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SPATIAL PATTERNS OF ECONOMIC ACTIVITIES IN ŁÓDŹ

Wzorce przestrzenne rozmieszczenia działalności gospodarczej w Łodzi

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Abstract: The article contains the results of the analysis on the distribution of economic activities in modern Łódź conducted with the use of space syntax tools. The study encompassed selected street sections in the broadly-understood city centre (in total, approx. 30 km of streets, with more than 1300 recorded business locations). The analysis conducted has shown that the observed density of business activities in Łódź is connected to the spatial arrangement of the global street network integration. The configuration of the Łódź plan is a statistically important factor that influences the spatial patterns of economic activities. Depending on the location within the layout, individual street sections provide various conditions for the development of business activities, therefore they have varying significance to the shaping of the internal, economic image of the city area.

Keywords: economic activities, urban economy, Łódź, space syntax

Introduction

Urban areas are one of the spatial forms of social organisation. It manifests, among others, through the intense and diverse manner of spatial development, use and, usually, high population density. The street network, also an inherent attribute of urban areas, enables movement, necessary to the functioning of every society. However, such a description of the meaning of streets is an oversimplification. A street space is not merely a communication route or a "technical" space of flows. A street is a complex set of features including the quality of road surface, the presence of greeneries and urban furniture, the nature of development, the application and the specificity of the neighbourhood. As a result, it is a space which can be favourable or unfavourable to the fulfilment of cultural processes (social and economic). Therefore, a street is not a mere connector between locations. It is an area where various aspects of urban life can be realised and intertwined, shaping the qualities of the city (neighbourhood, place).

Currently, it is common to emphasise that the planning of urban structures can have a major influence on the functioning of their users. The internal diversity of a plan determines, for instance, the availability of locations or the 'permeability' of the urban tissue, therefore it can spatially marginalise some residents or determine their movement options. This, in turn, influences the secondary diversification of the city area on the economic and social level (spatial segregation). It should not be assumed that each space is predestined to fulfil the same functions. As established on the level of space syntax, the complex system of communication routes with the same movement and use conditions has an internal hierarchy determined directly by the layout configuration – that is, the relations between the streets themselves[1]. Streets located on the outskirts of the layout have a different position in the hierarchy from the streets located in its topological centres, just as the streets with more communication connections have a different position from those with a lesser number of intersections, etc.

The presented study attempts to analyse the distribution of economic activities in a complex urban area, using the tools and techniques of space syntax. The term 'economic activites' used throughout the article signifies activities in the form of retail or services. The purpose of the study is to identify the potential relationships between the configurational qualities of the street network and the observed density of trade and service activity within the city space.

The research area selected is the central part of Łódź encircled by the railway line (Fig. 1). The railway line is a major spatial barrier in the city, it is strongly

[1] Here, 'configuration' signifies the set of relations existing within a given structure that is typical of it, for example, the relationship between city streets or rooms in a building (Hillier et al.,1987; Hillier, 2007).

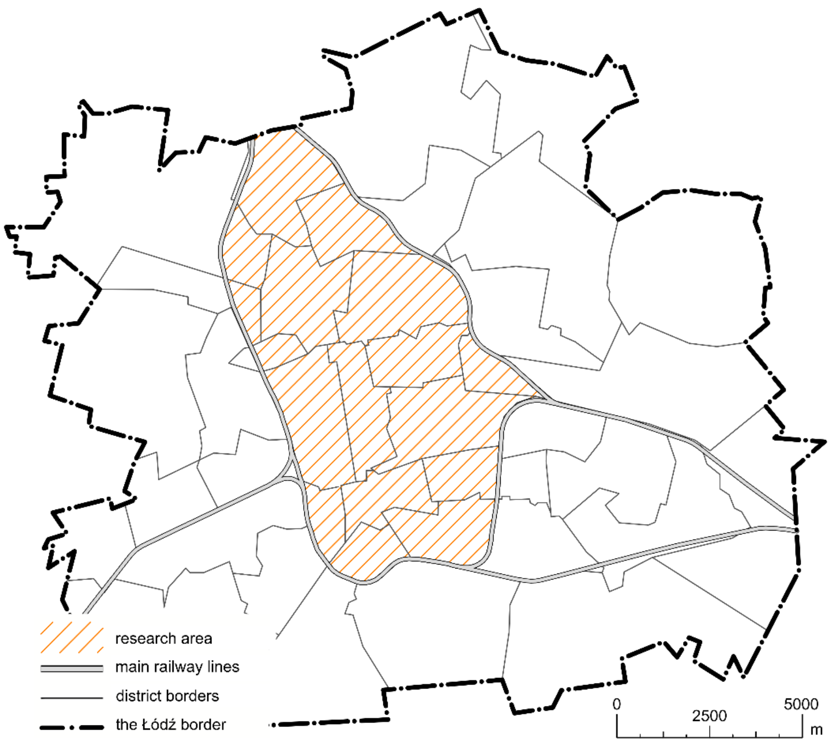

Fig. 1. Research area.

Source: own elaboration.

expressed in the city plan and, therefore, also in the configuration of its street network. The encircling railway line makes the internal area of Łódź resemble an island separated from the other urban structures and connected to them only through relatively few roads that are akin to bridges.

