ACTA Acta Sci. Pol., Administratio Locorum 20(2) 2021, 139–152.
https://czasopisma.uwm.edu.pl/index.php/aspal plISSN 1644-0749 eISSN 2450-0771 DOI: 10.31648/aspal.6536

ORIGINAL PAPER Accepted: 19.03.2021

MEASUREMENT OF SPATIAL ORDER AS AN INDICATOR OF SUSTAINABLE DEVELOPMENT OF FUNCTIONAL URBAN AREAS IN REGIONAL CAPITALS

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ABSTRACT

The preservation of spatial order is one of the key objectives of spatial planning. Due to the dynamic changes associated with rapid urbanization, special attention should be paid to cities and the surrounding areas. The aim of this study was to measure spatial order in social, economic and environmental dimensions in the Functional Urban Area of Olsztyn, the capital city of the Polish voivodeship of Warmia and Mazury, and to propose indicators for measuring spatial order. Socioeconomic development should be balanced with environmental protection to promote spatial order and improve the quality of life. Functional urban areas should be regularly monitored to ensure that planning measures contribute to the preservation of spatial order, and to minimize local problems and conflicts. The municipalities belonging to functional urban areas should be regarded not only as distinct territorial units, but also as members of a cohesive area whose development in every dimension of spatial order contributes to an improvement in the quality of life for local communities.

Keywords: spatial planning, socioeconomic development, sustainable development indicators, Perkal's method, multidimensional comparative analysis

INTRODUCTION

The Polish spatial planning system is composed of three levels: national, regional and local. Planning documents, strategies, programs and acts of local law are developed at each level to promote sustainable development and preserve spatial order. The Act on the principles of development policy was amended in 2020, and it replaced the National Spatial Development Concept 2030 which had delineated the main trends, challenges and scenarios for the socioeconomic development of Poland, as well as the directions of sustainable spatial development [Act on the principles of development policy and selected legal acts, 2020]. The National Spatial Development Concept 2030 placed strong emphasis on spatial order which was regarded as one of the policy priorities and one of the key development goals [National Spatial Development Concept 2030, 2013]. In the light of the Act on spatial planning and land management, spatial order and sustainable development constitute the basis for spatial policy and land management principles

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[Act on spatial planning and land management, 2003]. According to the above act, the preservation of spatial order is the main goal of spatial management at all levels of planning: national, regional and local.

In spatial management, spatial order is defined as the preservation of order, balance and harmony between different elements and functions of space. Spatial order is one of the criteria for evaluating the quality of changes in land management and their impact on socioeconomic processes, living standards and the quality of life [Prus et al., 2015]. Spatial order reflects on the existing social and economic mechanisms and the condition of the natural environment [Parysek, 2007]. However, spatial order is not a categorical concept that is associated with one specific phenomenon, and its scope is influenced by context. This multidimensional concept harmoniously combines several aspects [Wdowicka & Mierzejewska, 2012]. Mierzejewska [2003] identified six dimensions of spatial order: functional, economic, environmental, political, cultural and esthetic. According to Mikołajczyk & Raszka [2019], spatial order can be analyzed in four dimensions: environmental, socioeconomic, functional and cultural. Spatial order can also be regarded as a component of integrated order which combines environmental order, social order, economic order, and institutional and political order [Borys, 2011]. In some cases, spatial order is assessed in combination with environmental order, whereas social and economic dimensions are examined separately. According to another approach, environmental, social and economic components of spatial order can be identified [Polski, 2014]. A review of the literature clearly indicates that a wide variety of approaches can be applied to define and identify the dimensions of spatial order.

