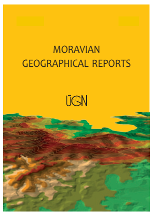

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Comparing two distance measures in the spatial mapping of food deserts: The case of Petržalka, Slovakia

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Abstract

Over the last twenty years or so, researchers' attention to the issue of food deserts has increased in the geographical literature. Accessibility to large-scale retail units is one of the essential and frequently-used indicators leading to the identification and mapping of food deserts. Numerous accessibility measures of various types are available for this purpose. Euclidean distance and street network distance rank among the most frequently-used approaches, although they may lead to slightly different results. The aim of this paper is to compare various approaches to the accessibility to food stores and to assess the differences in the results gained by these methods. Accessibility was measured for residential block centroids, with applications of various accessibility measures in a GIS environment. The results suggest a strong correspondence between Euclidean distance and a little more accurate street network distance approach, applied in the case of the urban environment of Bratislava-Petržalka, Slovakia.

Keywords: *food access, food deserts, distance measures, GIS, Bratislava-Petržalka, Slovakia*

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1. Introduction

Food is a core element of the basic economies and quality of life of individuals (Sadler et al., 2016). The "food environment" has recently become a focus in numerous scientific disciplines (Caspi et al., 2012; Glanz, 2009; Glanz et al., 2016; Charreire et al., 2010; Lytle et al., 2017; McKinnon et al., 2009; Pinard et al., 2016). The concept of a "food environment" can be interpreted in many different ways (McKinnon et al., 2009): in this paper, it is perceived as a retail environment where food retail is operated. Food retail covers both small-scale and large-scale retail units. Not surprisingly, the food environment influences consumer food selection and health outcomes (Gustafson et al., 2013). As noted by Glanz et al. (2009), research on the food environment has revealed that good access to supermarkets may be associated with greater fruit and vegetable consumption, more affordable prices and reduced BMI (Body Mass Index). Methodologies employed to assess the food environment include sales analysis, menu analysis, nutrient analysis and geographic analysis (McKinnon et al., 2009). Between 2007 and 2015, the most frequent methodology used to study the food environment was geographic analysis, utilised in 65% of all the articles (Lytle et al., 2017). Hence, geographical approaches, mostly based on the measurement of accessibility to food stores, still remain one of the most frequent (McKinnon et al., 2009), in spite of the criticism of some researchers (Caspi et al., 2012; Lytle, 2009, Minaker et al., 2013).

In the two last decades, attention has been increasingly paid to food access solutions (Shannon, 2014; Walker et al., 2010). According to Andreyeva et al. (2008, p. 1387): "… access to healthful food is a critical domain of securing high-quality nutrition". Not surprisingly, access to food is increasingly considered as one of the main attributes of life-quality research, as low food accessibility is frequently closely related to phenomena of social inequalities, marginality or transport disadvantages (see, e.g. Hendrickson et al., 2006, or Raja et al., 2008). For geographers, research on the spatial distribution of food sources (and food stores, specifically) is routinely applied, but this approach invites challenges concerning the methodology and data sources leading to proper results and correct interpretations. Similarly, the identification of food deserts is a relatively new phenomenon in geography. Especially in the transitive societies of post-communist Europe, this was not an issue

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until a short time ago. Only a few studies have examined the issue of food access and food deserts in Slovak conditions (see for instance, Křižan et al., 2015).

Measuring access to food sources generates multiple questions: Jaskiewicz et al. (2016) warn that most of the methods used to measure food accessibility have certain limitations. Various approaches bring different results and limitations, and are therefore often not comparable. The development of GIS (Geographic Information System) tools more generally, has brought revolutionary progress in visualisation as well as analytical research methods utilised in food accessibility mapping.

An assessment of the two most frequently used GIS approaches to distance measurement of food accessibility in a post-socialist urban environment is the main aim of this paper. First, Euclidean distance applications are utilised, and then the shortest network distance is evaluated. Specific attention was paid to a comparison of the application of both measures to assess food accessibility in Bratislava-Petržalka. In this paper, the authors compare the results generated by food environment accessibility measurement in Bratislava-Petržalka, which is the largest residential neighbourhood from the communist period in Central Europe, with a specific post-communist urban structure different from the urban environment typical for Canadian or U.S. cities.

