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DEGREE AND FEATURES OF URBAN SPRAWL IN SELECTED LARGEST POLISH CITIES

STOPIEŃ I CECHY ZJAWISKA *URBAN SPRAWL* W WYBRANYCH NAJWIĘKSZYCH POLSKICH MIASTACH

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Abstract: The aim of the article was to evaluate urban sprawl in Kraków, Wrocław and Łódź using a method based on publicly obtainable statistical data. The modified method of evaluation proposed by G. Galster et al. was used, which characterized urban sprawl by such land use indicators as: density, continuity, concentration, clustering, centrality, as well as mixed uses. The data for the calculation of these indicators came from The Local Data Bank of the Central Statistical Office of Poland and Google Earth. The results of the analysis indicated that the greatest degree of sprawl is observed in the urban area of Łódź, and each of the three cities studied has a different profile of sprawl.

Keywords: urban sprawl, density, continuity, concentration, clustering, centrality, mixed uses.

Streszczenie: Celem artykułu jest ocena *urban sprawl* w Krakowie, Wrocławiu i Łodzi z zastosowaniem metody bazującej na danych statystycznych powszechnie dostępnych. Wykorzystano zmodyfikowaną metodę zaproponowaną przez G. Galstera i in., która charakteryzuje zjawisko przez pryzmat wskaźników dotyczących form zagospodarowania terenu, tj.: gęstości, ciągłości, skupienia, grupowania, centralizacji, zróżnicowania użytkowania. Dane do obliczenia wskaźników pochodzą z BDL-GUS i Google Earth. Wyniki analiz wskazały, że największy stopień *urban sprawl* obserwuje się obszarze miejskim Łodzi, a każde z trzech analizowanych miast cechuje się innym profilem sprawlu.

Słowa kluczowe: *urban sprawl*, gęstość, ciągłość, skupienie, grupowanie, centralizacja, zróżnicowanie użytkowania.

1. Introduction

The phenomenon of urban sprawl is associated primarily with a sparse form of housing, both on the outskirts of cities and suburbs. For many years this phenomenon

has been considered as a negative one, due to the macroecomic as well as microecomic costs it generates, e.g.: increase in public expenditure on the construction and maintenance of infrastructure and public services; commercially negative impact on the city center; increase in consumption of energy and fuel; inefficiencies of negative impact on household budgets [Mumford 1961; McHarg 1969; RERC 1974; Jackson 1985; Downs 1994; Bank of America 1995; Fulton et al. 2002]. The difficulty of urban sprawl is recognized in the current Polish government documents, i.e. The National Spatial Development Concept 2030 [MRR 2012], which dedicates to this issue one of its six policy objectives of The National Spatial Development (Goal 6). Meanwhile, research on the sprawl implications of economy is not commonly conducted in Poland, which is furthermore recognized in the Concept [MRR 2012, p. 165], moreover, the diagnosis of sprawl effects in the document is based on the study of foreign research studies – mostly American. On the other hand, there are the conclusions of current studies conducted outside of Poland, which indicate that a large sprawl of the city can be potentially beneficial from an economic point of view [Anas 2012]. The insignificant amount of studies on the effects of sprawl in Poland is caused by the lack of developed methods of measuring this phenomenon. The purpose of this article is to define the practicality of urban sprawl along with its methodical operationalization but also the availability of specific data required.

Thus bearing in mind the need for the development of empirical research on urban sprawl in Poland, the aim of the article is to assess the degree of this phenomenon in urban areas of selected Polish cities: Kraków, Wrocław and Łódź. The intermediate aim is also to create a method of research, which would allow the usage of free and widely available statistical data, which would encourage the development of other studies related to the impact of urban sprawl on economy, but also on society, the environment, etc.

2. Materials and methods

The literature describing the phenomenon of urban sprawl does not encompass a unified definition, but is rather presented through the dominant characteristics that can be applied to a specific area of the city outskirts and suburbs [Bose 2004; Burchell et al. 1998; Daneshopur, Shakibamanesh 2011; Ewing 1997; Ewing, Pendall, Chen 2002; Knapp 2002; Lisowski, Grochowski 2009; Nelson, Duncan 1995; Neuman 2005; Wassmer 2002]. Thus, the phenomenon of urban sprawl is described as a dispersion process of the cities' population to more suburban municipalities. Among the features of urban sprawl the authors mention dispersion of buildings and low density rates. The phenomenon of urban sprawl is also associated with a sparse, chaotic form of housing and the lack of spatial continuity. Very often the lack of building continuity is referred to as a leapfrog effect, which is to illustrate the rise of housing estates within agricultural land thus creating a patchwork.