The main drivers of spatial change are urbanization processes [Szarek-Iwaniuk, 2020]. The measures and policies targeting sustainable development and the preservation of spatial order aim to instill harmony in social, economic and environmental dimensions [Alińska et al., 2018]. Spatial order and sustainable development are the key objectives of spatial planning and urban policies. The main goals of the National Urban Development Policy are to promote the sustainable development of Polish cities and the surrounding areas, to coordinate various measures that aim to achieve spatial order, and to improve the quality of life. This policy document emphasizes the significance of cities in contemporary economies, and their role in job creation, economic growth and the provision of high-quality public services. The document underlines that special attention should be paid to cities and suburban areas where dynamic urbanization processes take place [National Urban Development Policy 2023, 2015]. In view of the above, the aim of this study was to measure spatial order in social, economic and environmental dimensions in a functional urban area. The studied object was the Functional Urban Area of Olsztyn, the capital city of the Voivodeship of Warmia and Mazury. The analysis covered a period of ten years between 2010 and 2019. Data were analyzed in a dynamic (2010–2019) and a static (2019) approach. The two approaches were combined to conduct an in-depth analysis of the studied phenomenon and to determine whether rapid urbanization in territorial units was accompanied by equally high levels of development in the evaluated categories. Three main dimensions of spatial order were identified for the needs of the study: social, economic and environmental (Fig. 1).

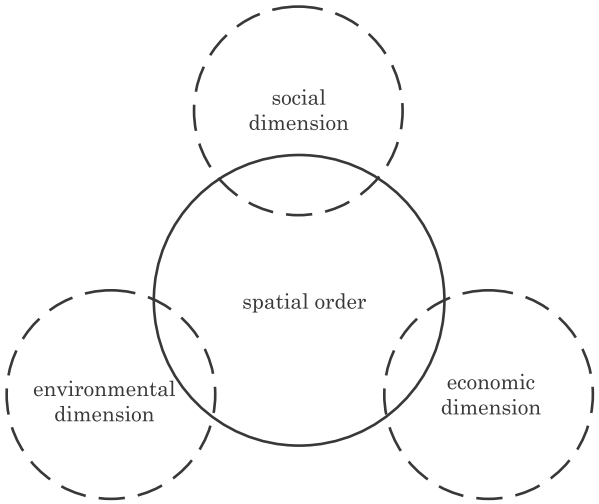

Fig. 1. Dimensions of spatial order
Source: own elaboration.

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The changes in functional urban areas should be regularly monitored to promote sustainable development and the preservation of spatial order. However, there are no universally acknowledged standards or datasets for measuring spatial order at the regional or local level, which poses certain diagnostic problems. Therefore, a detailed goal of this study was to propose indicators for measuring spatial order in both absolute terms and in each of the identified dimensions. The discussed problem plays a very important role in spatial planning and urban policy which aim to maintain spatial order and promote the sustainable development of regions.

MATERIALS AND METHODS

Indicators and methods for measuring spatial order

Sustainable development and spatial order can be described and analyzed with the use of various types of statistical data. Depending on the research objective, data can be presented in a dynamic approach to identify changes that occur in a specific time interval, or a static approach to describe the situation at a given moment of time (year, quarter, etc.). The selected diagnostic attributes should be available for all analyzed territorial units, and they should guarantee the required level of detail. The indicators that can be applied in analyses of the social, economic and environmental dimensions of spatial order are presented in Tables 1, 2 and 3, respectively. These data can be analyzed to expand the knowledge about the socioeconomic development of the examined territorial units, as well as the success of local policies aiming to promote sustainable development and the achievement of spatial order. The presented indicators are not exhaustive, and they can be modified subject to research needs, the availability of data and the required level of detail. A wide variety of diagnostic attributes are available at the level of macroregions (NUTS 1), regions (NUTS 2) and subregions (NUTS 3). Data for international comparisons can be obtained