The research process involved several stages:

– the construction of a graphic model of street sequences in the form of a collection of segments, that is straight-line sections representing street fragments divided by intersections,
– the calculation of the integration value for each segment and the selection of a set of segments that is representative in this regard for further field studies,
– the accumulation of data on the observed density of trade and service entities on the given street sections,
– the evaluation of the accordance between the arrangement of entities and the calculated theoretical values representing the integration level of the selected street fragments.

The studies presented are a continuation of the work on the development of theoretical foundations of the studies on the diversification of social and economic processes in the context of the agency of urban structures (Lamprecht, 2016; 2020b; 2020c).

1. The study method and context in light of the subject literature

Studies on the relationships between the activities of societies and the methods of configuring urban environment can be positioned within the non-human agency in the broad sense, developed, among others, as part of the actor-network theory (Latour, 2010; Abriszewski, 2008). Space syntax provides tools for the evaluation of the agency of urban structures. They are based on the analysis of the configuration of spaces that make up these structures and the activities of both individuals and social groups that occur within. The tools are, above all, a characteristic form of the urban space model. It takes on the form of a dual graph, whose vertices represent spaces (streets or their fragments), while edges represent the intersections of the street network (that is links between street spaces). The graph makes it possible to apply mathematical measures of centrality, developed and applied in many academic and research fields (for instance, mathematics, sociology and space syntax), in the evaluation of urban space.

Space syntax is the result of the search for the correlations between the society and the built environment (Hillier et al., 1976; Hillier et al., 1983; Hillier, Hanson, 1984; Hillier, 2007). It is both a theory (space syntax theory), and a collection of analytical tools (space syntax analysis) that constitute a certain mosaic of mathematical ideas used to study spatial layouts and spatial patterns of human activity. Space syntax understands space as relatedness. A sequence of spaces (material objects), such as, for instance, streets and squares, creates an urban arrangement of connections, wherein a given society functions. The spaces work as a system, whose fundamental function is to enable movement in order to fulfil needs. That is how the configuration of non-human material structures shapes that which is human – that is the patterns of use and behaviour in space. Through configurational analysis, space syntax searches for the relations between the spatial layout and the social processes that occur within.

One of the important elements of space syntax is the natural movement theory. It is based on the assumption that street network configuration is one of the factors that shape pedestrian movement. This stems from the relation between the configuration, the movement and the attractors (Fig. 2). The configuration (C) is the most stable element of the system, with a one-directional influence on both pedestrian movement and the distribution of attractors. Attractors such as, for example, service entities (A) and pedestrian movement (M) (that is destination points and their clients, respectively) correlate in an obvious way. However, in other cases the relations are one-sided: configuration (C) influences the attractors' choice of location, but attractors are generally unable to shape the configuration itself. Similarly, configuration shapes the patterns of pedestrian movement, but the relation does not occur in reverse. Therefore, configuration is crucial to the understanding of the distribution of attractors, the spatial distribution of pedestrian movement and the morphology of the analysed layout. It is

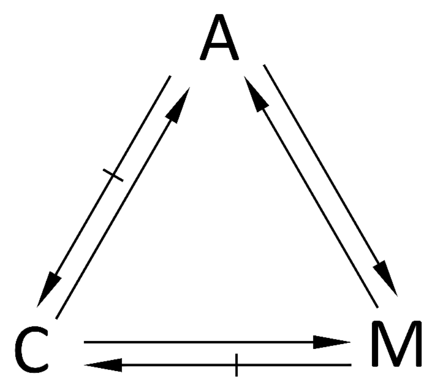

Fig. 2. Relationships between attractors (A), pedestrian movement (M) and configuration (C) in Bill Hillier's theory of natural movement.

Source: Hillier et al. (1993).

configuration that shapes the patterns of pedestrian movements in cities. This theory defines the notion of "natural movement" as this part of movement in the general pedestrian flows that is conditioned by the layout configuration.

Space syntax has repeatedly proven the existence of the connections between the mathematical description of space and the presence of people within. Research results also indicate that the spatial patterns of human activity are linked to the configuration of the street network. This confirms the existence of certain kinds of spatial order (hierarchies) determined by the planning of an area in societies that make use of that area. Due to the context of the study, the results of the research on land use and economic activity in urban areas conducted so far draw special attention. Authors of the studies conducted in Barcelona (Porta et al., 2012) have divided activities into primary ones, which draw people to their locations (offices, industrial locations, apartments, sometimes entertainment, education or recreation areas, at times museums, libraries and galleries), and secondary ones – local services that develop as a supplement to basic activities to serve the people drawn in by them. Studies have shown that secondary activities show higher correlation with the central location of a street than the primary ones. Authors explain that basic activities are attractive enough to draw people in, mostly due to their functions. Secondary activities need to make use of locations with highest movement intensity to survive, therefore they place themselves on the most central streets. The results of the research on the spatial organisation of economic activity in Antwerp in the 19th century are also interesting (Froy, 2016). Their author has shown that although the economic activity at the time was dispersed throughout the whole street grid of the city, some activities (retail, wholesale and artisans) were more frequently located in the network of more available streets. The relationship between the spatial patterns of retail and the spatial configuration of the street network was studied via the methodology of space syntax also in various types of Israeli cities (Omer, Goldblatt, 2016). The conclusion was that the trade activity in cities planned according to modernist rules concentrates in less accessible locations than in older cities.