The measurement of urban sprawl is typically based on the indicators of housing densities and residence [Ewing, Pendall, Chen 2002; Fulton et al. 2002; Galster et al. 2001; Gleaser, Khan 2003; Knaap et al. 2005; Pendal 1999; Sierra Club 1998]. However, the discussion in literature concerning urban sprawl points to additional significant measures which in combination with density may better depict this phenomenon. This suggests the need to take into account a multi-criteria analysis to measure urban sprawl. This approach to sprawl can be found in the work of P.M. Torrens and M. Alberti [2000] who propose an approach based on: density, scatter, esthetic, ecology, and accessibility. The multi-criteria analysis is also suggested by A. Frenkel and M. Ashkenazi [2005] in an attempt to measure sprawl from the perspective of the landscape, using the inventory of land use. According to them sprawl can be measured by: growth rates, density, spatial geometry, accessibility, and esthetic measures. Both approaches to measure sprawl, although appealing, are characterized by high demands in terms of methodological skills and the availability of the required data.

An interesting approach is presented by G. Galster et al. [2001] who indicate the possibility of measuring urban sprawl from the perspective of its eight dimensions that relate to the form of land use. These are: density, continuity, concentration, clustering, centrality, nuclearity, mixed uses, proximity. The method is used to assess the degree of urban sprawl in a given area, but does not serve to a delimitation of the phenomenon. In their work, G. Galster et al. [2001] proposed both a theoretical framework for measuring urban sprawl based on statistical indicators, exemplifying this approach in assessing the degree of urban sprawl in 13 US metropolitan areas. Thus, this method allowed for the presentation of both the overall degree of urban sprawl and differences between the studied cities.

In this article, an approach proposed by G. Galster et al. [2001] is proposed to evaluate sprawl modified to the availability of free data from The Local Data Bank of the Central Statistical Office (LDB) of Poland and Google Earth. Due to methodological requirements the data taken from LDB were collected at the level of villages (units smaller than municipalities). The data encompasses the year 2011, being the most recent data regarding villages. The functions of Google Earth made it possible to acquire data from 2011.

The assessment of urban sprawl refers to housing characterized by the following indicators: density, continuity, concentration, clustering, centrality, as well as mixed uses. The study is conducted in relation to the three cities: Kraków, Wrocław, Łódź. These cities apart from the capital of Poland (Warszawa) are amongst the largest in the country. Due to the nature of the phenomenon of sprawl, the study involved municipalities primarily neighboring the listed cities. The spatial extent of the analysis is presented in Figure 1.

The method used in this paper is associated with the assessment of the degree of urban sprawl to the following indicators: density, continuity, concentration, clustering, centrality, and mixed uses.

Figure 1. Study area

Source: own work.

Density: number of housing units (single-family house, apartment in a multi--family building, etc.) per 1 ha. of developable land. Developable land (DL) is the area that does not have the natural features or development barriers that would prevent housing development. In this study DL is the difference between the total area of a municipality and the sum of the following areas: the land beneath the waters, forests, recreation areas, roads and land transport, ecological usage.

Density measurement is carried out at the municipal level included in the study area. Densities can be represented by the formula:

$$D(i)u = \sum_{m=1}^{M} \frac{[T(i)m]}{Au},$$

where: $T(i)m$ – the total number of housing units in the m-th spatial unit (municipality), Au – DL throughout the study urban area.

Continuity: the degree to which the DL has been developed in an unbroken fashion. Research is conducted in the smallest possible area networks – villages in the presented case. For each village there is determined average density housing in

its DL. A certain village is considered to be developed if the density is greater than 5 housing units per 1 ha. The proportions of all the villages that are this developed are a measure of continuity. Continuity shows a pattern:

$$\mathrm{CONT}(i)u = \sum_{s=1}^{S}[D(i)s > 5\mathrm{housunits} = 1; \mathrm{otherwise} = 0] / S,$$

$$[\min = 0; \max = 1],$$

where: $D(i)s$ – density of housing units in a village, S = number of villages.