2. Food deserts as a subject of geographical research

As a consequence of expert discussions, the term "food deserts" was introduced and used for the very first time in the mid-1990s (Cummins and Macintyre, 1999; Reisig and Hobbiss, 2000; Wrigley, 2002).

The phenomenon known as food deserts is broadly and generally defined, but particular definitions might differ in their context according to the scientific focus of their authors. A food desert can be defined as an "… area, where foods are expensive and relatively unavailable" (Cummins and Macintyre, 2002, p. 2115). As noted by McEntee and Agyeman (2010, p. 165), the literature has agreed on a general definition of food deserts, defining them as "areas of relative exclusion where people experience physical and economic barriers to accessing healthy food". For the purposes of this paper, a food desert is perceived as a territory where (respecting relevant criteria) consumers have no access to large-scale retail units offering cheap and healthy food compared to local small-scale retail units.

Guy and David (2004, p. 223) describe the main attributes of food deserts and their residents as follows:

- the residents may be physically disadvantaged in terms of mobility and accessibility;
- the residents may also be economically disadvantaged due to low incomes;
- such residents will probably have poor nutrition since they eat cheaper foodstuffs of lower quality;
- they will be geographically disadvantaged because of poor choice of food stores in their living environment; and
- local small-scale food-stores supply only limited selection of foods at higher prices compared to large-scale stores.

Scientific literature on food deserts may be classified according to various factors. Settlement-spatial aspect is surely one of them. Based on this, we may distinguish (i) urban and (ii) rural food deserts. The issue of food deserts was initially researched in British cities which explains why most of the relevant literature on urban food deserts covers British urban environments. The issue was generally received in academic periodicals, however, later covering rural environments as well.

Numerous interdisciplinary studies have been published on this issue in the last twenty years (Walker et al., 2010). Essentially, the following three approaches within food deserts research may be distinguished: (i) the medical approach (Budzynska et al., 2013; Glanz et al., 2012); (ii) the spatial approach (Widener et al., 2015; Chen and Clark, 2015); and (iii) the economic-social approach (Hendrickson et al., 2006; Raja et al., 2008). Each particular approach is based on different input data and methods applied to analyse them (black population, obesity, low income, pregnant women, etc.). All approaches are united in measuring the distance, which stems from the elementary definition of food deserts. Authors do differ, however, in their approaches aimed at the identification and mapping of accessibility (Shaw, 2006). As McEntee and Agyeman (2010) indicate, an easily applied universal method for the identification of food deserts has yet to be developed.

With numerous concepts developed on food deserts issues and their criticism, a new concept named 'food oases' has appeared, contributing a somewhat more complex and critical view upon food deserts (Walker et al., 2011). The term 'food oasis' was implicitly described for the first time in the study by Short et al. (2007) depicting the impact of small-scale stores on food safety. Although the text of the study does not define a food oasis as a phenomenon, it is perceived as an antonym to food deserts. Thus, food oases represent a concentration of food stores highly accessible for low-income communities (cf. Walker et al., 2011, 2012).

3. Methods and data

The analysis was carried out in a GIS environment. Geographic information systems were originally developed as a tool to assess and visualise information of a geographical nature. The evolution of regional sciences and related scientific disciplines using GIS as an interdisciplinary analytical instrument has engendered a significant integration of spatial analysis and information systems (see Goodchild, 1987). GIS have been increasingly applied in economics, too (Cliquet, 2006). As Cromley and McLafferty (2002, p. 234) underline: "GIS necessarily emphasise accessibility, the geographical dimension of access." Recent research on food deserts primarily makes use of an approach based on Geographic Information Systems (GIS)-based analysis (Shannon, 2015). GIS-based spatial analysis has become an essential tool for food system research, and the proximity of residences to large supermarkets or supercentres is a commonly-used proxy for access (Mulrooney et al., 2017).

Since healthy and inexpensive foods are usually offered by large-scale retail units (as reported by Andreyeva et al., 2008, or Křižan et al., 2015), the analysis presented here is focused on mapping accessibility to supermarkets. Accessibility may be effectively examined by various accessibility measures (Handy and Niemeier, 1997; Vale et al., 2015). Many recent studies assess accessibility of services via the perceptions of respondents, which allows researchers to become more sensitive to various accessibility aspects perceived by residents (see for instance, Vojnovic et al., 2014). In this paper, the large food-stores accessibility was assessed by the three following accessibility measures (Apparicio et al., 2007; Larsen and Gilliland, 2008; Leete et al., 2012; Sparks et al., 2011):

Acc1: measuring the distance to the nearest supermarket (Zenk et al., 2005):

$$Acc1=(\min|c_{ij}|)$$

where *Acc1* represents accessibility of node *i* quantified by minimum distance between node *i* and supermarket *j*; c_{ij} is the distance from the initial *i* node and target *j* point.