2. Research methods and data sources[2]

The starting point of the research presented was the construction of the model of urban space in accordance with the premises developed in the field of space syntax. The task of the model was to transform a two-dimensional plan of the researched area into a graph that enables a mathematical analysis. The studies made use of a model based on segment axial lines[3] (Hillier, Hanson, 1984; Liu, Jiang, 2012; Turner et al., 2005), while the evaluation of the configuration of the layout made use of the angular segment analysis (Turner, 2001). The advantage of the selected model is the possibility to analyse the spatial structure of a layout with high accuracy. This enables the evaluation of not only whole streets, but also their sections contained between the intersections. Angular analysis, developed as an expansion of axial analysis, introduces weighted measures, which express the angularity of the route taken, to the evaluation of urban space. It has been observed that the selection of a given route is largely influenced by how winding it is, which is measured through the values of curve angles in consecutive intersections. This stems from people's tendency to "linearise" routes, that is make more shallow turns on the way to their destinations (Dalton, 2003).

The construction of the model was based on the arrangement of streets that make up the main communication system of the Łódź area. It omitted low-ranked communication routes that frequently had limited access to traffic, such as avenues, alleys, and footpaths in parks, squares, cemeteries or allotments, but also in sports complexes or fitness trails. Entrances to internal quarter spaces, pedestrian routes in complex trade, service or industrial centres were also omitted with the exception of driveways to these complexes and the ring roads surrounding them. Thus constructed representation of spaces that make up the framework of communication traffic underwent configurational analysis. What emerged was a colourful map of segment axial lines in colours ranging from red to blue, whose temperature reflects their integration value interpreted as a theoretical expression of various levels of the density of social and economic life in the broad sense. The picture reveals a configurationally complex structure of the studied area, discussed in earlier studies (Lamprecht, 2020b; 2020a). The most important configurational features measured by the level of the integration of the street network include:

[2] The discussions presented refer solely to the research on pedestrian movements on an urban scale and selected techniques of space syntax based on axial lines.

[3] The foundation for the construction of the graph is a set of axial lines drawn up on a city plan in such a way, so as to cover all spaces that enable movement in a set of the longest possible, but at the same time fewest possible straight lines. The lines make up an axial map which reflects the topological properties of the researched structure.

– the lack of internal cohesion of the studied area on a local level[4]. The presence of valleys and the encircling railway line contributes to the disintegration of the analysed territory of Łódź into four separated, longitudinal structures (Fig. 3);

