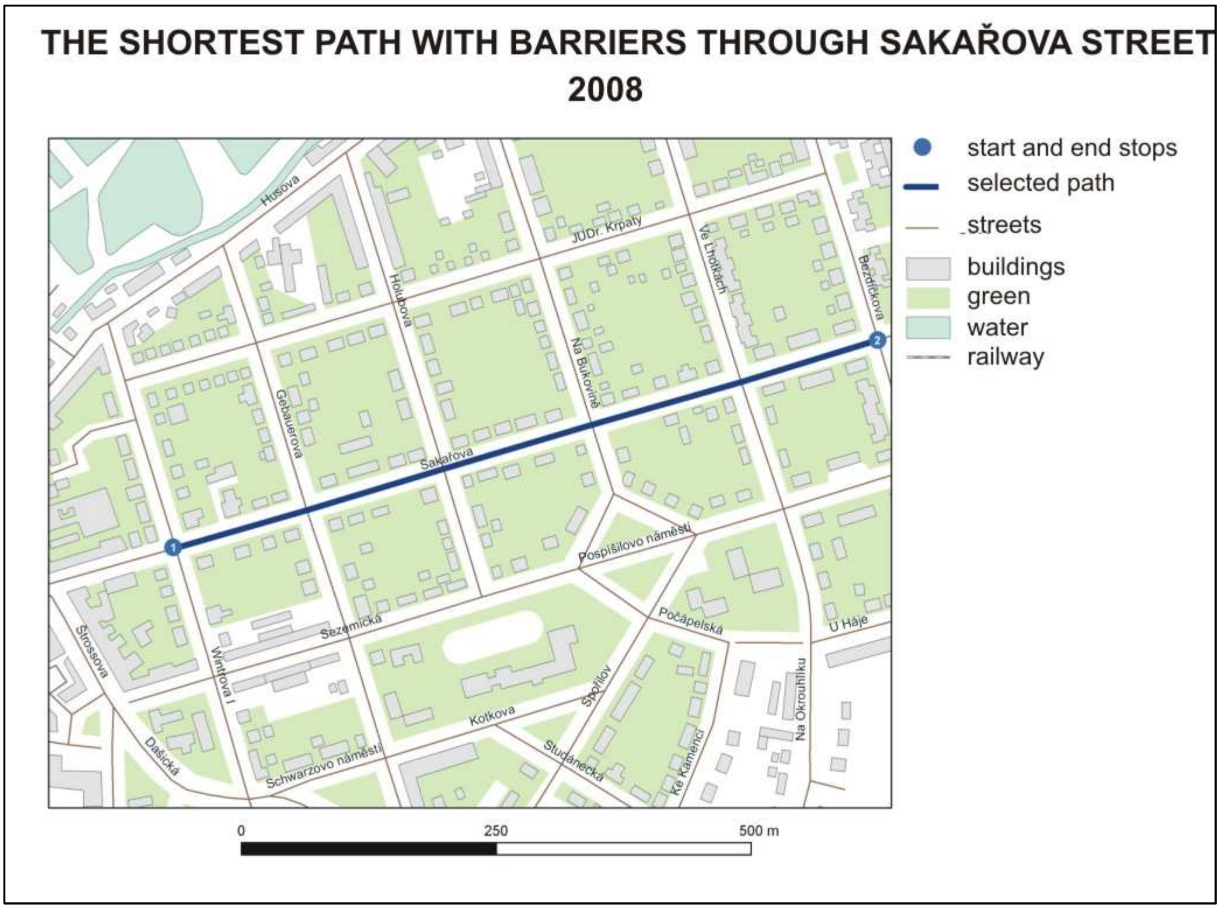

Fig. 5 – The shortest path with barriers through Sakařova street. (source: authors, based on [13])