Acc2: measuring the number of supermarkets located within 1 km of a neighbourhood (Smoyer-Tomic et al., 2006):

$$Acc2=\sum_{j\in S} S_j$$

where *Acc2* represents accessibility of node *i* quantified by number of supermarkets *j* accessible within *n* metres or minutes from node *i*; *S* is the total number of supermarkets in the analysed area, S_j represents number of supermarkets within *n* metres.

Acc3: the mean distance to three supermarkets belonging to different companies (Apparicio et al., 2007):

$$Acc3=\sum_{j}\frac{c_{ij}}{n}$$

where *Acc3* is accessibility of node *i* quantified by average distance between node *i* and each of the *n* nearest supermarkets *j*, c_{ij} is the distance between initial node *i* and supermarket *j*, *n* represents the number of the nearest supermarkets *j*.

According to Apparicio et al. (2008), the following four approaches to measuring distance are typically used: Euclidean distance (straight-line distance), Manhattan distance (distance along two sides of a right-angled triangle opposed to the hypotenuse), shortest network distance and shortest network time (Fig. 1). In this paper we compare two of them: a) Euclidean distance and b) shortest network distance.

A selection of appropriate territorial units representing the residential areas was necessary for the application of all the above-mentioned accessibility measures. Our ambition was to respect the specific urban structure of Petržalka, consisting of urban blocks of various sizes and ground shapes. Unlike most modern planned towns, Petržalka's ground plan is far from a grid pattern with square or rectangular shapes. In the territory of Petržalka, 143 residential areas (or residential localities) were identified, each clearly delimited by the street network as a particular block of residential buildings. The accessibilities were measured from the centroids of individual blocks in a GIS environment. Individual residential blocks are of various shapes, areas and population sizes. This was not an issue in this paper, however, as our aim was to examine the application of various accessibility measures rather than any detailed geographical interpretation of food deserts in the study area.

Data on the location of retail units and their attributes come from an extensive field survey supported by a VEGA project (contract No. 1/1143/12). There were 4,089 retail units located in the city in 2011. Their location corresponds well with the population distribution and daily routines of consumers (Križan et al., 2014).

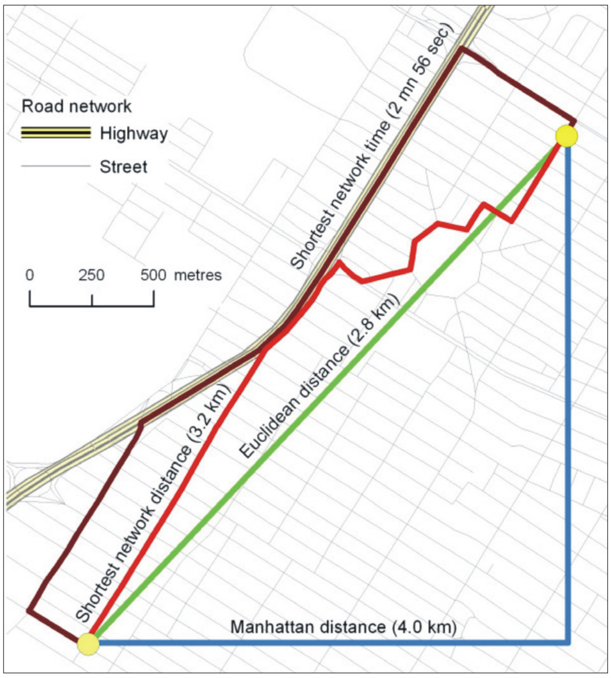

Fig. 1: Types of distance
Source: Apparicio et al. (2008)

4. Study area

Bratislava is the capital city of the Slovak Republic and is located in the southwest of the country (Fig. 2). The city of Bratislava is divided into 17 boroughs, of which Petržalka is the most populated. As of 2011, Petržalka registered 105,842 residents (Statistical Office of the Slovak Republic), which was 25.7% of the total population of the city. With a population density up to 3,700 thousand residents per km^2, the site ranks among the areas with the highest population densities in the country (Buček and Korec, 2013). Petržalka was designed as one of the most ambitious projects of the former communist regime and represents one of the the largest prefabricated housing estate in Central Europe.