Table 1. Selected indicators of spatial order in the social dimension

Demography	Population density per 1 km^2
	Population growth rate
	Natural increase per 1000 population
	Number of marriages per 1000 population
	Infant deaths per 1000 live births
	Average life expectancy at the age of 65 years
	Foreign emigration rate
Education	Number of children aged 3–5 years per one place in preschool education establishments
	Public expenditure on education (% GDP)
	Gross education ratio – primary school
	Public expenditure on education per capita
Healthcare	Population per outpatient clinic
	Total expenditure on healthcare per capita
	Number of outpatient clinics per 10,000 population
	Infant deaths per 1000 live births
	Disability-free life expectancy at the age of 65 years
	Population per commercial pharmacy
Culture, sports, recreation	Public expenditure on culture and national heritage protection per capita
	Registered public library users per 1000 population
Employment	Unemployment rate in the working age population
	Unemployed women per 100 working-age female population
	Registered unemployment rate
	Employment rate of persons with disabilities
Safety	Detection rate for offenders
	Road fatalities per 1 million population
	Crime detection rate per 1000 population
	Total expenditure on public safety and fire protection services per capita
Social participation	Number of foundations, associations and social organizations entered into the REGON register per 1000 population

Source: own elaboration.

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Table 2. Selected indicators of spatial order in the economic dimension

Municipal finance	Municipal revenue per capita
	Municipal own-source revenue per capita
	Municipal expenditure per capita
Entrepreneurship	Number of business entities entered in the REGON register per 10,000 population
	Number of self-employed persons per 1000 population
	Number of new business entities entered in the REGON register per 10,000 population
Economic dependency by age	Dependency ratio (number of people of non-working age per 100 persons of working age)
	Old-age dependency ratio in total population
	Child dependency ratio in total population
Housing	Number of new build dwellings per 10,000 population – three-year average
	Average usable floor area per new build dwelling
Tourism	Number of beds in tourist establishments per 1000 population
	Number of overnight visitors in tourist establishments per 1000 population
Public utilities	Length of the water supply network per 100 km^2
	Length of the sewer network per 100 km^2
	Length of the gas supply network per 100 km^2
Availability of public utilities and services	Percentage population served by the sewer network in total population
	Percentage population served by the water supply network in total population
	Percentage population served by water treatment plants in total population

Source: own elaboration.

Table 3. Selected indicators of spatial order in the environmental dimension

Environmental protection	Legally protected area in the total area of the municipality
	Natural monuments per 100 km^2
Municipal services	Municipal waste generated per capita
	Household waste collected per year per capita
	Percentage of waste collected for recycling in total collected waste
	Industrial and municipal wastewater that requires treatment and is evacuated to water bodies or the ground per year per capita
Resource use	Electricity consumption per capita
	Water consumption per capita
Land management	Built-up and urbanized area in total area
	Forest cover
	Parks, green squares and residential green space in total area
	Area covered by local zoning plans in total area

Source: own elaboration.

from Eurostat, the statistical office of the European Union. However, detailed statistical data describing territorial units (NUTS 4) are less available, and accurate data are least available at the local level (NUTS 5) which is characterized by the highest level of detail and the highest number of analyzed units.

Regardless of the selected analytical method, diagnostic variables should fulfill the following criteria [Grabiński, 1988, Zeliaś, 2000]:
– they should be universal,
– indicators should be measurable,
– data should be available,
– data should be of high quality (they should be informative and clearly formulated),
– variables should be characterized by high variation,
– variables should be bound by weak correlations,
– variables should be economical (to minimize data collection costs),
– variables should be easy to interpret (data should be non-ambiguous and should meet research criteria),
– variables should exert the same effects (stimulants, destimulants and nominants),
– variables should be clearly expressed (preferably by indicators).

A comparative analysis of territorial units described by various diagnostic attributes can pose numerous problems. Multi-dimensional comparative analyses, including taxonomic methods, are widely applied in research. These methods are used to build synthetic indices for analyzing objects that are described by numerous attributes [Tarka, 2010]. Multi-dimensional comparative methods provide aggregate data and support analyses of complex phenomena that are characterized by many attributes.