Concentration: the degree to which the housing units are disproportionately located on a relatively low area rather than spread throughout the area. The analysis is conducted at the municipal level. For the described calculation of the concentration a so-called delta index is used:

$$\mathrm{DELTA}(i)u = \left(\frac{1}{2}\right)\sum_{m=1}^{M}\left|\left[\frac{T(i)m}{T(i)u}\right] - \left[\frac{Am}{Au}\right]\right|,$$

where: $T(i)u$ – the total number of housing units in the total study urban area u,
Am – the total area of DL in m-th space unit (municipality).

Clustering: degree to which development has been tightly bunched to minimize amount of land in each of the municipality DL. For calculating clustering the following formula is used:

$$\mathrm{CLUS}(i)u = \frac{\left[\sum_{m=1}^{M}\left(\sum_{s=1}^{4}\left[D(i)s - D(i)m\right]^2 / 4\right)^{\frac{1}{2}} / M\right]}{\left[\sum_{m=1}^{M} D(i)m / M\right]},$$

where: $D(i)m$ – the density of housing units in a municipality, M – number of municipalities.

Centrality: the degree to which a building is located in relation to the center of the city core. The measurement is based on the calculation of the average distance of housing villages from the city center. The city center is defined as the address of the City Hall. The center of village councils were assigned by Google Earth. The discussed is presented by the pattern:

$$CBD\mathrm{dist} = \frac{T(i)u\sqrt{A}}{\sum_{s=1}^{S} F(k,s)T(i)s},$$

where: $F(k, s)$ – the distance between the center of the city and villages, $T(i)s$ – the total number of observations i-th of land use (housing units) in land area s (village).

Mixed uses: the degree to which a significant number of two different types of land use (residential and agricultural) operate in the same area of analysis furthermore this pattern is characteristic to the study area. As a unit of analysis, proposed is the surface area of the municipality. The measure is expressed by the formula:

$$MXU(j,i) = \sum_{m=1}^{M} \left(D(i)m \left[\frac{D(j)m}{T(j)u} \right] \right) / D(i)u \,,$$

[min = 0; max = $D(i)m$ observed any area occupied by j],

where: $D(j)m$ – the density of farm units in the municipality, $T(j)u$ – the total number of the j-th observation area use (farms) in the total study area u.

3. Results and discussion

Table 1 shows the raw results of calculations of the six selected dimensions (indicators) of urban sprawl. Each of the indicators is divided into two results: "City & Suburbs" as the index for the city core and the surrounding municipalities; "Suburbs" as the index only for municipalities surrounding the city core.

Table 1. Indicators of urban sprawl

		Average	Standard deviation	Kraków	Wrocław	Łódź
Density	City & Suburbs	4.08	1.90	6.01	2.22	4.02
	Suburbs	0.84	0.40	0.92	0.41	1.20
Continuity	City & Suburbs	0.15	0.09	0.11	0.08	0.25
	Suburbs	0.09	0.10	0.06	0.00	0.20
Concentration	City & Suburbs	0.65	0.03	0.63	0.68	0.63
	Suburbs	0.34	0.23	0.24	0.17	0.59
Clustering	City & Suburbs	0.15	0.06	0.10	0.21	0.12
	Suburbs	–	–	–	–	–
Centrality	City & Suburbs	116.61	28.32	147.84	109.37	92.61
	Suburbs	16.24	2.43	14.69	15.00	19.04
Mixed uses*	City & Suburbs	–	–	–	–	–
	Suburbs	0.00027	0.00029	0.00014	0.00008	0.00060

* Participation of residential in rural areas.

Source: own calculations.

From the data in Table 1 it can be noted that for each dimension of sprawl a *Z* Score has been developed (the ratio of the difference between the indicator value and the average to standard deviation). The lower the value of the *Z* Score, the higher the degree of sprawl. Consequently the 6 *Z* Scores of each city have been summed to provide the Sprawl Composite Index. The calculation results from the *Z* Scores and the Sprawl Composite Index are both presented in Table 2. The urban area (City & Suburbs) with the highest degree of sprawl is Łódź. Interestingly, the sprawl assessment conducted only in the suburbs indicates that municipalities around Łódź are strongly characterized by the smallest sprawl. This means that these suburbs are the most compact amongst the considered in the study, but there is a high degree of sprawl within the city of Łódź itself (outskirts).

The urban area with the lowest degree of sprawl is Kraków. At the same time sprawl in the surrounding municipalities is relatively high – significantly higher than that in municipalities around Łódź. Thus, the high position of the Kraków urban area is due to a high densification of the city itself.

Wrocław's rating indicates a very high degree of sprawl in the municipalities surrounding the city. In contrast, due to the high densification of the city core, Wrocław as the urban area has a moderate degree of urban sprawl.