In the last 25 years Bratislava has witnessed a considerable transformation, as demonstrated by vast suburbanisation processes unprecedented in Slovakia (Novotný, 2016; Tóth, 2012; Šveda and Podolák, 2014), although this transformation has not been accompanied by proper transformation of the urban transport infrastructure and capacities (Seidenglanz et al., 2016). As in other post-communist cities (see Maryáš et al., 2014), these changes have certainly had huge effects on the urban retail environment (Križan et al., 2014).

The retail sector is one of the most transformed sectors of economic activity (Križan et al., 2016). The formation of Petržalka has had its own specific pattern. According to the 1970s and 1980s planning practices, there was a discrepancy between living spaces and the structures where food stores were supposed to operate. First, these facilities were mainly localised in the middle of residential blocks as small supermarkets, and a long time after that some extra retail facilities without conceptions of planning were opened. Generally, by the beginning of the 1990s, retail capacity was not sufficient to meet the growing demands of the area's inhabitants (Spišiak, 1994).

As noted by Mládek (1994), like other similar urban structures, Petržalka suffered from a general lack of services for its residents. One of the reasons was the fact that the

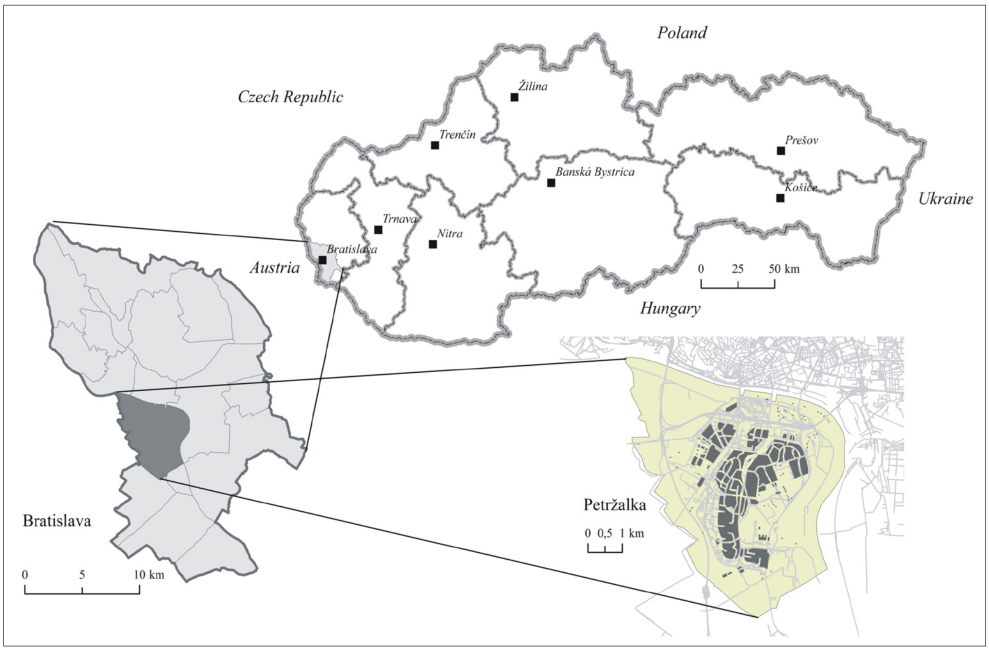

Fig. 2: Study area. Source: authors´elaboration

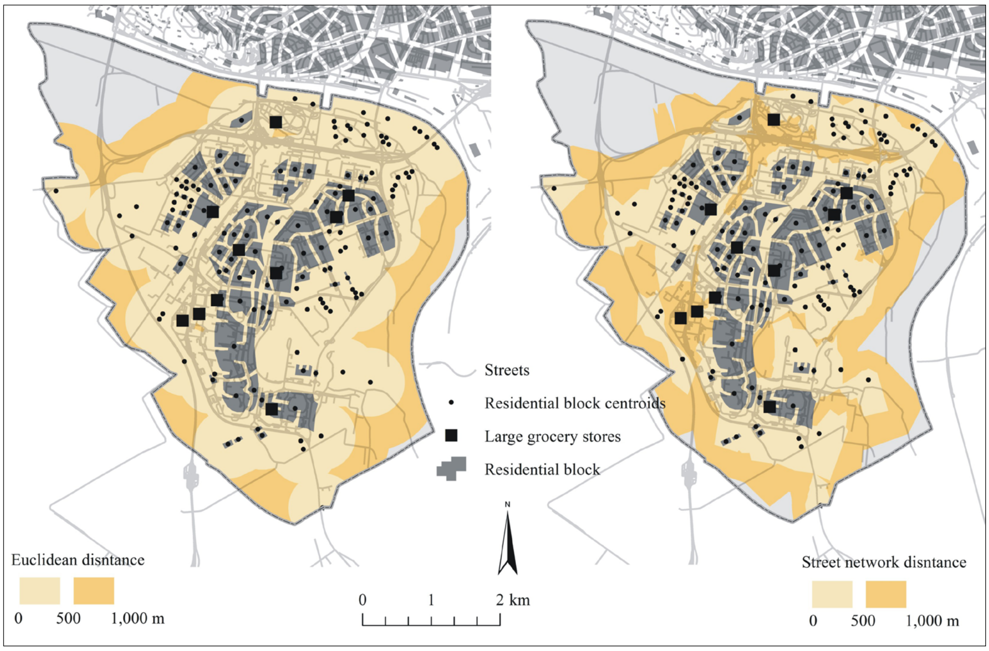

Fig. 3: Accessibility of large grocery stores in Petržalka
Source: authors´elaboration based on field research

location of most of these facilities had been planned for the main urban axis of the neighbourhood, which, however, was never completed. In 1993, there were 207 food stores in Petržalka, representing 50% of all retail capacities with an area reaching over 14 thousand square metres (Spišiak, 1994).

Later, this under-developed food environment witnessed a severe retail atomisation process. By now, the food environment has gradually been concentrated into large-scale retail units. This process is largely followed by consumer behaviour adaptation (Bilková et al., 2016).