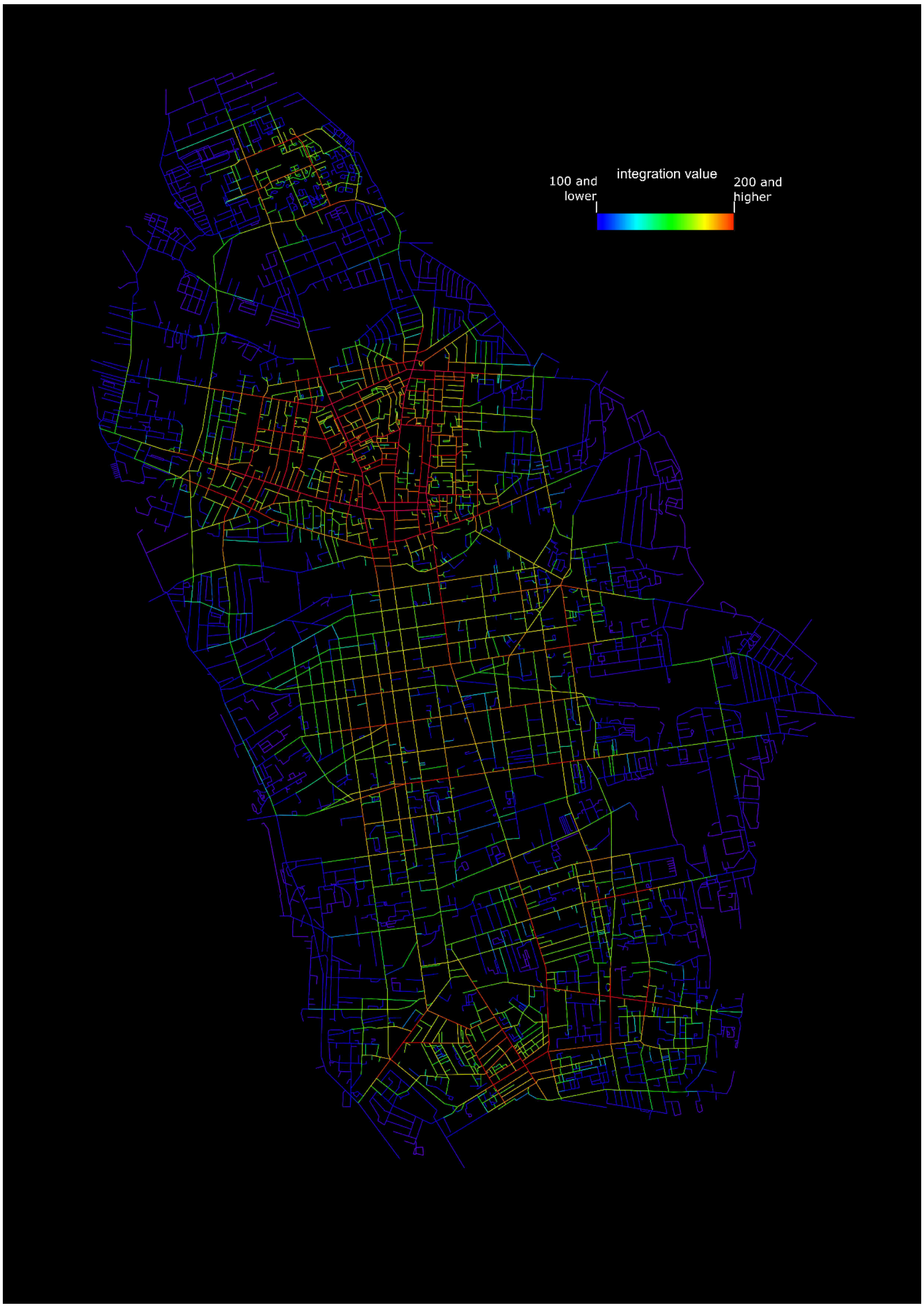

Fig. 3. The arrangement of local integration values (analysis radius: 1200 m) in Łódź, within the encircling railway line. Red lines mark the best integrated sections in the layout (5% of all), orange – sections that are supplementary to the core, green and yellow – lower-rank sections, azure – sections of lesser significance, blue – marginal (50% of lowest-value sections).

Source: Lamprecht (2020b).

4 On this level, the neighbourhood of each segment was analysed within 1200 m, which corresponds with an approx. 15-minute-long march. The metric radius means that the segments within this radius were analysed, while the evaluation of the local structures defined in this way assumes the nature of a topological analysis each time, which means that it is the street segments (topological steps) covered during the trip that are counted instead of their length.

– the centralised structure on a global level; the core of the structure is the strict Łódź city centre with a quite monotonous (orthogonal) street grid created as a result of the regular planning of a 19th century town that had been undergoing industrialisation (Fig. 4).