Table 2. Urban sprawl indicators: *Z* Scores

		Kraków	Wrocław	Łódź
Density	City & Suburbs	1.02	–0.98	–0.03
	Suburbs	0.20	–1.08	0.89
Continuity	City & Suburbs	–0.39	–0.75	1.14
	Suburbs	–0.28	–0.83	1.11
Concentration	City & Suburbs	–0.42	1.14	–0.72
	Suburbs	–0.42	–0.72	1.14
Clustering	City & Suburbs	–0.74	1.14	–0.40
	Suburbs	–	–	–
Centrality	City & Suburbs	1.10	–0.26	–0.85
	Suburbs	–0.64	–0.51	1.15
Mixed uses	City & Suburbs	–	–	–
	Suburbs	–0.47	–0.67	1.15
Composite Index	City & Suburbs	0.57	0.29	–0.86
	Suburbs	–1.61	–3.83	5.44
RANK	City & Suburbs	1	2	3
	Suburbs	2	3	1

Source: own calculations.

It may occur that extreme values of one or two sprawl dimension may affect the assessment of the overall Composite Index. Therefore it has been proposed in the study to carry out the ranking for each dimension of the sprawl followed by sum-

ming them for each of the cities. The lowest value of the sum represents the lowest sprawl, which is the highest position in the ranking. The ranking results are shown in Table 3.

Table 3. Ranking of urban sprawl indicators

		Kraków	Wrocław	Łódź
Density	City & Suburbs	1	3	2
	Suburbs	2	3	1
Continuity	City & Suburbs	2	3	1
	Suburbs	2	3	1
Concentration	City & Suburbs	2	1	3
	Suburbs	2	3	1
Clustering	City & Suburbs	3	1	2
	Suburbs	–	–	–
Centrality	City & Suburbs	1	2	3
	Suburbs	3	2	1
Mixed uses	City & Suburbs	–	–	–
	Suburbs	2	3	1
Total	City & Suburbs	9	10	11
	Suburbs	11	14	5
RANK	City & Suburbs	1	2	3
	Suburbs	2	3	1

Source: own calculations.

The results in Table 3, aside from the overall assessment degree of sprawl also allow observing the special features of urban sprawl as for the interpretation of results for individual dimensions for sprawl (sub-indicators). This detailed measurement should be carried out on the basis of Table 3, in conjunction with the analysis of the results from Tables 1 and 2. Thus, it enables to specify the profile of sprawl in the examined three urban areas (City & Suburbs):

- a characteristic of Kraków's urban sprawl is the deficiency in clustering of housing in settlements. Housing is freely and randomly located in the study area (the lowest assessment of the clustering in the evaluation of *Z* Score and rank). The described housing is however, relatively dense and located in close proximity to the city core (high marks from the *Z* Score and ranked in terms of density and centrality). This high density is a result of high land cost in the mentioned study area;
- the urban sprawl of Wrocław is characterized by a lack of continuity of spatial development, i.e. leapfrog combined with a relatively low density of houses (lowest scores from the *Z* Score and ranked in terms of continuity and densi-

ty). These residences, however, are not very dispersed, but rather grouped (high *Z* Score concentration and clustering);
- the sprawl of Łódź is characterized by two features. The first one is the lack of centralization, which means the housing development is located relatively far from the city core. The second feature is the lack of concentration of housing, which means houses are scattered throughout the area, especially along roads (continuity is high so the dispersion of housing can be sustainable).

4. Conclusions

The dimensions of urban sprawl studies in this article differ conceptually. Each of them relates to a process of land development, which can be observed and quantified on the basis of the widely available and free of charge statistical data in Poland. The method of calculating the indicators is accessible, allowing its use for a broad measure in relationships between urban sprawl and other crucial phenomena based on science or public policy. There is a possibility to study an individual indicator-dimension of sprawl as well as the assessment of the overall phenomenon in the form of the Sprawl Composite Index. Such analysis may therefore be carried out not only by the experts but also individual researchers.

A review of the results of this method with additional related data may determine the economic consequences of urban sprawl or its individual dimensions. From the viewpoint of public policy makers it becomes possible to set up appropriate action on the one hand, and on the other, to evaluate their effectiveness. Since the method shows a couple of dimensions of sprawl, mentioned policies and their evaluation as well as scientific research can be specific and targeted. Sprawl analysis can also be carried out in respect of a smaller segment of the urban area as well as all metropolitan areas in Poland.

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