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However, there are no generally recognized rules concerning the number of indicators that should be considered in analysis [Mikołajczyk & Raszka, 2019]. Multi-dimensional comparative analyses are widely used in geographic research, including in analyses of socioeconomic development, sustainable development and economic growth [Cheba & Szopik-Depczyńska, 2017, Chrzanowska & Zielińska-Sitkiewicz, 2018, Janusz, 2019, Rogalska, 2018, Sojka, 2008, Zygmunt, 2017]. The Wrocław taxonomic method (dendritic method) was applied to assess the development of small towns belonging to the Cittaslow network [Senetra & Szarek-Iwaniuk, 2020]. Hellwig's taxonomic method for identifying development patterns, a synthetic measure of development and Ward's method were used in a comparative analysis of access to ICT infrastructure [Łogwiniuk, 2011]. Perkal's method of natural indicators belongs to the group of classical taxonomic methods [Perkal, 1953]. This approach was applied to evaluate cultural resources in Poland's largest cities, to analyze the competitive advantage of regions, and assess the socioeconomic development of rural municipalities [Feltynowski, 2009a, 2009b, Kruk & Waśniewska, 2017, Namyślak, 2013]. Perkal's method and Hellwig's taxonomic method were also used to evaluate the innovation potential of regions [Feltynowski & Nowakowska, 2009].

Sources of data and the applied method

The study was conducted at the local level (NUTS 5) to analyze the research object, a functional urban area, based on detailed data. Data for the analysis were obtained from Statistics Poland [2020]. The acquired data covered 2019 (in the static approach) and the period between 2010 and 2019 (in the dynamic approach). The volume of household waste collected per year per capita was determined based on more recent data because the relevant information was not available for 2010. This indicator was selected for analysis because it is an important determinant of spatial order in the environmental dimension, and the annual changes are easy to observe and quantify.

Three dimensions of spatial order were taken into consideration in the study: social, economic and environmental. Each dimension was analyzed separately. The study was divided into several stages. In the first stage, diagnostic attributes for each analyzed dimension were selected from the sets of criteria presented in tabular form. In every evaluated dimension of spatial order, one diagnostic criterion was selected from each major category, and a total of seven diagnostic attributes were chosen in each dimension. The only exception was the environmental dimension, where a total of seven diagnostic attributes were selected from four major categories. In each dimension, the choice of diagnostic attributes was based on two factors: 1) availability of data for every territorial unit, and 2) relatively high variation of data describing the analyzed territorial units. A total of seven diagnostic attributes were ultimately selected in each dimension (Table 4).

Two analytical approaches were used in the study. Changes in descriptive parameters that occurred over a period of 10 years (2010–2019) were analyzed in the dynamic approach, whereas data covering 2019 only were analyzed in the static approach. The two approaches were combined to conduct an in-depth analysis of the studied phenomenon and to determine whether territorial units that had undergone the most extensive changes in the analyzed decade were characterized by the highest levels of development in each evaluated dimension in 2019.

Perkal's method was applied in the study [Chojnicki & Czyż, 1991] to develop a synthetic index as the sum of standardized values of partial indicators. The analysis was conducted on the assumption that all attributes have equal weight and that all analyzed variables exert the same effect on the studied phenomena. Stimulating and destimulating variables were identified. Stimulating variables exert a positive influence, whereas destimulating variables exert a negative influence on a given phenomenon. All destimulating variables were converted to stimulating variables. To compare the relative impact of each variable, the analyzed variables were standardized with the use of below formula:

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$$X` = \frac{x_i - x_{avg}}{\delta}$$

where;

x_i – value of attribute,
x_{avg} – average value of attribute in the analyzed sample,
δ – standard deviation of a sample.

Perkal's synthetic indicator was calculated in the next stage of the study. The indicator is expressed by the sum of partial standardized values, and it was calculated with the use of the following formula:

$$WP = \frac{1}{n}\sum_{j=1}^{n} X`_{ij}$$

where:

WP – Perkal's indicator,
$X`_{ij}$ – standardized value of the j-th attribute in the *i*-th object when destimulating variables are converted to stimulating variables,
n – number of objects.