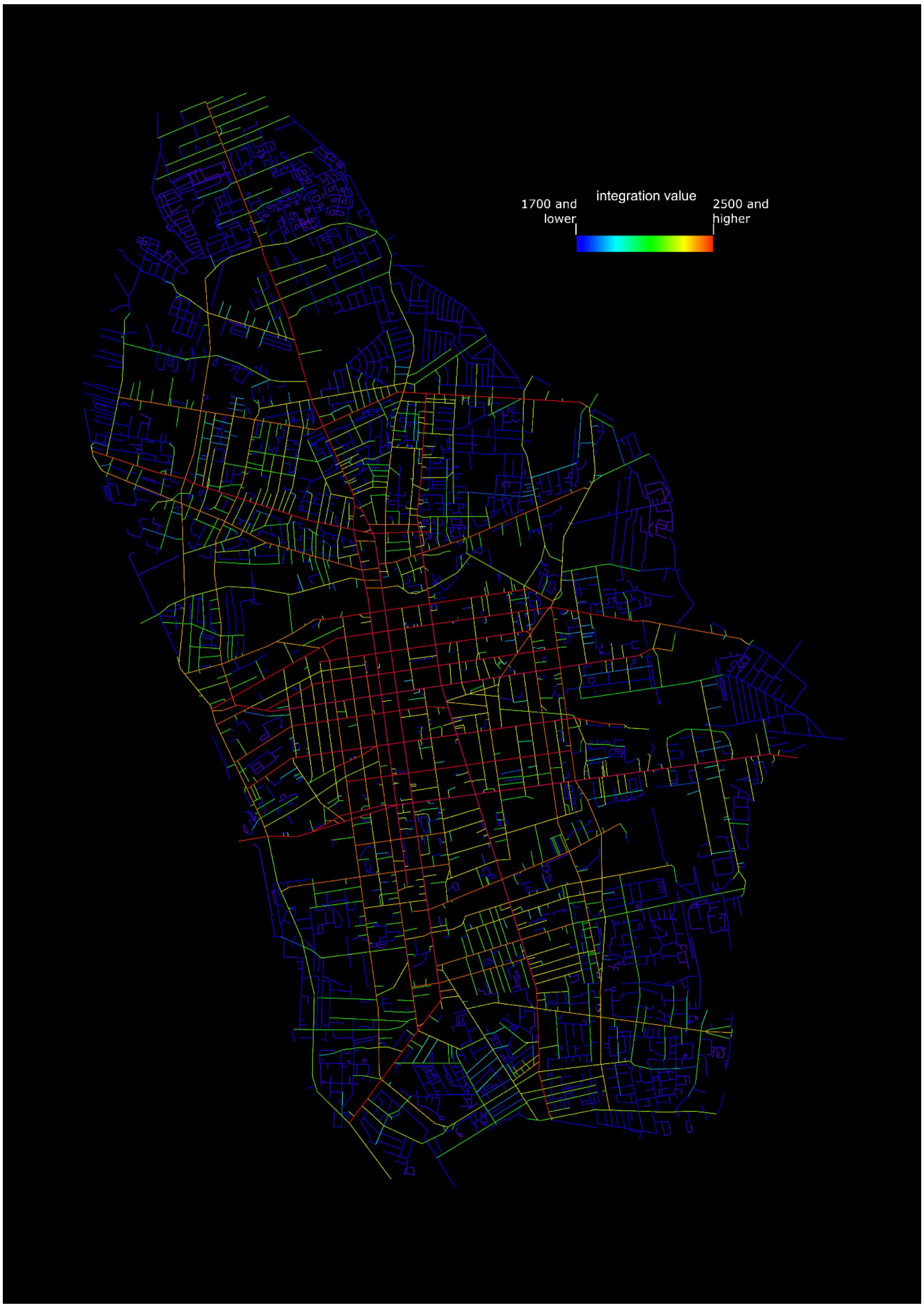

Fig. 4. The arrangement of global integration values in Łódź, within the encircling railway line.
Red lines mark the best integrated sections in the layout (5% of all), orange – sections that are supplementary to the core, green and yellow – lower-rank sections, azure – sections of lesser significance, blue – marginal (50% of lowest-value sections).

Source: Lamprecht (2020b).

The dual image of the city, reflecting the local and global perspective, has become a foundation of the search for the relationships between the level of street network integration obtained through mathematical calculations and the density of trade and service activities within the city space.

The measure of integration is one of the centrality measures, in network analyses also known as closeness centrality. Spaces that integrate the studied layout show high integration values, while spaces separated from the layout show low integration values. Integration takes into account the relation between a given space and each different space in the system (global integration) or spaces within a set distance (local integration) (Hillier, Hanson, 1984). The formula for calculating integration is:

$$INT_i = \frac{1}{RRA_i};$$

where:

RRA_i (Real Relative Asymetry) $= \frac{RA_i}{D_{value}}$;

RA_i (Relative Asymmetry) $= \frac{2(MD_i-1)}{n-2}$;

$D_{value} = \frac{2\left\{n\left[\log_2\left(\frac{n+2}{3}\right)-1\right]+1\right\}}{(n-1)(n-2)}$;

MD_i (Mean Depth) $= \frac{D_i}{n-1}$;

D_i (Total Depth) $= \sum_{j=1}^{n-1} d_{ij}$;

n – number of vertices in a graph (spaces in the analysed layout),
d – one topological step,
i – analysed space (vertex in a graph).

The integration measure evaluates the level of topological closeness of a given space in relation to other spaces in the system. Its value depends on the number of "steps" (number of spaces) that need to be taken from a given space to reach all other spaces in the system (global integration) or spaces within a given distance (local integration). Integration is considered an essential measure of space syntax, as it facilitates the understanding of the relationship between the users and space. It is believed that integration value also corresponds with the social contact and trade activity indices (Hillier, 2007). Therefore, integration can be considered a measure of the quality of urban space, as it provides information about its potential.

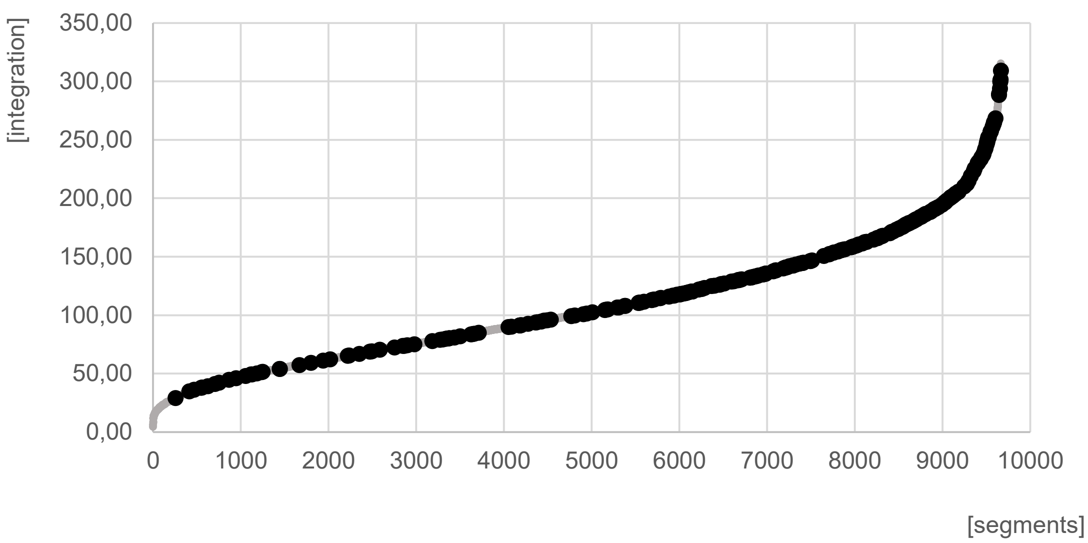

Fig. 5. The values of local integration (1200 m) of the street network segments in the centre of Łódź put into order. Grey dots mark integration values for all street network segments in the researched area, black dots mark the segments under observation.

Source: own elaboration.