Today, over 31% of the overall food store capacity of Bratislava is located in Petržalka (75 stores in total), which seems to be sufficient. Petržalka is home to more than 50% of all retail capacities of the city (28,295 m^2), with several large-scale shopping centres and numerous smaller food stores located there. The study area comprises 18 large-scale stores (hypermarkets, supermarkets) and 58 small-scale stores (Fig. 3). The floor areas of the retail units vary between 10 m^2 and 5,800 m^2 (Križan et al., 2015).

5. Results

Most consumers use passenger cars to reach food stores in Bratislava (Bilková et al., 2016). In Petržalka, nearly 70% of consumers prefer passenger cars or walking. This is one of the arguments for our selection of relevant accessibility measures and types of distances.

When assessing food environment accessibility, one might discuss consumer perceptions and food environment on the one hand (cf. Moore et al., 2008), or consumer satisfaction with food stores accessibility on the other (Bilková et al., 2016). The question is whether consumer perceptions are really linked with accessibility values to various food stores as indicated by various accessibility measures. Though we respect the fact that distance to food outlets is a significant predictor of healthy food perceptions (Barnes et al., 2016), we are not able to simply compare the food stores accessibility measurement results with consumer perceptions, since our data on consumer perceptions do not cover all residential blocks in the study area.

The following part of the paper presents the application of the three above-mentioned accessibility measures to the examination of the accessibility to large-scale retail units in Petržalka. The first case covers the application of Euclidean distance measures, the second one applies the street network distance method. The Euclidean distance approach utilises buffer tools, while the latter method rests on service areas in a network analyst tool. The general picture of the large-scale stores accessibility in Petržalka is shown in Figure 3. Not surprisingly, the Euclidean distance approach brings somewhat less accurate results, finding most of the inhabited area as food oases, generally defined as opposed to food deserts (represented by residential blocks located over 1 km from the nearest large-scale unit: see Križan et al., 2015).

