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THE USE OF CENTROGRAPHIC MEASURES IN ANALYSING THE DISPERSION OF HISTORIC FACTORIES, VILLAS AND PALACES IN ŁÓDŹ (POLAND)

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Abstract
The paper presents a proposal to investigate the distribution of historic villas, palaces and factories listed in the register of historic monuments using centrographic measures. Information about the monuments have been projected onto a map as points, which were analysed using the GIS tools in ArcGIS 10.4.1 software. The study included the following measures: Spatial Mean or the centre of gravity, Spatial Median, Standard Distance, Standard Deviational Ellipse. This allowed a discussion on the validity of using centrographic measures for this type of analysis, and a spatial analysis of the distribution of the city's historic buildings in relation to its spatial layout and the tourist space, in which these monuments serve as one of the main assets.

Key words:
Centrographic measures, historic buildings, tourism space, GIS, Poland

INTRODUCTION

Centrographic measures have been used for two centuries to search for the "centre of area" and "centre of population" (Hayford 1902), as well as to analyse the distribution of points in space. (Lefever 1926, Sviatlovsky and Eells 1937, Yuill 1971). At the turn of the 20th and 21st centuries, owing to the possibilities offered by the Geographic Information Systems (Mitchell 2005), the number of applications of these measures for spatial analysis significantly increased (Fischer et al 1996, Wong 1999). They were used, among others, to analyse changes in the center of gravity of cities and urban population in Poland in the 20th century (Jażdżewska 2006), distribution of accommodation facilities (Nalej 2014), as well as spatial research of cultural heritage (Lechowski 2011, Wang et al 2014, Qiana, Kanga, and Wenga 2016). The centrographic measures will be recommended to spatial analysis of the heritage, for example castle ruins (Matlovičová K and Husárová 2017) or murals (Jażdżewska 2017).

The analysis of distribution has been applied to immovable monuments, such as factories, villas and palaces listed in the municipal register of historic monuments

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of the city of Łódź. In this context villas mean residential buildings, mostly small, with an adjacent garden. On the other hand, palaces are more elegant residential buildings with no defensive features, the residences of rulers, lords or patricians.

The aim of the work was the spatial analysis of monuments using cetrographic methods and an attempt to answer the question whether these measures aptly describe the distribution of the examined monuments, refer to the urban development of the city and the tourism space of Łódź described by Liszewski in 1999.

RESEARCH AREA

The research area is Łódź, the third largest city in Poland, developed in the 19th century, the age of industrialisation. Łódź – known as the Manchester of the East – was dominated by the textile industry. Over a century, it was transformed from a small agricultural town into a city of several hundred thousand inhabitants (Liszewski 1997). There was an influx of entrepreneurs from abroad (Silesia, the Czech Republic, Saxony, France, Germany and other areas of Western Europe), as well as from different areas of the Kingdom of Poland, who built new factories and residential buildings for themselves and their workers. Unlike medieval cities, with their defensive walls, churches, fortresses, etc., these structures are the cultural heritage listed in the register of historic monuments (Liszewski 1992, 2009). Industry came to the city after 1815, with the main axis of development along the meridional Piotrkowska street. The impressive brick factories gave the city a distinctive industrial character (fig. 1). Most of them no longer serve any manufacturing functions, but their appearance reminds the city of its history. Entrepreneurs also constructed magnificent villas, sometimes even palaces for themselves and their families (fig. 2).

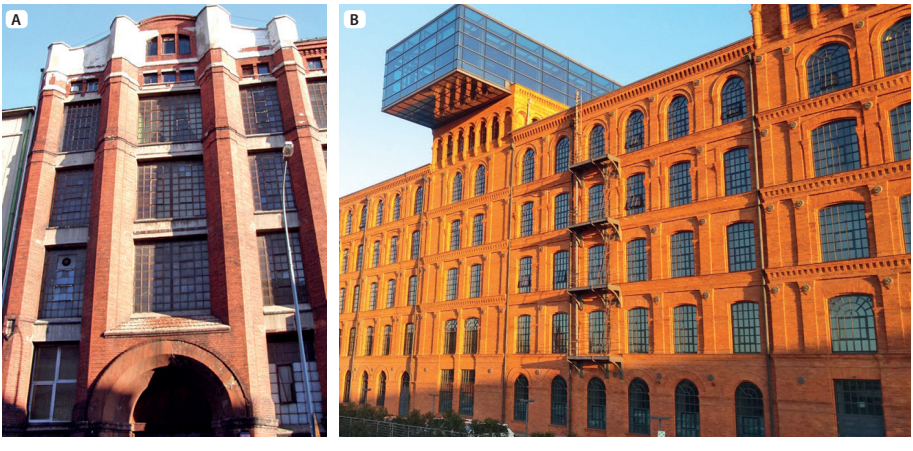

Figure 1
a) Former Adolf Daube factory (currently an office building)
b) Izrael Kalmanowicz Poznański factory (currently the Hotel Andels)

