BADANIA FIZJOGRAFICZNE
R. I – SERIA D – GOSPODARKA PRZESTRZENNA str. 63 – 76

CITY BOUNDARY VERSUS CITY REGION WITHIN THE URBAN SPATIAL STRUCTURE OF WROCLAW

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Abstract: The purpose of the article is an analysis of spatial features of the urban structure within the administrative boundaries of a city and within the limited scope of the urban region. The author uses the comparative method to study different spatial variants of urban structures. The article presents the theory of space syntax as the methodology of analysing and understanding the structure of the urban space.

The article studies the case of the spatial urban structure of the city of Wrocław. The results of the analysis confirm the fact that the administrative borders of Wrocław have a direct impact on the evolution of the spatial features of the urban structure. It can be also observed that the suburban structures also influence the city centre.

The conclusions of the studies may be used as helpful instructions and points of reference for urban planners and urban authorities. They may also contribute to rethinking and reshaping the boundaries of the spatial urban structure of Wrocław, more effective from the point of view of development of cities.

Keywords: Urban Spatial Structure, Spatial Characteristics, Administrative Boundary, Space Syntax Theory, Wroclaw

INTRODUCTION

The Administrative boundary of the city is one of the most deep and complicated issues in urban spatial analysis. An administrative boundary is defined as the limits of responsibility over an area which is composed of a county, city, district or parcel. The attributes of the administrative boundary are all derived from these sub-classes. Administrative boundary classes, such as countries, counties, cities, districts, parcels interact with geographical entities such as roads, railways, waterways and historic elements (Hamilton et al. 2005).

The paper aims to analyze the effects of the administrative boundary on the spatial characteristics of urban structure from two perspectives. The first type of urban structure represents the administrative boundary of the current Municipality of Wroclaw, while the second type of urban structure represents the zone lying within a radius starting from Wroclaw's city center. From the analysis, there are several questions that emerge: will the urban core of Wroclaw occupy the same area regarding the two types of urban spatial structure? Does the urban structure

outside Wroclaw's administrative boundary influence the urban spatial syntax of Wroclaw? Are there sub centers outside the city boundary that are related more spatially and functionally to the urban structure of Wroclaw city center (within the administrative boundary)? These questions can be answered by analyzing, investigating, and understanding the urban spatial structure of Wroclaw from the two perspectives outlined, using the methodology of space syntax.

The paper is structured as follows. Section 2 describes the methodology of space syntax used to calculate the spatial characteristics of the urban structure of the city. Section 3 deals with the urban spatial structure of Wroclaw. Empirical results are presented in section 4. Conclusions are then drawn in the final section.

METHODOLOGY OF RESEARCH

Space syntax is a research program developed by Hillier and Hanson (1984) at the Unit for Architectural Studies, University College London. It is a technique that can be used for morphological analyses of buildings, architecture and urban planning. The aim of this technique is to describe different aspects of the relationships between the morphological structure of human-made environments and social structures or events. It is a tool to give quantitive descriptions of urban space for comparative analysis.

Space syntax depends upon two important principles; open space versus closed space, and large space versus small space. In an urban environment, the open versus closed spaces distinction is generated by the existence of boundaries between the streets and the built-up environment, i.e. open and closed spaces are interdependent as they share a common physical boundary. In the context of a city, urban blocks or plots are considered as closed spaces, while streets and squares as parts of open space (Jiang and Claramunt 1999).

The distinction between large-scale and small-scale spaces is a fundamental assumption for the application of space syntax. From the point of view of spatial perception, a large-scale space is that which is beyond human physical perception, and cannot be perceived from a single vantage point; while a small-scale space is presumably larger than human body, but can be perceived from a single vantage point. In large-scale environments, a human being updates his/her perception of small-scale space whilst moving along in the large-scale space. In other words, perception of a large-scale space is generated from perception of small-scale spaces (Jiang and Klarqvist 2000).