The nearest supermarket accessibility measure (Acc1) is the first of the proposed accessibility measures employed in our study (see Fig. 4). Application of the Euclidean distance approach reveals residential blocks which might be identified as potential food oases, with accessibility below 1 km. More realistic results have been shown by applying the street-

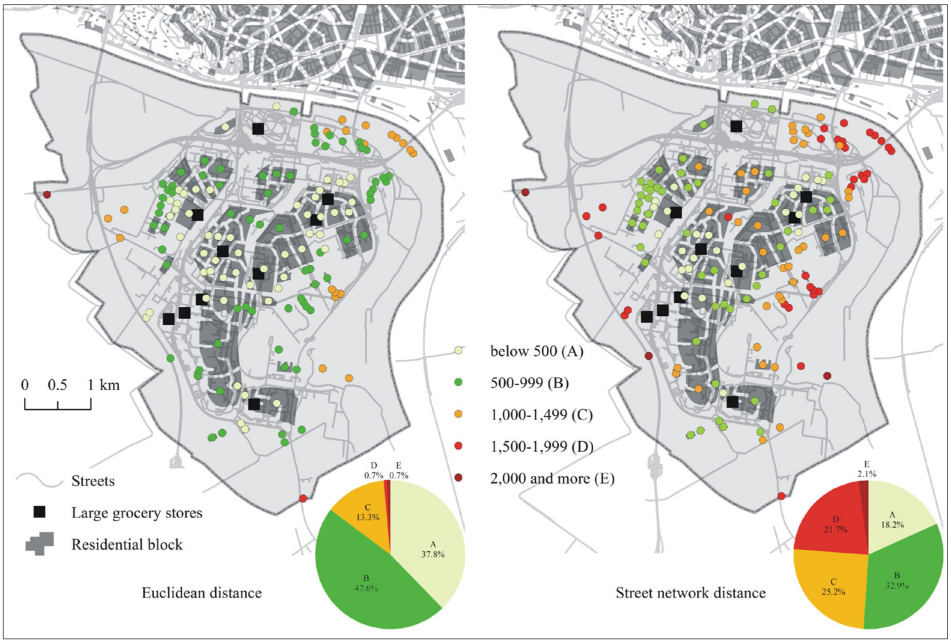

Fig. 4: Accessibility of large grocery stores (metres) accessible within 1 km (Acc1)
Source: authors´ elaboration based on field research

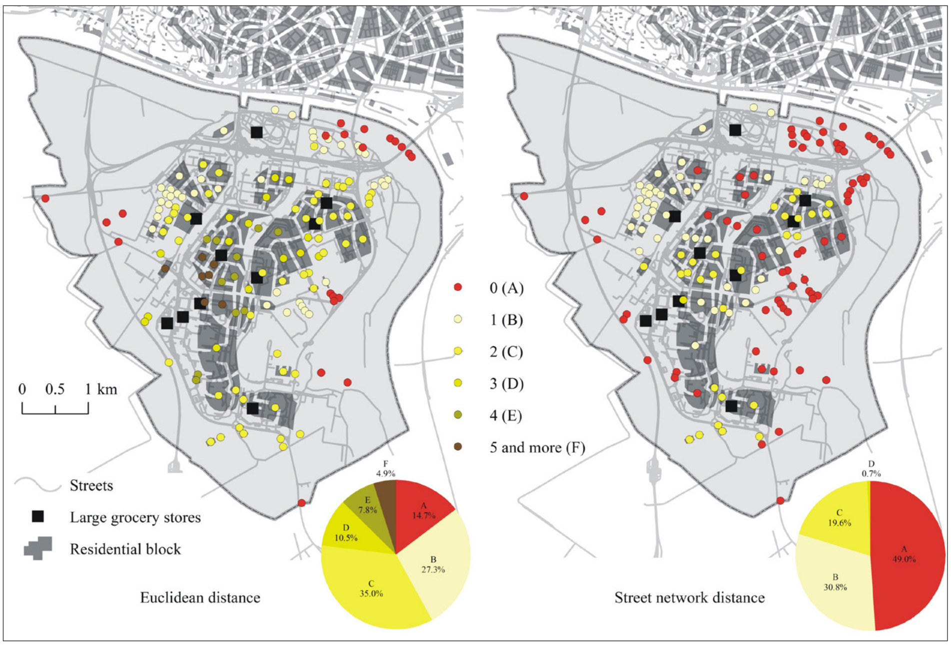

Fig. 5: Number of large grocery stores accessible within 1 km (Acc2)
Source: authors´ elaboration based on field research

network distance approach (similar to the approach used by Sadler et al., 2013). Based on this measure, nearly one-half of the 143 surveyed residential blocks may be considered as potential food deserts. While the first approach reveals potential food deserts only in the marginal areas of Petržalka, the latter detects some areas also in its central part as a consequence of the complicated access road network. The average Euclidean distance to the nearest large-scale retail unit is 667 m, while the average street-network distance is higher at 1,054 m. There is a significant positive relationship between the Euclidean distance and street network distance measures: r = 0.83 ($p < .0001$).