Perkal's indicator is applied to rank objects based on a set of selected attributes. The objective of the

Table 4. Indicators of spatial order selected for analysis in each dimension

		Social dimension	**Variables***
X_1	Demography	Natural increase per 1000 population	S
X_2	Education	Number of children aged 3–5 years per one place in preschool education establishments	D
X_3	Healthcare	Number of outpatient clinics per 10,000 population	S
X_4	Culture, sports and recreation	Registered public library users per 1000 population	S
X_5	Employment	Unemployment rate in the working age population	D
X_6	Social participation	Number of foundations, associations and social organizations entered into the REGON register per 1000 population	S
X_7	Safety	Total expenditure on public safety and fire protection services per capita	S
		Economic dimension	
X_8	Municipal finance	Municipal own-source revenue per capita	S
X_9	Entrepreneurship	Number of business entities entered in the REGON register per 10,000 population	S
X_{10}	Economic dependency by age	Dependency ratio (number of people of non-working age per 100 persons of working age)	D
X_{11}	Housing	Number of new build dwellings per 10,000 population – three-year average	S
X_{12}	Tourism	Number of beds in tourist establishments per 1000 population	S
X_{13}	Public utilities	Length of the sewer network per 100 km^2	S
X_{14}	Availability of public utilities	Percentage population served by sewer networks in total population	S
		Environmental dimension	
X_{15}	Environmental protection	Legally protected area in the total area of the municipality	S
X_{16}		Natural monuments per 100 km^2	S
X_{17}	Municipal services	Household waste collected per year per capita	D
X_{18}		Industrial and municipal wastewater that requires treatment and is evacuated to water bodies or the ground per year per capita	D
X_{19}	Resource use	Water consumption per capita	D
X_{20}	Land management	Forest cover	S
X_{21}		Area covered by local zoning plans in total area	S

* S – stimulating variables; D – destimulating variables
Source: own elaboration.

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ranking process is to determine which objects occupy higher positions in the ranking. The results obtained in each analyzed dimension (social, economic and environmental) were presented in diagrams. The results were analyzed and discussed in the last stage of the study.

Study area – Olsztyn Functional Urban Area

The Act on spatial planning and land management [Act on spatial planning and land management, 2003] defines functional areas and functional urban areas of the capital cities of Polish voivodeships. In the light of the above act, a functional area is defined as a compact spatial structure composed of functionally related areas with similar conditions for development and similar anticipated development goals, where various spatial phenomena or spatial conflicts occur. Functional urban areas of the capital cities of Polish voivodeships are functional areas that play special role in the national spatial policy. Such a functional urban area is composed of a city which is the seat of a voivodeship self-government or a voivodeship governor as well as adjoining areas that are functionally linked with the urban core [Act on spatial planning and land management, 2003].

The Olsztyn Functional Urban Area is situated in the voivodeship of Warmia and Mazury. It consists of the urban core – city of Olsztyn and six municipalities that surround the urban core (Table 5). The municipalities within the Olsztyn Functional Urban Area differ considerably in population and area. As the capital city of the voivodeship of Warmia and Mazury, Olsztyn plays an important role in the national and regional settlement network, and it is part of a functional network of Polish cities. Olsztyn performs a wide range of functions at the national level as well as several metropolitan functions. The city's functions extend beyond its administrative boundaries. The urban core and the surrounding suburban areas are bound by increasingly stronger functional and spatial links, as demonstrated by the number of residents who commute to work and school on a daily basis. Rapid suburbanization is a negative consequence of these processes [Land use plan of the Voivodeship of Warmia and Mazury, 2018].