An open space can be shaped by one of the most important concepts of space syntax; axiality. An axial space is a one-dimensional space, represented by an axial line which is drawn between two points and perceived as a directly accessible and visible step (Hillier et al. 1987). The axial map is defined in the spatial

system by drawing the least number of the longest straight axial lines within the entire open space.

Syntactic Characteristics of Urban Structure

Basically, there are two types of syntactic measures in space syntax; firstly the global measures such as mean depth, global integration and global choice, secondly the local measures such as local integration, connectivity and control value.

- *Mean Depth* (Di) : is simply the topological distance to another axial line in the urban system, *dij*. Since axial lines are straight, in practice this corresponds to the number of turns an individual would have to make. It follows that the depth from one directly accessible axial line to another is 1. The total depth is the sum of all topological distances between one axial line and all other axial lines (L) in the urban system, and is defined as:

$$D_i = \sum_{j=1, j \neq i}^{L-1} d_{ij} \tag{1}$$

The mean depth ($\overline{D}i$) indicates how close on average an axial line (L) is to all other axial lines in the urban system and is defined as (Hillier and Hanson 1984):

$$\overline{D}_i = \frac{D_i}{L-1} \tag{2}$$

- *Relative asymmetry*: is defined as the ratio of the difference between the actual mean depth of a line and the minimum mean depth ($Di - 1$) to the difference between the maximum mean depth and the minimum mean depth ($\frac{L}{2} - 1$). Thus:

$$RA_i = \frac{2(\overline{D} - 1)}{L-2} \tag{3}$$

This transformation standardizes the mean depth to a value between zero and one. Figure (1) depicts the construction of RA_i (Hillier and Hanson 1984;Teklenburg et al. 1993).
Thus, the real relative asymmetry (RRA_i) is:

$$RRA_i = \frac{RA_i}{RA^D} \tag{4}$$

where RA^D is the relative asymmetry of the root of the diamond-shaped system.

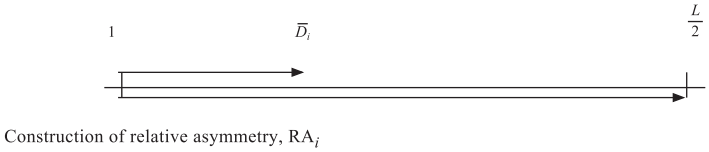


Fig. 1. Construction of Relative Asymmetry
Source: Teklenburg et al. 1993

- *Global Integration*: is defined as the inverse of RRA_i, and is expressed for a space by a value that indicates the degree to which a space is integrated from a system as whole:

$$Integration\ Value = \frac{1}{RRA_i} \tag{5}$$

- *Global Choice:* is defined as the strong choice value of space when many of the shortest paths, connecting all the spaces to all other spaces of the urban system, pass through it. Regardless of its depth, the urban system is represented as a tree of connectivity graph, which has k spaces (axial lines) and *k*–1 links (intersections of axial lines), and will have only one route from one space to any other. Alternative routes will therefore show themselves as rings in the graph. Spaces can be distinguished from each other according to whether or not they lie on rings, how many rings they lie on, and which rings they lie on (Hillier and Hanson 1984).
- *Local Integration*: can be derived from the integration value but it is expressed for a space by a value that indicates the degree to which a space is integrated in a partial system being only a few steps away (Hillier and Hanson 1984).
- *Connectivity*: is defined as the number of axial lines directly linked to each individual axial line in a connectivity graph:

$$C_i = k \tag{6}$$

where *k* is the number of axial lines directly linked (Jiang and Klarqvist 2000).

The connectivity graph is a dual graph from an axial map, and it is derived by representing axial lines and line intersections from an axial map

as nodes and links, respectively, as shown in figure (2) (Jiang and Claramunt 2002).