The second accessibility measure (Acc2) applied in this study basically detects the number of large-scale retail units accessible within 1 km distance (Fig. 5).

The Euclidean distance application has shown that no large-scale store is accessible from 14.7% of the residential blocks identified in northern parts of Petržalka and in its peripheral western and eastern neighbourhoods. On the other hand, one fifth of the blocks demonstrate good accessibility (within 1 km) to three or more large stores. The street network distance method, however, shows such accessibility of three large stores only for 1 locality. On average, the Euclidean distance measure results in 1.8 large stores within 1 km distance, while only 0.7 stores have been identified by using the street-network distance approach (see Tab. 1). There is not a significant relationship between the Euclidean distance and street network distance measures in this case: r = 0.47 (Tab. 2).

The third approach applied in this study is based on accessibility of three supermarkets operated by three different companies (Acc3) within various radiuses from the residential blocks. In this case, the variability in distance measurement was most evident (see Fig. 6). For the radius up to 3,000 m, the Euclidean distance method application shows the cumulative share of such blocks reaching 54%, while it is only 20% if the street network distance approach is applied. With the radius up to 5,000 m, the cumulative shares of the residential blocks rise up to 94.4%, and 78%, respectively. The average Euclidean distance to three large stores in Petržalka is 3,006 m, while the average street-

Accessibility measure	A	B
Acc1	.83	.86
Acc2	.47	–
Acc3	.84	.85

Tab: 2: Pearson correlations (A) and Spearman rank correlations (B) between alternative types of distance
Note: All coefficient values are significant at the p < 0.0001 level. Source: authors´ elaboration

Acc	N	Mean (m)	S.D.	Median (m)	Minimum (m)	Maximum (m)
Acc1a*	143	667.4	362.28	604.0	70.5	2,301.9
Acc1b**	143	1,053.6	535.58	990.2	89.4	2,633.8
Acc2a	143	1.8	1.34	2.0	0	6
Acc2b	143	0.72	0.79	1.0	0	3
Acc3a	143	3,005.8	1,067.72	2,876.6	1,113.8	7,685.5
Acc3b	143	4,722.1	1,458.99	4,885.2	1,637.2	9,856.0

Tab. 1: Descriptive statistics of food access measures (Acc)
*Notes: *a refers to Euclidean distance; ** b refers to street-network distance. Source: authors´elaboration*

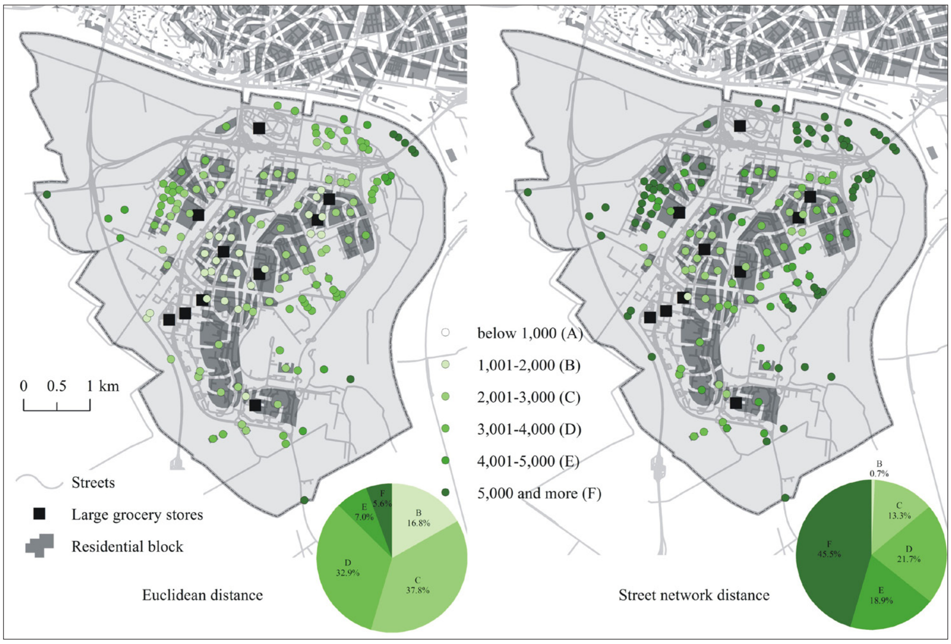

Fig. 6: Accessibility (in metres) of three large grocery stores operated by different companies (Acc3)
Source: authors´elaboration based on field research

network distance is 4,722 m. There is a significant positive relationship between the Euclidean distance and street-network distance measures: r = 0.84 (Tab. 2).