Most of the city's monuments that stand out are associated with the "industrial era" and their arrangement refers to the spatial development of the city.

The term "monument" can be interpreted in many ways. A Polish legal act from 2003 (Journal of Laws no. 16, item 1568) indicates that the term "monument" is understood as *"real estate or movable property, their parts or complexes, being man-made or related to human activity and being a testimony of a bygone era or event, whose preservation is in the public interest due to their considerable historical, artistic or scientific value"*.

Figure 2
The former palace built for the son of Łódź factory owner Izrael Kalmanowicz Poznański (currently the Academy of Music)

DATA SOURCES

Data on historic buildings were obtained from the list of address cards of the municipal register of monuments of the city of Łódź, available in the form of a table with the name of the object and its address (street name and number). The source of data necessary to find objects on the map was the Address Database of the Łódź Voivodship (BAWL), available through the Łódź Voivodeship Geoportal, in the form of a WMS browsing service[1]. Another source of data was field research done in 2016 by a student of geoinformation Roksana Graczyk, during which photographic documentation of the objects was made, followed by the creation of three *shape*-type point layers for the historic factories, villas and palaces. The whole study was developed in ArcGIS 10.4 software, in which the appropriate geodatabase was created.

1 http://geoportal.łódźkie.pl

To interpret the results of analyses, historical maps of the city of Łódź were used, along with vector maps with street networks, the city's boundaries and scientific literature on the subject of tourism space in Łódź (Liszewski 1999)

RESEARCH METHOD

The monuments presented on the map were represented as points in the city space, which is why spatial analysis methods intended for research on discrete objects presented as points were used. The most important information was the geographical coordinates of the points (x, y) and the type of the monument. Centrographic measures selected (Ebdon 1988):

- Spatial Mean or the centre of gravity
- Spatial Median,
- Standard Distance
- Standard Deviational Ellipse.

The ArcGIS software was used, in which these measures were defined as follows (Table 1):

Table 1 Centrographic measures description

Tool	Description
Central Feature	Identifies the most centrally located feature in a point, line, or polygon feature class. Accumulated distances are measured using Euclidean or Manhattan Distance
Mean Centre	Identifies the geographic centre (or the centre of concentration) for a set of features.
Median Centre	Identifies the location that minimizes overall Euclidean distance to the features in a dataset.
Standard Distance (SD)	Measures the degree to which features are concentrated or dispersed around the geometric mean centre.
Directional Distribution	Creates standard deviational ellipses to summarize the spatial characteristics of geographic features: central tendency, dispersion, and directional trends.

Source: Mitchell (2005)

RESULTS

Centrographic measures can be presented in numerical form in a table (table. 2 and 3) and in spatial form on a map (Fig. 3-10). Owing to this, it is possible to analyse individual types of monuments and to compare the dispersion of each of them.

The distribution of factory buildings in Łódź was analysed first (Fig. 3,4). They appeared as one of the first buildings in industrial Łódź. Three presentation points