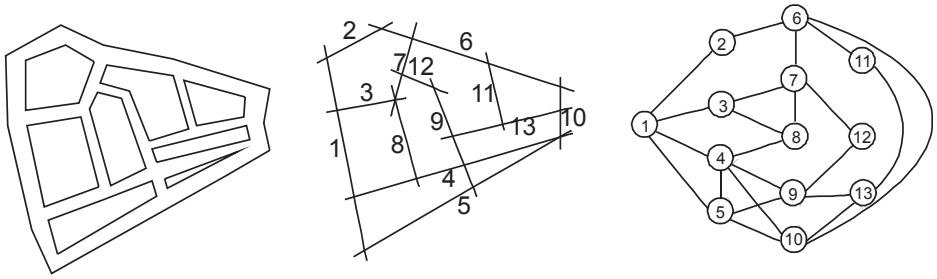


Fig. 2. The Connectivity Graph of Axial Map
Source: Jiang, 2002

- *Control Value*: is defined as a parameter which expresses the degree of choice each axial line represents for axial lines directly linked to it. The control value ($ctrl_i$) of an axial line (i) is given by the sum of the inverse connectivity values of the *jth* directly linked axial lines (k) (Jiang and Klarqvist 2000), as the following equation:

$$ctrl_i = \sum_{j=1}^{k} \frac{1}{c_j} \tag{7}$$

Configuration Characteristics of Urban Structure

The configuration characteristics of urban structure can be defined by the correlations between the global and local measures. These correlations describe the part-whole relationship within the spatial configuration of urban structure. There are two kinds of configuration properties, namely intelligibility and synergy.

- *Intelligibility*: is defined as the degree to which what can be seen and experienced locally in the system allows the large-scale system to be learnt without conscious effort (Hillier 1996). The intelligibility value is calculated by the degree of linear correlation between the connectivity and global integration values (Hillier and Hanson 1994).
- *Synergy*: Synergy, calculated by the degree of linear correlation between local integration and global integration, it is used to lessen the influence of system size (Hillier et al. 1993).

URBAN SPATIAL STRUCTURE OF WROCLAW

Wroclaw is one of the oldest cities in Poland. It is a town with a more colorful and torrid history than most. It emerged in the Lower Silesia region on the River Odra, located at the crossing point of the major old trade routes leading from the south of Europe to the north, towards the Baltic coast, and from the west to the east, towards the Black Sea (http://www.wroclaw.pl/m6852).

Today, Wroclaw is the capital city of Lower Silesia and Poland's fourth largest city, with a population of about 634,000. It lies on the Odra River Valley at the edge of the Sudetes Mountains and encompasses 12 islands connected by 112 bridges (ARAW, 2009). Wroclaw's boundaries are surrounded by 9 local governments (Gmina); Wisznia Mala, Oborniki Slaskie, Miekinia, Katy Wroclawskie, Kobierzyce, Zorawina, Siechnice, Czernica and Dlugoleka, within three counties (Powiat); Trzebinski, Sredzki and Wroclawski. It is the South-Western gateway from Poland to the rest of Europe, and at the same time it is the crossing point of roads that connect Lower Silesia with the whole of Poland. The A4 Berlin – Krakow road connects with Wroclaw at the southern part in Bielany Wroclawskie.

The urban environment of Wroclaw has a direct effect on the urbanization process, irrespective of territorial administrative boundaries, on the level of the area of the city and its surroundings. This urbanization process has been conducted by its own rules and by the principles of economic competitiveness. From another side, the protection of the natural environment of Wroclaw has played a key role in limiting urban development planning across the city both on the level of the urban area and the metropolitan area, too.

Over seventeen years the transformation of the Polish economy from the traditional communist-era type, which was planned and controlled centrally by the state, to a free market economy democratically managed by local authorities, has had a significant impact on the process of urbanization and the agglomeration of Wroclaw. The geo-communications, economic, functional and historical features of Wroclaw reinforced the attractiveness and competitiveness of the city throughout Poland and Europe.

The urban structure of Wroclaw is uneven, both in functional and spatial terms. This is mainly the result of years of backwardness and shortcomings in investment. First, due to the destruction of the urban fabric of buildings during the war, then due to under-investment mainly affecting the spatial organisation of the city, especially in its western parts, as well as errors in the localization of residential development projects.