6. Discussion and conclusions

Two approaches to measuring accessibility to supermarkets in an urban environment have been evaluated in this paper, applying methods developed with the use of Geographical Information Systems. When evaluating spatial accessibility, the choice of distance type is likely to generate different results, potentially leading to significant measurement errors.

As noted by Glanz et al. (2016, p. 286), the science and art of measuring retail food store environments has expanded and matured significantly in the past decade, although standardised measures are not used routinely and there is much work to be done. We realise that food accessibility might affect food consumption, but there are many more factors acting in this. Moreover, selection of food store is not always linked with its distance (Ledoux and Vojnovic, 2013). In spite of that, research on accessibility measures concerning the food deserts issue can be considered as highly relevant (cf. Barnes et al., 2016).

This research contributes to a better understanding of accessibility, especially due to the fact that it represents one of the first attempts to investigate quantitatively, food deserts on a town-wide scale in Slovakia. So far, food deserts research has been mainly case-based and often descriptive rather than analytical. More specifically, this research is the first to deliver a comprehensive analysis of the distances that may possibly influence the results perceived by retail chains' marketing experts.

The quality of food access in Petržalka, as a typical post-communist housing estate, is surprisingly comparable with conditions observable in U. S. or Canadian cities (Apparicio et al., 2007; Leete et al., 2012; Sparks et al., 2011; Jaskiewicz et al., 2016). In the case of Euclidean distance measures, the mean distance to a large grocery store is below 1 km, but ranges from 0.07 to 2.3 km (Tab. 1). There are only 1.8 large grocery stores within a 1-km buffer radius around a building centroid, and the mean distance to the nearest three different large grocery stores is 3 km. In the case of street-network distance, the results are less favourable: the mean distance to a large grocery store hardly exceeds 1 km, the number of large grocery stores within a 1-km service area around a building centroid reaches only to 0.7, and the distance to the nearest three different large grocery stores is 4.7 km. Related to this, we should emphasise that the geography of access to retail units is highly dependent on the selection of tools used to measure accessibility, specifically when transit travel costs are regarded (Widener, 2016). Which of the accessibility measures is the most appropriate, then? There is no simple answer, as every argument may be rooted in different research goals. It is one of the reasons why this paper has focussed on a comparison of various accessibility measures.

Despite a significant positive correlation between the Euclidean and street-network distances (cf. Apparicio et al., 2008; Sparks et al., 2011), spatial and empirical perspectives suggest that more realistic results are derived from the shortest network distance method compared to the Euclidean distance approach. Therefore, the shortest network distance application seems to be more appropriate for investigating accessibility to food stores in urban environments.

Retail markets are highly saturated, which emphasises the need for managers to understand the existing competitive structure for putting in place strategies which will allow retail chains to survive (Križan et al., 2014; Sinha, 2000). Of course, this study has some limitations in terms of measuring any results of place marketing and the geographic extension of the research, and this may give direction to possible future research. GIS represents a helpful visualisation and analytical instrument useful for identification and assessment of food accessibility (Charreire et al., 2010; McEntee and Agyeman, 2010; Shannon, 2015). In addition, this type of analysis could provide a useful tool to retailers in terms of their strategies.

The conclusions of this study cover only one of the numerous aspects of food environment research focused on accessibility measures and distance types. Surely, further detailed research on how accessibility affects consumer behaviours is necessary. Apart from distance, the temporal aspects of the food environment and its dynamics are important (Farber et al., 2014; Widener and Shannon, 2014). Recently, more attention has been paid to research on temporal changes in the food environment (Widener et al., 2017).

Further research on the accessibility to food stores and the utility of types of distance measures could also cover the less urbanised post-communist environments (e.g. small towns) of Central Europe, as well as rural environments. Due to the low density of existing over-ground communication networks in rural areas, however, this will probably call for more specific approaches.

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