Table 5. Municipalities of the Olsztyn Functional Urban Area

No.	Municipality	Type	Population (2019)	Area [km^2] (2019)
	Urban core			
1.	Olsztyn	urban	171,979	88
	External zone of the functional urban area			
2.	Stawiguda	rural	10,548	223
3.	Jonkowo	rural	7430	169
4.	Gietrzwałd	rural	6685	172
5.	Dywity	rural	12,004	161
6.	Barczewo	urban--rural	18,019	320
7.	Purda	rural	8708	317

Source: own elaboration.

RESULTS AND DISCUSSION

Data relating to spatial order in social, economic and environmental dimensions were analyzed. The changes that took place in the examined decade (2010 to 2019) were first analyzed in the dynamic approach, followed by the static approach (2019). The municipalities in the functional urban area were evaluated and ranked in each dimension of spatial order. The extent to which the observed changes affected spatial order in the investigated municipalities was discussed.

Social dimension

The social dimension of spatial order concerns the processes and changes relating to demography, employment, education, healthcare, safety, culture, entertainment, sports and social participation. Considerable changes in these areas took place in all of the analyzed territorial units between 2010 and 2019 (Fig. 2a). The observed changes were largely positive in the municipalities surrounding the urban core, in particular in Stawiguda as well as Dywity and Jonkowo. A marked decrease in the unemployment

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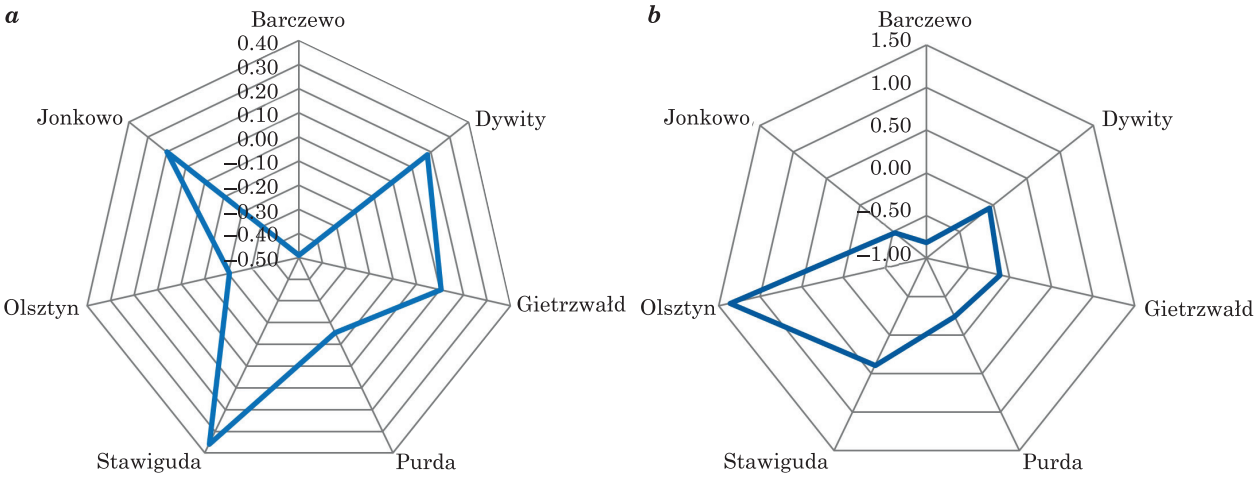

Fig. 2. Perkal's indicator in the social dimension (a) in the dynamic (2010–2019) and static (b) approach (2019)
Source: own elaboration.

rate in the working age population and an increase in the number of foundations, associations and social organizations were noted in all territorial units. Total expenditure on public safety and fire protection services and total expenditure on healthcare increased in most of the evaluated municipalities. The population growth rate decreased in the Olsztyn functional urban area, but this negative phenomenon is consistent with the national trend. Population growth was highest in the Stawiguda municipality. Most changes in the functional urban area were positive, and they contributed to an improvement in the social dimension of spatial order.