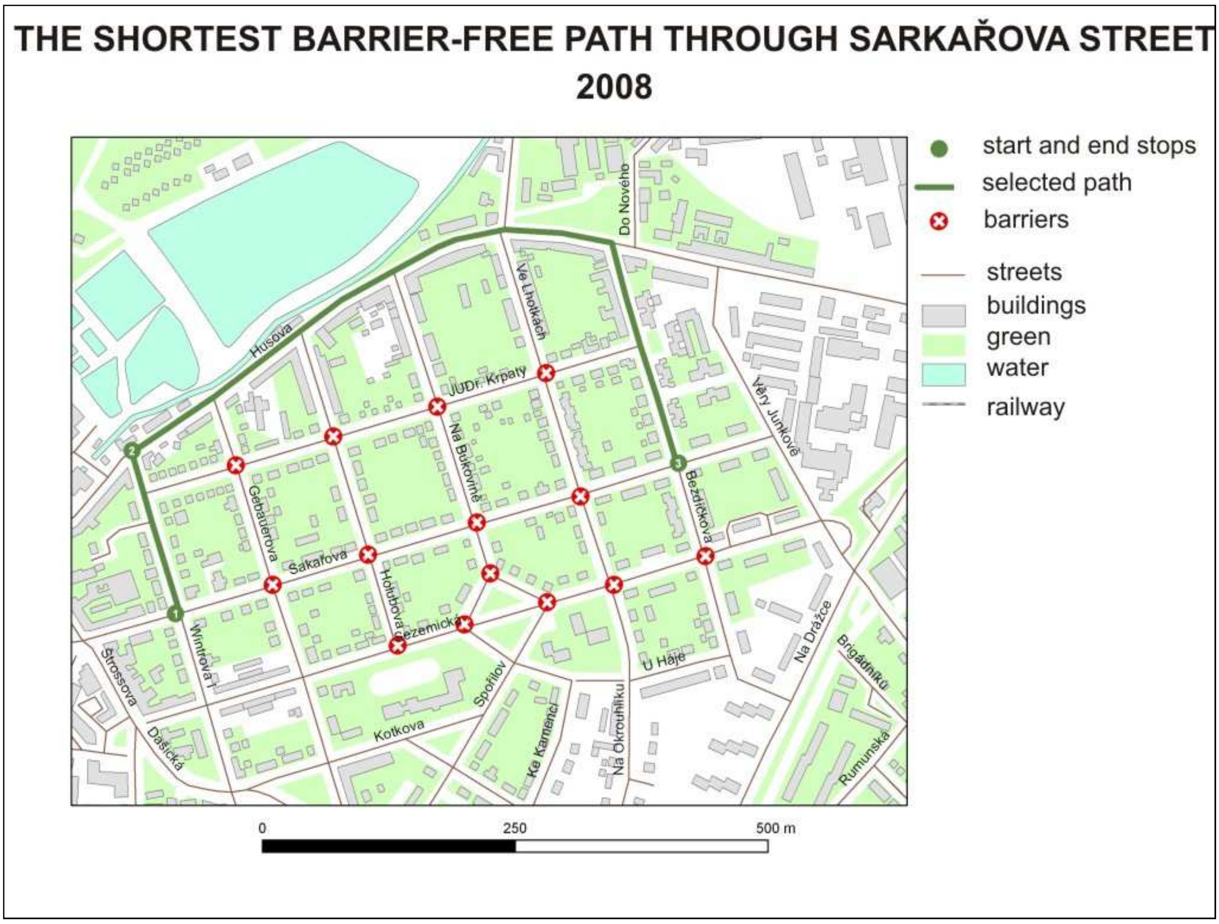

Fig. 6 – The shortest barriers-free path through Sakařova street. The shortest path through the street is 708 m long but the barrier-free path is 1292 m long. (source: authors, based on [13])

3.3.3 Network analyses

Network analyses need vector data with correct topological information. They can solve path optimization tasks and location-allocation tasks.

The case study: to get an overview, buffer can be used to identify the barrier-free bus stops and parking places within a given distance from the POI. There is one important disadvantage of buffer – only straight distance is measured although connecting pavements or streets needn't to be straight. For this reason, network analysis is more appropriate but in comparison with buffer it requires geometrically correct data with topological information included. Dijkstra's algorithm was used to run network analyses.

The first analysis identifies the shortest path from railway station (it provides barrier-free access) to the East Bohemian Theatre. In this case the shortest path is completely barrier-free (Fig. 4). It is accessible for people with both physical and visual impairment because all crossing are equipped with acoustic signals too. This path uses on of the main streets in the city centre. One part of the path is a street where car traffic is quite limited; the street is mostly used by pedestrians, cyclists and public transportation trolley-buses.