As a result of this uneven development and the consequent problems within the urban structure of Wroclaw, many opportunities have been created to push through spatial investment decisions affecting the qualities of both the natural and cultural environment of Wroclaw. Under the presence of these complex problems and restrictions, meeting the overriding urgency of the city's needs

hinders the implementation of the environmental policy objectives of the city and its agglomeration (Wojtyszyn 2010). Thus, the substantial urbanization of Wroclaw and its agglomeration takes place in two ways: around the junctions along the main flow in an area with improved transport accessibility and gradually thickening up towards the borders around the city.

SPATIAL ANALYSIS OF WROCLAW URBAN STRUCTURE

The urban structure of Wroclaw has been selected as a case study to analyze and investigate the spatial characteristics of urban structure from two perspectives. The first is the urban structure of Wroclaw within its administrative boundary (inner city structure). The second is the urban structure of Wroclaw within a limited radius . This limited zone has been determined by drawing a circle with a radius of 14km starting from the city center. It includes the urban area within the administrative boundary of Wroclaw and parts of the urban areas of the nine local governments surrounding Wroclaw; Wisznia Mala, Oborniki Slaskie, Miekinia, Katy Wroclawskie, Kobierzyce, Zorawina, Siechnice, Czernica and Dlugoleka, as shown in Fig. 3. This limited urban structure is referred to in this paper as the city region.

Fig. 3. Administrative Boundary of Wroclaw and Local Governments surrounding it

According to space syntax methodology, the urban structure of Wroclaw from both perspectives is represented as axial maps, by drawing a set of axial lines covering the whole open space of the urban structure. In this study blind roads and undeveloped roads are ignored in the axial maps. These axial maps were generated by using the space syntax application; DepthMap. The mathematical values that were calculated by the space syntax model were represented by ArcMap GIS as grayscale maps ranging from dark gray for high values to light gray for low values.

The spatial characteristics of Wroclaw's urban structure from both perspectives will be analyzed by understanding and studying both the syntactic characteristics and the configuration characteristics of the urban structure.

Syntactic Characteristics of Wroclaw Urban Structure in All Conditions

The syntactic characteristics of Wroclaw's urban structure, within the administrative boundary and within the limited radius zone, were calculated by the syntactic measures; global integration, mean depth, global choice, local integration, connectivity and control value. Table 1 shows the averages of syntactic characteristics of Wroclaw's urban structure from both perspectives.

Table 1. Syntactic Characteristics of Wroclaw's Urban Structure from both perspectives

Spatial Characteristics / Urban Structure Case	No. of Axial Lines	Syntactic Characteristics					
		Global Integ.	Mean Depth	Global Choice	Local Integ.	Connecti-vity	Control Value
Within Administrative Boundary of Wroclaw	4868	0.5541	11.9724	0.0042	1.8381	4.5456	0.9999
Within Limited Radius Zone (City Region)	7101	0.4122	16.3871	0.0041	1.6868	4.1076	0.9999
Within Administrative Boundary – Region Values	4892	0.4614	11.9779	0.0046	1.4424	4.5671	1.0012

The global integration of Wroclaw's urban structure within the administrative boundary was higher than global integration within the limited radius zone. While the mean depth in the second analysis was higher than the first because the larger urban structure has higher topological distances. The global choice values in both studies were almost equal. As shown in Figs. 4c and 5c, the

shortest roads that connect the city center with the edges of the urban structure within the global structure, as well as the local structures among them, were the same in both cases.

The local integration and the connectivity of Wroclaw's urban structure within the limited radius zone are lower than in the first case. The local integration was used as a dynamic local parameter to investigate the process of generation of sub centers within the urban structure as a result of urban growth and expansion. The connectivity was defined as a static local parameter to account for all the direct connections each road has to other roads in the urban structure.

In this study, a third condition can be derived as a result of the comparison between the two cases. A third case can be represented by the axial lines within the administrative boundary of Wroclaw's urban structure, but they have values that have been calculated in the second case (limited radius zone). The averages of syntactic characteristics of the third case are shown in Table 1.