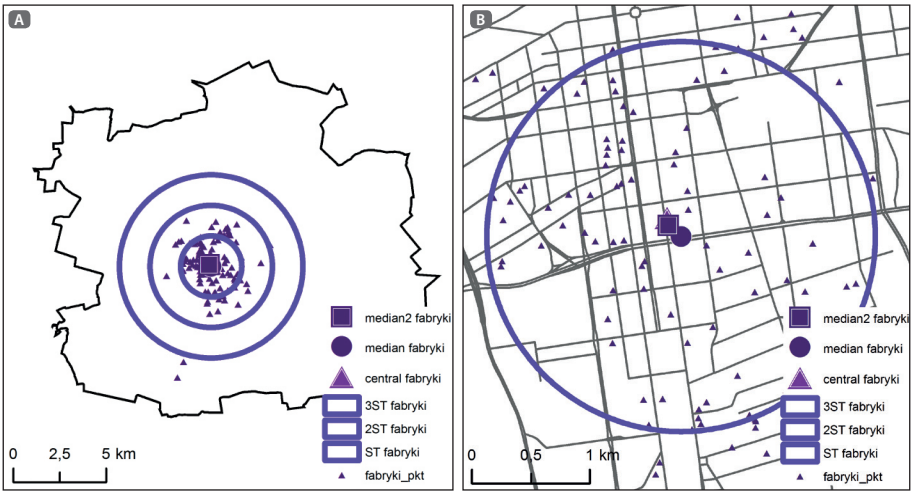

Figure 3
a) Spatial Central Tendency and Dispersion
b) Historical factories in Łódź

(Central Feature, Mean Centre, MedianCentre) are located very close to each other (maximum distances are only 130 m) which can be seen as a testament to the even distribution of points around these measures. The circle with a radius of 1647 m representing one standard deviation (SD) of the distance from *the geometric mean centre* contains 68.8% of objects, the other 2SD has a radius of 3294 m and contains 98.2%, and the third 3SD with a radius of 4941 m – 98.8%. Four factory facilities, which were located at a distance further than 3SD, lie in the area of Ruda Pabianicka. It is a unit that was incorporated into the city in 1939, and previously functioned as an independent town.

The standard deviational ellipse is extended longitudinally, which is probably due to the existence of historic monuments located in Ruda Pabianicka on the list. They cause the ellipse to have the longer axis at an angle of 175° (Figure 4).

Villas built by Łódź townspeople and factory owners were created as the industry developed and the owners grew rich. Many of them were built in the vicinity of factory buildings, which is confirmed by measures of dispersion of points.

The three points presenting the average measures are located very close to each other which can testify to the even dispersion of points around these measures (Fig. 5). The circle (r = 3243m) representing one standard deviation of the distance from *the geometric mean centre* is much bigger than the one for historic factories, which contains 79% of objects, while the next 2SD contains 90%, and the third 3SD 99.6%.

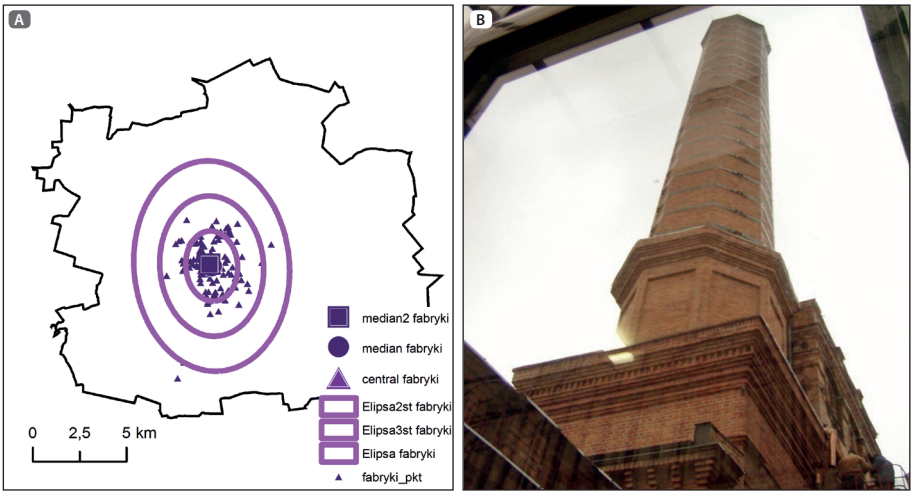

Figure 4
a) Distribution of historical factories in Łódź
b) Element of the Ludwik Geyer factory (now the Central Museum of Textiles in Łódź)