In 2019, the most favorable values of the analyzed social indicators were noted in the city of Olsztyn (Fig. 2b). Between 2010 and 2019, not all changes and processes in the functional urban area were desirable (compared with the remaining territorial units), and Olsztyn ranked first and second in all categories of social order. The Stawiguda municipality was also characterized by largely positive social trends, including very high population growth and the lowest unemployment rate. Social indicators also assumed largely positive values in the municipalities of Dywity and Gietrzwałd. The least satisfactory values of social indicators were observed in the Barczewo municipality which was characterized by the highest unemployment and the lowest population growth.

An analysis of the social dimension of spatial order and its changes in the functional urban area revealed that the social situation was most favorable in the city of Olsztyn, which differed considerably from the surrounding municipalities, followed by the Stawiguda municipality. The most positive changes were observed in the municipalities of Stawiguda, Dywity and Jonkowo. In turn, the Barczewo municipality was characterized by the least favorable social situation and the least desirable social changes in the examined period.

Economic dimension

The economic dimension of spatial order concerns the processes and changes associated with entrepreneurship, economic dependency by age, the financial performance of territorial units, the availability of public utilities, housing and tourism. The economic performance of all analyzed territorial units improved between 2010 and 2019. The most positive changes were noted in the external zone of the functional urban area (Fig. 3a). Own-source revenues per capita increased in all territorial units, which points to the growing affluence of the examined municipalities. A clear improvement was also observed in the entrepreneurship category (highest in the Gietrzwałd municipality and lowest in the city

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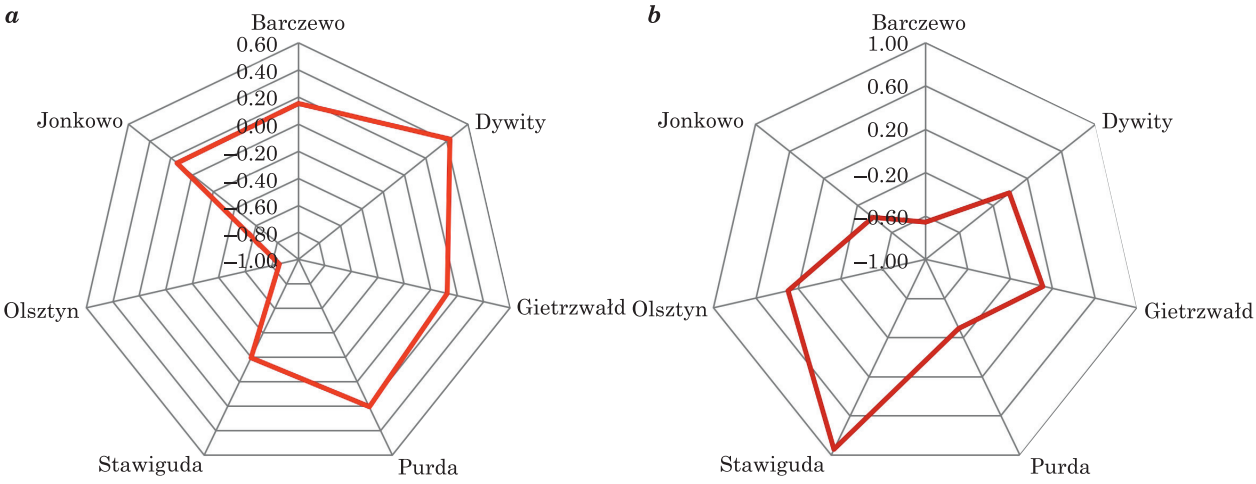

Fig. 3. Perkal's indicator in the economic dimension (a) in the dynamic (2010–2019) and static (b) approach (2019)
Source: own elaboration.

of Olsztyn). The availability of public utilities improved in all examined territorial units. An increase was noted in the length of the sewer network per 100 km^2 (by more than 170% in Purda and Jonkowo) and the percentage of population served by sewer networks (by more than 45% in Gietrzwałd, and by more than 80% in Jonkowo). The Stawiguda municipality witnessed particularly desirable changes in housing construction. The greatest positive changes in the economic dimension were noted in Dywity, followed by Jonkowo and Purda. The city of Olsztyn and the municipality of Stawiguda were characterized by the smallest changes in the evaluated economic indicators.