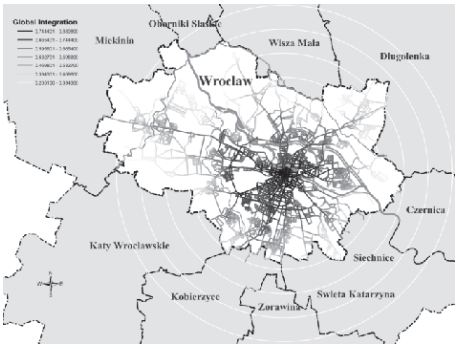
The global integration of Wroclaw's urban structure within the third case is lower than in the first case but higher than in the second case. This result explains that the urban structure of Wroclaw's outskirts influences the global urban structure of Wroclaw city center. Figs. 4a and 5a confirm that the urban core of Wroclaw is tightly interwoven at the same places in the first two cases.

The global integration pattern (global choice) of Wroclaw's urban structure in the third case has a higher value than the first and second cases. In fact, the results show that the routes through the city center and the outskirts of the urban structure of Wroclaw, and among the local structures, would be connected strongly if they were calculated within the wider urban structure of the city region.

The local structures (sub centers) of Wroclaw emerge weakly in the third case because the administrative boundary of Wroclaw is surrounded by the local structures of Wroclaw's outskirts. These local structures within Wroclaw's surrounding structure have a direct effect on the local structures within Wroclaw city center. Additionally, these local structures within the third case have higher averages for local characteristics (connectivity and control value) than in the first case.

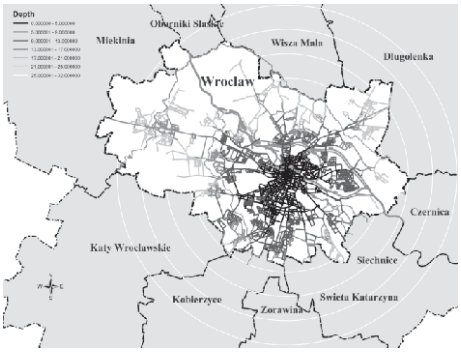
Configuration Characteristics of Wroclaw's Urban Structure in All Cases

The configuration characteristics of Wroclaw's urban structure, in all cases, can be measured by the figures for intelligibility and synergy. Intelligibility was measured by the correlation coefficient (R^2) that is analyzed statistically by a linear regression model between global integration (as an independent variable) and connectivity (as a dependent variable). While synergy was measured by the correlation coefficient between global integration and local integration.



a) Global Integration

d) Local Integration



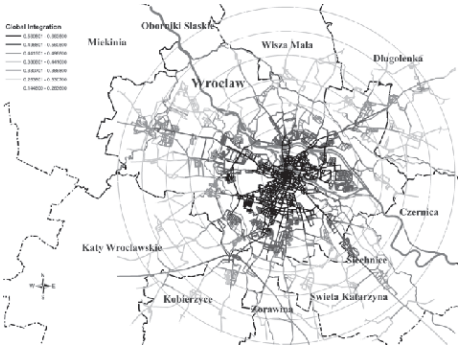
b) Mean Depth

e) Connectivity

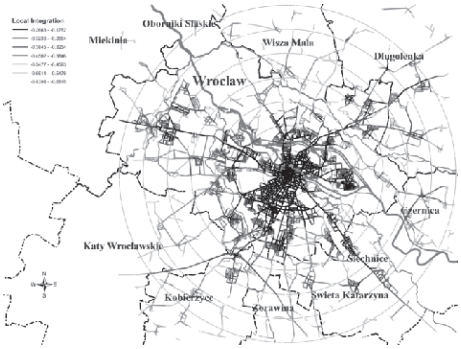
c) Global Choice

f) Control Value

Fig. 4. The Syntactic Characteristics of Wroclaw's Urban Structure within its Administrative Boundary



a) Global Integration



d) Local Integration

b) Mean Depth

e) Connectivity

c) Global Choice

f) Control Value

Fig. 5. The Syntactic Characteristics of Wroclaw's Urban Structure within the Limited Radius Zone

Table 2 shows the intelligibility of Wroclaw's urban structure in all cases is almost the same, while the synergy of Wroclaw's urban structure is also almost identical but in two cases only; the urban structure within the administrative boundary and within the limited radius zone. In the third case, the synergy was higher than in the first and second conditions, which confirms that Wroclaw's urban structure within the administrative boundary has been affected by the urban form around the boundary.