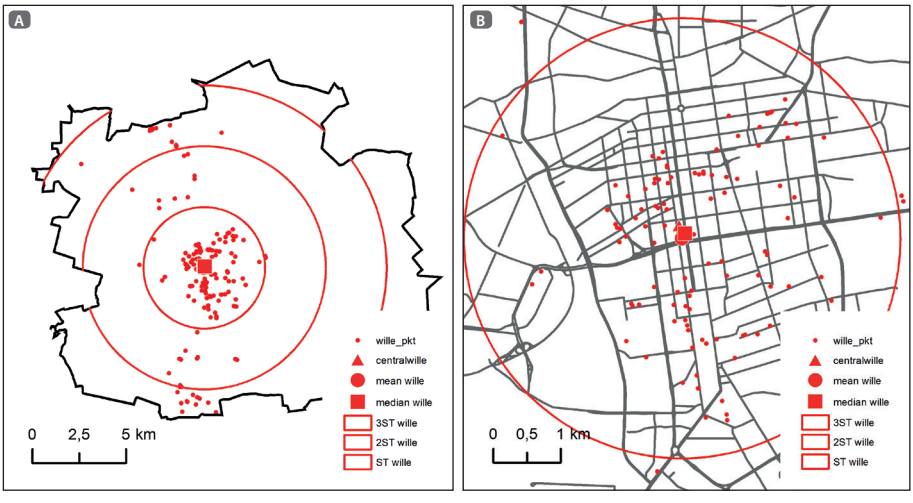

Figure 5
a) Spatial Central Tendency and Dispersion
b) Historical villas in Łódź

The area of one SD and the standard deviation ellipses are located within the city limits, but the subsequent ones go beyond these limits (Fig. 5. 6), which confirms the large dispersion of historic villas in Łódź. The ellipse is sloped at an angle similar to that representing historic factories (Table 3).

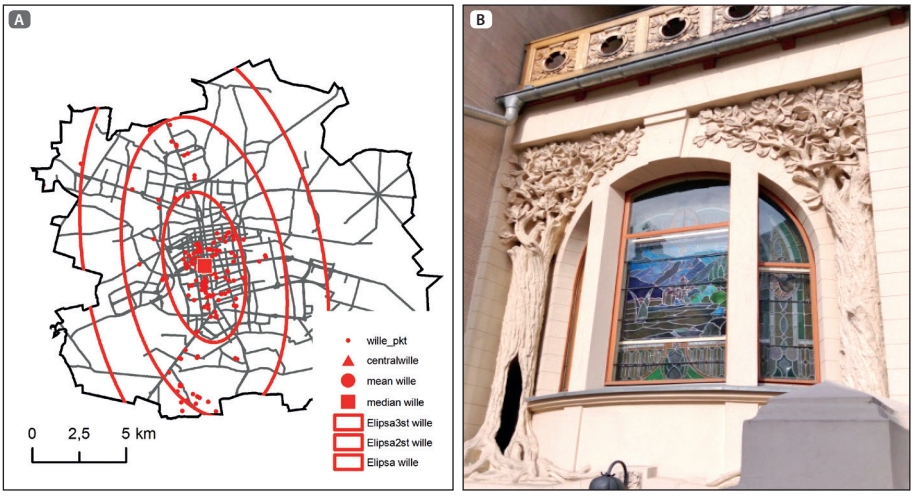

Figure 6
a) Distribution of historical villas in Łódź
b) Villa of Leopold Kindermann and his wife Laura Eliza Feder (now Municipal Art Gallery)

The palaces of factory owners in Łódź lie mainly in the city centre (Fig. 7), 91% of them are within the range of a circle with a radius of 2527 m representing one SD. Points representing their averages (Central Feature, Mean Centre, Median Centre) are located along Piotrkowska Street, (distances between them are approx. 350 m), which may mean the uneven distribution of points around these measures (Fig. 7).