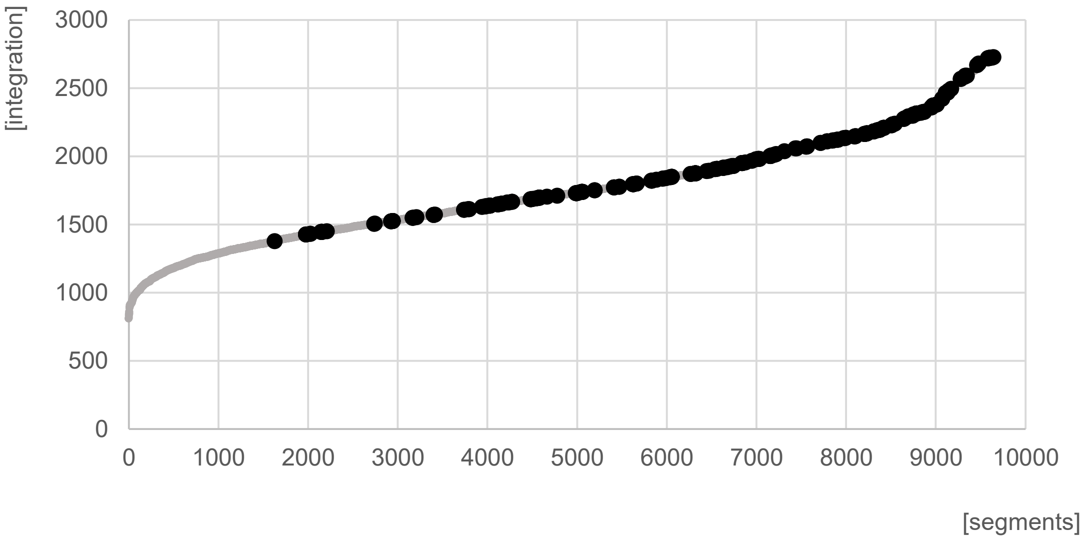

Fig. 6. The values of global integration of the street network segments in the centre of Łódź put into order.
Grey dots mark integration values for all street network segments in the researched area, black dots mark the segments under observation.

Source: own elaboration.

The source of data on the density of trade and service activity was a field inventory, compiled during the working days of summer months in 2021. It encompassed the segments[5] of the street network selected to reflect both the spectrum of integration values calculated on local (Fig. 5) and global (Fig. 6) scales, but also the internal disintegration of the city plan in light of the local integration (Fig. 3) proven earlier on.

3. Research results. Configuration of space and economic activity

During the field research, 123 street segments with a total length of more than 37.7 km (Fig. 7) were inventoried. 1353 trade and service locations were recorded in total. Both economically active locations (open during the field research) and inactive ones (closed) were included. This made it possible to obtain information on the current, but also the potential density of economic activity (with full use of the establishments on a given street section). The density of economically inactive locations can also be interpreted as a range of negative phenomena that manifest themselves through the degeneration of economic activity[6].

The average length of a segment observed was 206.5 metres and the average number of registered businesses in one street section was 11.0 (including 3.1 inactive businesses). The average number of subjects observed on a 100 m stretch was 3.6 (including 1.0 inactive ones). In total, among 1353 locations, 379 (28%) were economically inactive.

The analysis of the correlation between the density of economic entities and the value of integration on a local scale (1200 m) was dictated by the internal disintegration of the city plan, visible on the scale. It was expected that the spatial distribution of small trade and service enterprises with relatively small impact strength (and those predominate in the inventory), would reflect the level of integration of urban structures on a local scale. The juxtaposition of field research with the mathematical calculations has shown that the density of economic activity in each of the three measured aspects (active locations, inactive locations, total locations) is unrelated to the local integration index (Tab. 1). In this case, the Pearson correlation coefficient nearly reaches zero each time, and data manipulation (removing 10% of segments that extremely disturb the result

[5] Here, a segment denotes a street section from one intersection to another, in accordance with the structure of the model applied, wherein street sections (segment axial lines) constitute graph vertices.

[6] A number of other features omitted in the presented analysis were also recorded: the level of degradation of abandoned locations and the detailed location of businesses (building fronts, annexes). No information was collected on the reasons or time of abandonment.