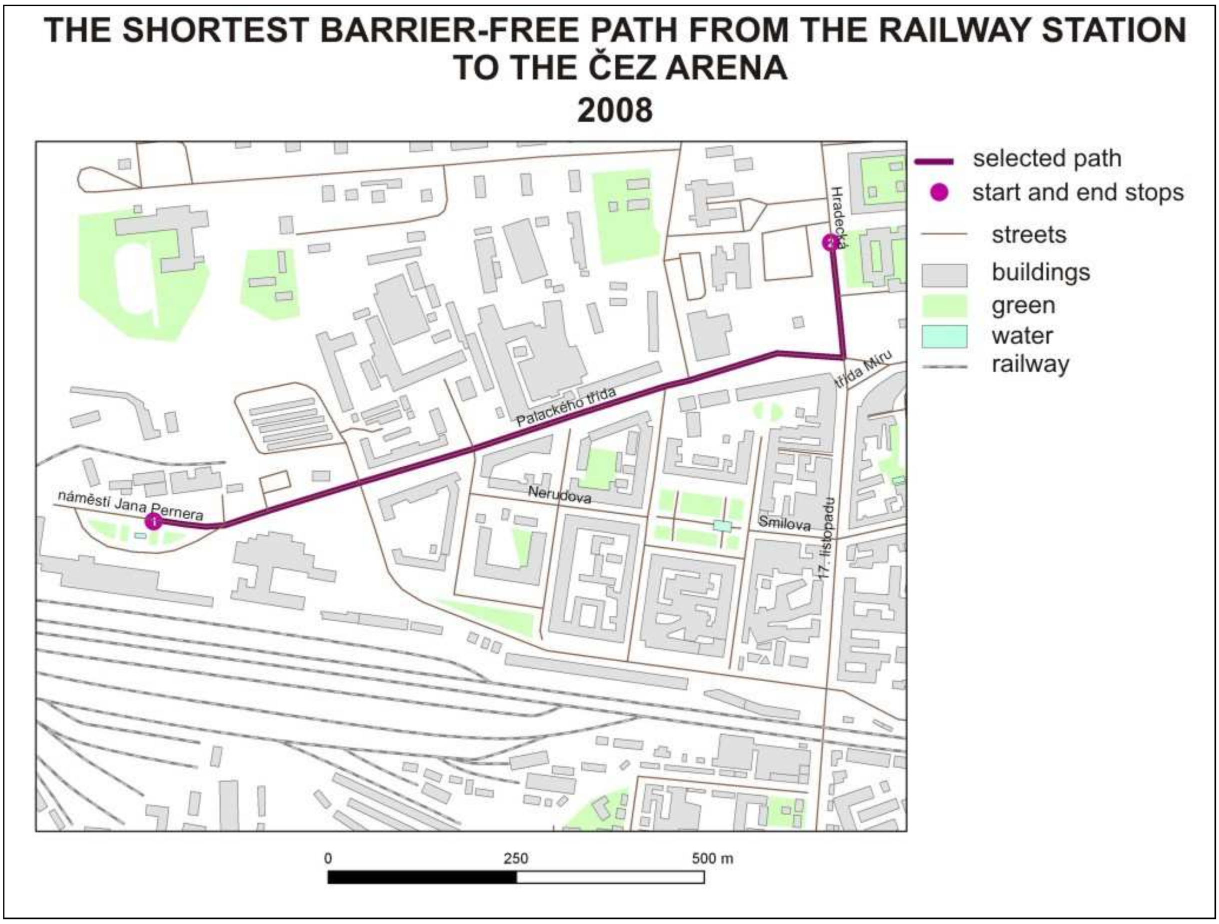

Fig. 7 – An optimum path from the railway station to the ČEZ ARENA (source: authors, based on [13])

For the next analysis, side street to the previous one was selected. The shortest path through the street is 708 m long (Fig. 5) but the barrier-free path is 1292 m long. Result is shown in the Fig. 6.

Kind of Czech national abilympics (Olympics for people with impairment, kind of Paralympics) takes place in Pardubice in indoor sports-stadium ČEZ ARENA. In this case, the barrier-free path from the railway station is again the same as the shortest path. Results are shown in the Fig. 7.

4 Conclusions

As it was stated many times, e.g. [4, 6, 17, 18], the precise and enriched database is required for applications focused on disabled people. Database has to be frequently updated and carefully maintained. For the purpose of this study selected information has to be measured or verified in terrain too.

As it was shown by our case study, spatial analyses provided by GIS software can significantly help to analyse city environment and identify barriers for impaired people. In the paper, a method was proposed and it was used to analyse situation in the city of Pardubice, county city and the 10th biggest city in the Czech Republic. Attention was paid to barriers for physically impaired people. As it was shown, these people are able to move around the city, use some services but their possibilities are still limited.

5 Future Work

For the future, model of terrain and possibly remote sensing data could be included as well to provide some additional information, e.g. slope which can cause many problems to persons using wheel-chair. Remote sensing data represent today a large amount of input data. They can for example provide very fast updating of available data, collecting various attribute information (e.g. road and pavement surfaces) and refine precision of geometric data.

Acknowledgments. The authors would like to thank the Grant Agency of the Czech Republic for funding this research project under the grants No. 205/09/P120 with title “Use of geoinformation technologies for detection of places in town with high risk for handicapped people” and No. 402/09/0219 with title "Usability of software tools for support of decision-making during solving spatially oriented problems".

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