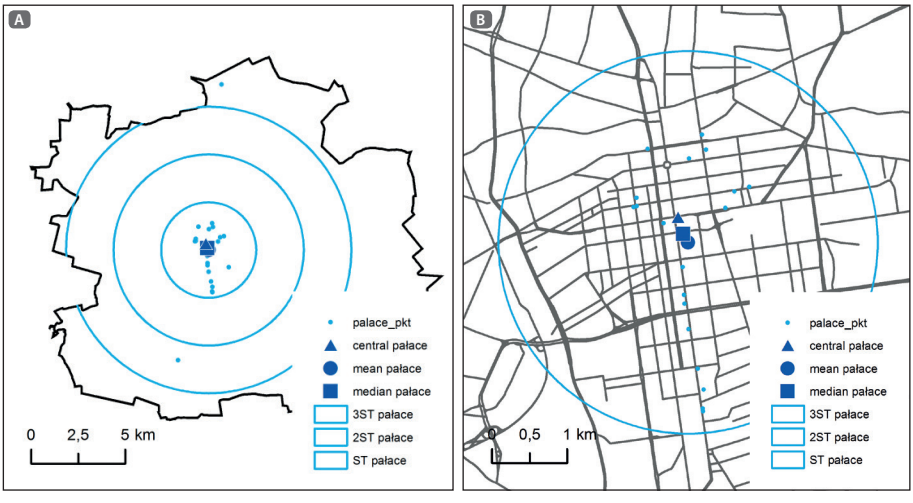

Figure 7
a) Spatial Central Tendency
b) Dispersion historical palaces in Łódź

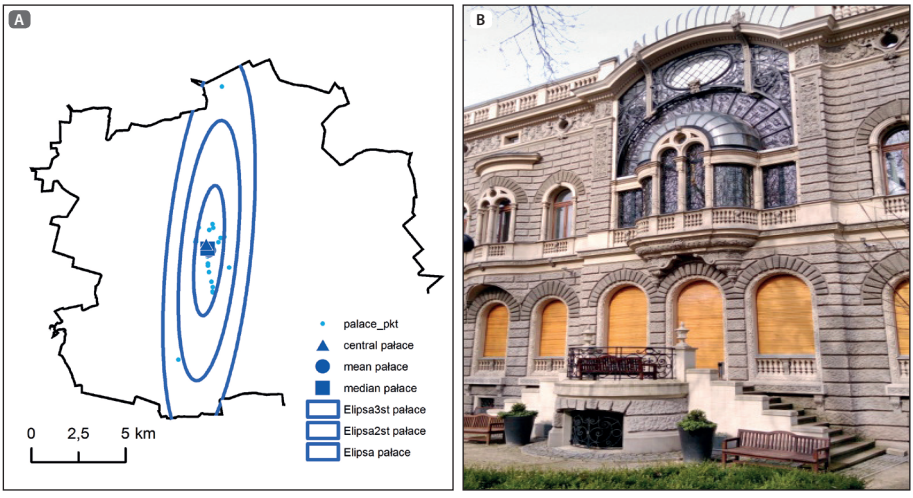

Figure 8
a) Distribution of historical palaces in Łódź
b) A fragment of the former palace of Karol Poznański (currently the Academy of Music)

Standard deviational ellipses is much narrower than the previous one and heavily stretched meridionally (Fig. 8). This is due to the existence of two historic palaces at the northern and southern edges of the city (previously outside of the city's administrative borders) in the dataset. Their location causes the shape of the ellipse to be so elongated.

Table 2 Standard distance and distribution indices for figures 3-8

Objects	Standard Distance [m]			Ellipse Area [km ^{2}]		
	1 SD	2 SD	3 SD	1 SD	2 SD	3 SD
factories	1647.1	3294.3	4941.4	8.14	32.57	73.29
villas	3243.0	6485.9	9728.9	27.15	108.61	244.38
palaces	2526.6	5053.2	7579.9	8.18	32.71	73.61
palaces corrected	1240.0	2480.1	3720.1	3.28	13.13	29.5

Source: author's work

Calculated values of centrographic measures for Łódź monuments are included in Tables 2 and 3. The most compact group of monuments in Łódź are the factories, as evidenced by the value of the standard deviation of 1647 m and the area of the standard deviational ellipses of 8 km^2. The second group of monuments with similar dispersion are palaces, with a higher standard deviation value of 2526 m and a similar area of the ellipse 8 km^2. The most dispersed were historic villas, with

the standard deviation value of 3243 m and the area of the standard deviational ellipse of 27 km^2. Indicators representing 2SD and 3SD confirm these observations, and it can additionally be pointed out that in relation to the city's area (293.2 km^2), the area of the ellipse for historic buildings occupies over 80% of the city's area.

This is due to the fact that some of the villas were built as "second homes" in a forested suburban area. In the 19th and early 20th centuries, Łódź had very polluted air, as most factories and residential buildings used coal for production and heating, so wealthier residents moved temporarily to these villas.

Table 3 Ellipse Indices for figures: 4, 6, 8, 9.

Objects	Axis length [m]			Angle of Rotation	Share of objects in the ellipse	
	longer	shorter	ratio		1 SD	2SD
factories	1874.61	1382.75	1.36	175,4°	66,1%	98,2%
villas	4062.91	2127.50	1.91	169,8°	74.5%	96.3%
palaces	3494.60	745.25	4.69	5.7°	73.9%	91.3%
palaces corrected	1632.8	639.9	2.55	174.4°	38.0%	100.0%

Source: author's work

It is also worth noting that all ellipses have an elongated meridional axis, but the proportions between the length of the longer and the shorter axes differ (Table 3). The ratio of lengths indicates whether the dispersion is even, if the lengths of both axes are similar, their ratio is close to 1. Such situation occurs in the case of historic factories (1.36), while the opposite is true for the ellipse representing palaces (4.69).