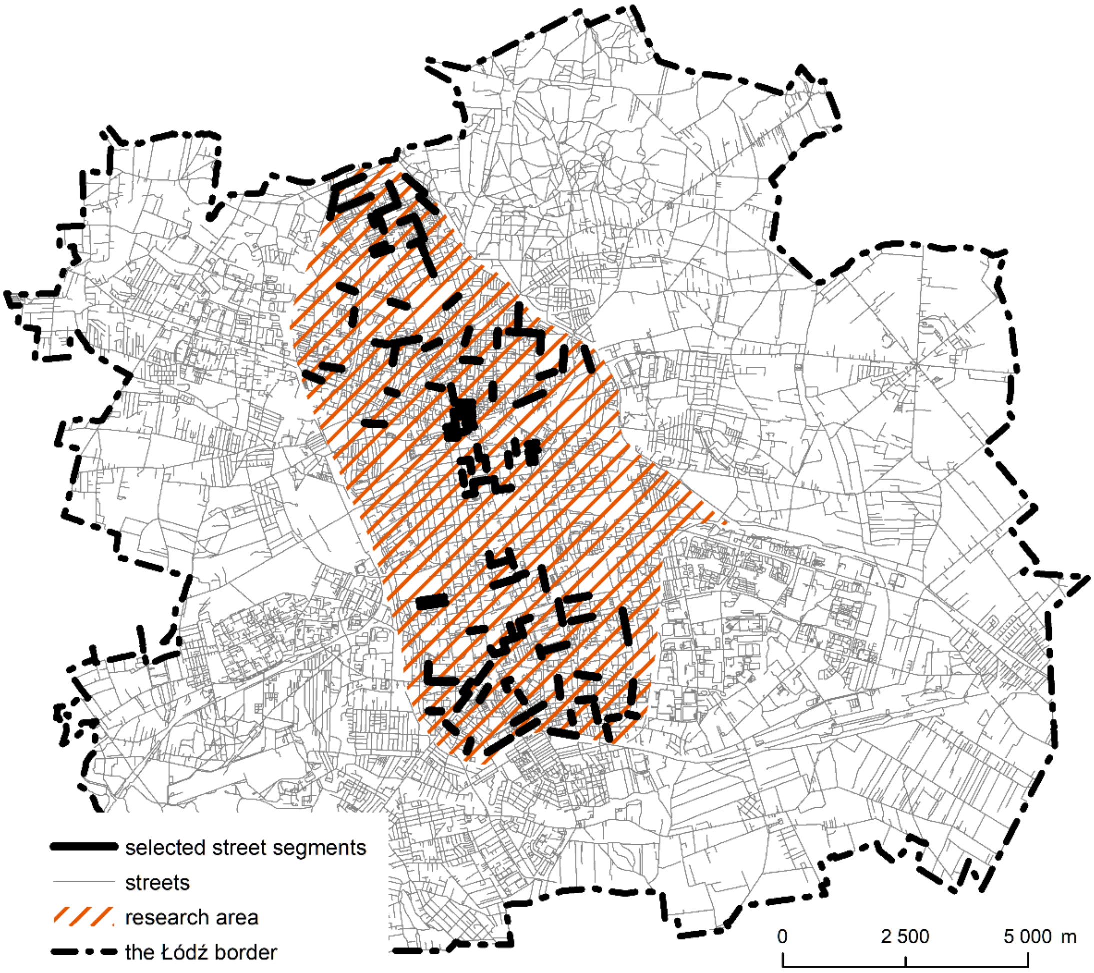

Fig. 7. Segments of the street network under field inventory.

Source: own elaboration.

Tab. 1. The values of correlation* between the integration value and the density of economic activity in the centre of Łódź, in 2021.

Economic activity	Local integration [1200 m]	Global integration	Local integration [1200 m]**	Global integration**	P-Value for global integration
In general	-0.0881	0.5653	0.0890	0.6496	P<0.00001
Active locations	-0.0988	0.5570	0.0856	0.6540	P<0.00001
Inactive locations	-0.0500	0.4350	0.0701	0.4839	P<0.00001

* The Pearson correlation coefficient.

** 10% of observations (12 segments) that extremely disturbed the correlation result were omitted. Those were street sections with either high integration values and no density or low-density of trade and service locations or low integration values and relatively high density of economic activity.

Source: own elaboration.

of the correlation) does not significantly change the conclusion. This means, that the internal structure of the plan of Łódź, manifesting itself in the form of a characteristic, clustered distribution of integration values, finds no reflection in the spatial patterns of the distribution of economic activity.

Different conclusions were obtained when correlating the results of field observations with the global integration values. In this case, the correlation value is statistically important (0.5653 with p-value<0.00001), and after removing 10% of segments that most disturb the correlation, the relationship value increases visibly (0.6496, p-value<0.00001). What is important is that during the analyses it has been observed that the value of correlations between the density of economic entities and the level of integration successively rises with the change of the scale of analysis. The greater the range of the analysed neighbourhood (radiuses taken into account: 800, 1200, 1600, 2000, 2400, 2800 and n metres), the higher the level of correlation in the studied features, with the strongest visible result being on the global level.

The relationships observed make it possible to apply a statistical generalisation in the form of a multi-level hierarchy of the street network, wherein the level of integration of a segment corresponds with the observed density of economic activity (Tab. 2).

(abandoned locations) on the two highest levels is also interesting. Although their percentage (30% or more) does not upset the general regularity – the higher the level, the higher the density of economic activity – such a high percentage of abandoned locations should require detailed analyses from the perspective of business demography (which are outside of the scope of the discussion presented in this article).

The regularities observed make it possible to conclude that the relationship between the configurational features of the plan of the centre of Łódź (measured via the level of global integration) and the trade and service activity within is essential. It should be emphasised that numerous exceptions exist in the observed set of street segments, for instance, there are street fragments with high integration values and low density of business activity and the other way round – fragments with low integration values, but relatively high economic activity. However, it should be noted that the observations were frequently conducted on relatively short street sections, which do not necessarily reflect the nature of the whole street (or its longer section). The fact may be partially responsible for the observations that disturb the correlation. An assumption cannot be made that the model that reflects spatial configuration would fully match the distribution of economic activity since economic life depends on

Tab. 2. Hierarchy of the street network in terms of economic activity in the centre of Łódź in light of the global integration value in 2021.