Table 2. Configuration Characteristics of Wroclaw Urban Structure in All Conditions

Spatial Characteristics / Urban Structure Case	No. of Axial Lines	Configuration Characteristics			
		Intelligibility		Synergy	
		R^2	y	R^2	y
Within Administrative Boundary	4868	0.2387	12.228x – 2.23	0.4604	3.1801x + 0.0759
Within Limited Radius Zone (City Region)	7101	0.2261	12.631x – 1.0992	0.4684	3.7871x + 0.1257
Within Administrative Boundary – Region Values	4892	0.2209	17.567x – 3.5389	0.5777	3.2851x – 0.0734

CONCLUSIONS

In this study, the findings of the analysis confirm that the administrative boundary has a strong influence on the evaluation process of the spatial characteristics of Wroclaw's urban structure. The comparison between Wroclaw's urban structure within the administrative boundary (inner city structure) and within the limited radius zone makes it possible to answer the questions that were raised as the aims of this paper. The urban structure of Wroclaw's outskirts (outside the administrative boundary) has direct effects on the global structure and local structures within Wroclaw city center (within the administrative boundary). The area of Wroclaw's urban core is strongly related at the same points within the urban structure from both perspectives. The local structures of Wroclaw city center are affected by the local structures of Wroclaw's outskirts, which are with the global structure. At the same time, the local structures within Wroclaw city center are connected by a more accessible pattern of global structure, if the spatial characteristics are calculated as parts of the wider urban structure of the region surrounding the city.

These findings can be used as a useful guide and reference for urban planners as well as decision makers, to help understand the spatial effects of Wroclaw's

administrative boundary, and to provide an opportunity for rethinking and reshaping a new boundary of the urban spatial structure of Wroclaw that is more efficient for urban development.

AKNOWELGEMENT

This paper is one of the requirements of the fellowship co-financed by European Union within European Social Fund.

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GRANICE MIASTA A REGION MIEJSKI W RAMACH STRUKTURY PRZESTRZENI MIEJSKIEJ WROCŁAWIA

Streszczenie

Celem niniejszego artykułu jest analiza przestrzennych cech struktury miejskiej wykonana pod kątem struktury przestrzeni miejskiej w ramach granic administracyjnych miasta oraz w ramach ograniczonego promienia regionu

miejskiego. W artykule korzystam z metody porównawczej, by zbadać warianty cech przestrzennych struktury miejskiej pod wspomnianymi dwoma kątami. W artykule przedstawiono teorię space syntax jako metodologię do analizy, dochodzenia i zrozumienia struktury przestrzeni miejskiej oraz do przedstawienia ilościowych, porównawczych opisów przestrzeni miejskiej.

Artykuł opiera się na przykładzie struktury przestrzeni miejskiej Wrocławia. Wyniki analiz potwierdzają, że administracyjne granice Wrocławia bezpośrednio wpływają na ewolucyjny proces cech przestrzennych struktury miejskiej Wrocławia. Ponadto lokalne struktury centrum miasta poddane są działaniu lokalnych struktur obrzeży Wrocławia, ściśle wpisanych w strukturę ogólną. Jednocześnie lokalne struktury w ramach centrum Wrocławia są powiązane za pomocą bardziej dostępnych wzorów struktury ogólną, gdzie cechy przestrzenne zostały obliczone jako części szerszej struktury miejskiej obszaru wokół miasta.

Wnioski płynące z badań mogą posłużyć jako przydatne wytyczne i odniesienie dla planistów miejskich oraz decydentów; mogą też wnieść wkład w doprowadzenie do ponownego zrozumienia i nadania nowego kształtu granicom struktury przestrzeni miejskiej Wrocławia, bardziej efektywnych z punktu widzenia rozwoju miast.