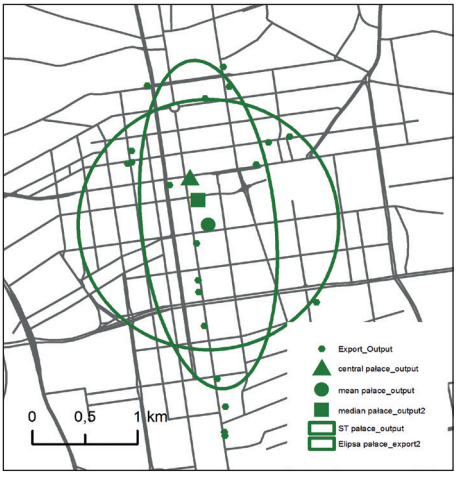

Figure 9
Spatial Central Tendency and Dispersion historic palaces in Łódź (corrected)

It can be discussed whether it would not be sensible to exclude "outlier" objects from the collection of historic palaces, as they have a large influence on average measures, in particular the two palaces that cause such a strong extension of the ellipse. Removing them causes the statistic values to change significantly (Tab. 1. 2.). The value of the standard deviation is only 1240 m, the surface of the ellipse is 3.28 km^2 (the smallest

of all), and the ratio of the axis lengths is 2.55 (Fig. 9). It should be noted that it better reflects the dispersion of these historic palaces in the city space, in the context of the distribution of tourist assets.

CONCLUSIONS

The calculated statistics, and in particular the layout of the standard deviation ellipse is similar to that in the studies by Lechowski (2011) and Nalej (2014), which shows the specificity of the city where the development axis was not a market as in medieval towns, but Piotrkowska Street. They also allow to confirm the thesis that the city was characteristic for the construction of residential buildings of factory owners close to their factories. They are within the limits of the perimeter railway (Fig. 10), which limits the city from three sides and has hampered its spatial development for a long time (Liszewski 1997).

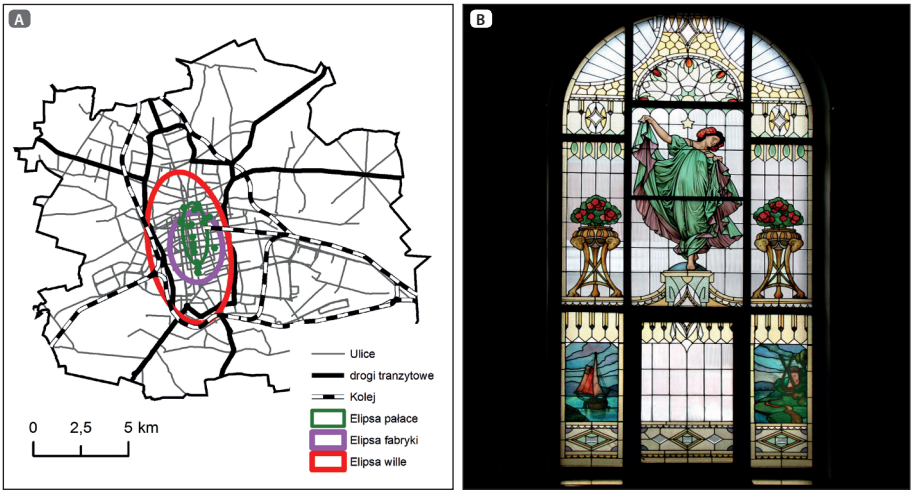

Figure 10
a) Distribution of historical factories, villas, palaces in Łódź
b) Stained glass "Flora" in palace of Maksymilian Goldfeder

The ellipses representing historic factories and palaces of Łódź manufacturers include the area of tourist assimilation designated for Łódź by S. Liszewski in 1999, which may confirm the validity of their use for the study of historic buildings, which are also tourist attractions.

The centrographic measures applied correctly describe the dispertion of points (historic objects) in the city space and give an opportunity for correct interpretation. We should, however, consider the cases when "outliers" are included in the set of points. These measures use the arithmetic mean, which is very sensitive to

such values. Therefore, it is recommended to check the set and possibly exclude the "outliers" from calculations and in-depth analyses.

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