Level of hierarchy measured by integration*	Total length of segments [m]	Number of entities			Number of entities per 100 m		
		in general	active	inactive	in general	active	inactive
I	7784	613	430	183 (30%)	7.87	5.52	2.35
II	8069	412	258	154 (37%)	5.11	3.20	1.91
III	12866	227	189	38 (17%)	1.76	1.47	0.30
IV	8937	101	97	4 (4%)	1.13	1.09	0.04

*Levels correspond with 25% of segments in a studied set, that is: level I – 25% of segments with highest values of global integration, level IV –25% of segments with the lowest integration values, levels II and III represent the 25% with average values.

Source: own elaboration.

In this generalised case, the dependency between economic activity and the level of integration of street segments is clearly visible. The average density of inventoried business locations (active and inactive) is seven times higher in the first level of the hierarchy than in the fourth one. The difference between the two first and two last hierarchy levels is also easily discernible, with the density of economic activity between them (calculated by the number of entities) changing drastically. The high percentage of inactive entities many other factors, such as the density of urban life in the broad sense, the diversity of space use or the method of development of street routes. Moreover, the model applied omits such features as the nature of development and its density, the presence of sources of movement or destination points. Societal features (e.g. wealth, age and inclination towards walking) are also omitted. The aspect of behaviours in space is also simplified, since it is assumed that the users of city space take the shortest routes possible.

4. Discussion

Each territory is perceived by individual users on different geographical scales. It depends, among other things, on their movement capability, which, in turn, depends on the technical means at an individual's disposal (e.g. car ownership) or their physical and mental abilities (e.g. motor functions and sense of direction). As a result, each territory, despite having, objectively speaking, the same features, can be reflected in a complex and diverse way in the society that uses it. However, despite the individual perception of reality being unique, mass observations and recordings of events make it possible to perceive certain social (cultural) regularities occurring in space. These statistical simplifications make it possible to search for answers to the question of whether the complexity of urban structures, resulting from their subjective perceptions by individuals, can be reflected in the whole of the social and economic processes occurring within.

The purpose of the research presented was the evaluation of the distribution of economic activity in the centre of Łódź in relation to the spatial distribution of one centrality measure: integration. Special attention has been paid to two scales: global and local. On the first scale, the analysis encompassed whole central Łódź, which is a perspective of a person with unlimited (physical, technical, temporal etc.) movement-related possibilities. On the second scale, the pedestrian-friendly perspective (as considered by subject literature) was emphasised. That means, the configuration of street segments was analysed in a spatial context limited to a 1200 m distance. This perspective was dictated by the configuration of the Łódź plan, which reveals its internal disintegration on this exact geographical scale.

The analysis conducted has proven there are connections between the observed density of economic activity in the Łódź centre and the spatial distribution of the value of the global integration of the street network. The configuration of the plan of Łódź on the global scale is therefore a statistically important factor, which influences the spatial patterns of economic activity. Depending on location, individual street fragments offer various conditions for the development of economic activity, therefore have a different significance in the shaping of the internal economic image of the city area. The studies prove that the layout configuration measured by integration, one of centrality measures, may reflect the density of economic life in such spaces. The measure also has an informative value: it shows which spaces have relative potential (in the context of the studied layout) for the development of trade and service businesses. High global integration identifies spaces statistically closest to the residents of the analysed area, therefore, theoretically, most frequented. The areas are crucial to the entities that base their functioning on services. Entities located on such streets have an advantage over subjects located on streets with lower global integration values. The academic studies in the field of space syntax conducted in various countries have revealed on numerous occasions that many spatial features such as opportunities for social contact, functionality and usefulness of location (rooms, streets, squares) are dependent on the method of configuration of a given structure (Hillier, Hanson, 1984; Peponis, Wineman, 2003). The research conducted in the centre of Łódź confirms the previous observations. It should also be mentioned that it also remains in accordance with the studies conducted in Barcelona and referred to earlier on (Porta et al., 2012).

The level of integration is a theoretical measure and should be treated as relative information – its higher value indicates spaces which, from a statistical viewpoint, will be used in a more intense manner. The reverse also applies – its lower value indicates smaller economic significance of the spaces. The information should be treated as a simplification of long-term social and economic processes within the city space. High, but low-density concentration of clients within the space does not provide economic bases for the functioning of trade and service entities. Unfavourable configurational location may therefore determine the short-term existence of services and, within decades, shape specific spatial patterns of economic activity. It should also be emphasised that the configuration of the city plan is not permanent. The spatial development of the street network even on the outskirts of the layout changes certain configurational features of streets in the fixed structures (e.g. historical centres of cities with protected spatial layouts) and modifies the conditions in which social and economic entities function.

The question of the relations between the density of economic activity (locations) and the spatial distribution of the value of local integration is a separate issue. However, it should be considered that the analysed area is merely a fragment of the Łódź territory, isolated from other urban structures through a spatial barrier in the form of a railway line. It is possible that only the structures that are external to the city centre have their own, local order in the spatial distribution of integration and, therefore, other spatial patterns of economic activity. However, the verification would require further, separate analyses. It should also be remembered that the layout configuration method does not fully explain the patterns in the spatial distribution of economic activity, and, therefore, the calculated correlation coefficient cannot reach the values that suggest a perfect linear relationship between the studied features.

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