In 2019, Stawiguda ranked first in terms of economic performance, and it clearly outpaced the remaining municipalities in this respect (Fig. 3b). A favorable situation was also observed in the city of Olsztyn. Stawiguda and Olsztyn ranked first or second in all of the analyzed economic categories. They were characterized by the highest own-source revenues per capita, the greatest availability of public utilities, the highest level of entrepreneurship, and positive changes in housing construction. Despite the above, Olsztyn was also characterized by the least desirable dependency ratio with nearly 70 people of non-working age per 100 persons of working age. In the remaining municipalities, this parameter ranged from 53 to 58 people of non-working age per 100 working-age population. In the static approach, the remaining municipalities were ranked in the following order based on the values of the analyzed economic indicators: Gietrzwałd, Dywity, Purda, Jonkowo and Barczewo. In 2019, Barczewo was characterized by the lowest own-source revenues per capita and the lowest entrepreneurship rate.

An analysis of the economic dimension of spatial order and its changes in the functional urban area revealed that the city of Olsztyn city and the municipality of Stawiguda were characterized by the highest levels of economic performance, and they differed most significantly from the remaining territorial units in this respect. The greatest positive changes were noted in the external zone of the functional urban area (municipalities of Dywity, Barczewo, Jonkowo, Purda and Gietrzwałd). These findings indicate that the municipalities surrounding the urban core are steadily improving their economic performance (the noted changes were most pronounced in these municipalities), which contributes to the sustainable development of the entire functional urban area.

Environmental dimension

The environmental dimension of spatial order relates to environmental protection, municipal services, resource use and land management. Changes

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in the environmental dimension were observed in all analyzed territorial units between 2010 and 2019. Positive changes were noted in Olsztyn and in the municipalities of Jonkowo, Barczewo and Dywity, whereas relatively unfavorable changes were observed in the municipalities of Stawiguda, Purda and Gietrzwałd (Fig. 4a). In 2010–2019, the share of legally protected areas increased in most municipalities, and the greatest increase of 18% took place in Purda. A small decline in legally protected areas was observed in Stawiguda. The number of natural monuments increased only in Olsztyn (by 100%), and this parameter decreased or remained unchanged in the remaining municipalities. Forest cover increased in the entire external zone of the functional urban area, which contributed to environmental protection and improved the local environmental conditions. The volume of household waste collected per capita increased in all municipalities in the external zone of the functional urban area, and the said increase reached 19% in Gietrzwałd and 23% in Stawiguda. A significant increase in the volume of generated municipal and industrial wastewater per capita was observed in the municipalities of Purda (140%) and Gietrzwałd (53%). In turn, the volume of wastewater that requires treatment decreased by around 20% in Barczewo and Dywity. Water consumption per capita increased considerably in most of the examined municipalities, which was an undesirable change.

In 2019, the Purda municipality ranked first in the environmental dimension of spatial order, and it clearly outpaced the remaining territorial units in this respect (Fig. 4b). The environmental status of Barczewo was also largely positive. Purda and Barczewo were characterized by the lowest volume of household waste collected per capita, lowest water consumption per capita, and the lowest volume of municipal and industrial waste per capita which was three to even four times lower than in the remaining municipalities. The percentage of legally protected areas was also highest in these municipalities. In the environmental ranking, Purda and Barczewo were followed by the municipalities of Gietrzwałd, Jonkowo and Dywity. The least satisfactory values of the analyzed environmental indicators were noted in Olsztyn and Stawiguda. These municipalities were characterized by the highest volume of municipal and industrial wastewater per capita (considerably higher than in the remaining municipalities), the highest volume of generated waste, and high water consumption per capita (which was highest in Stawiguda, differing considerably from the values noted in the remaining municipalities).

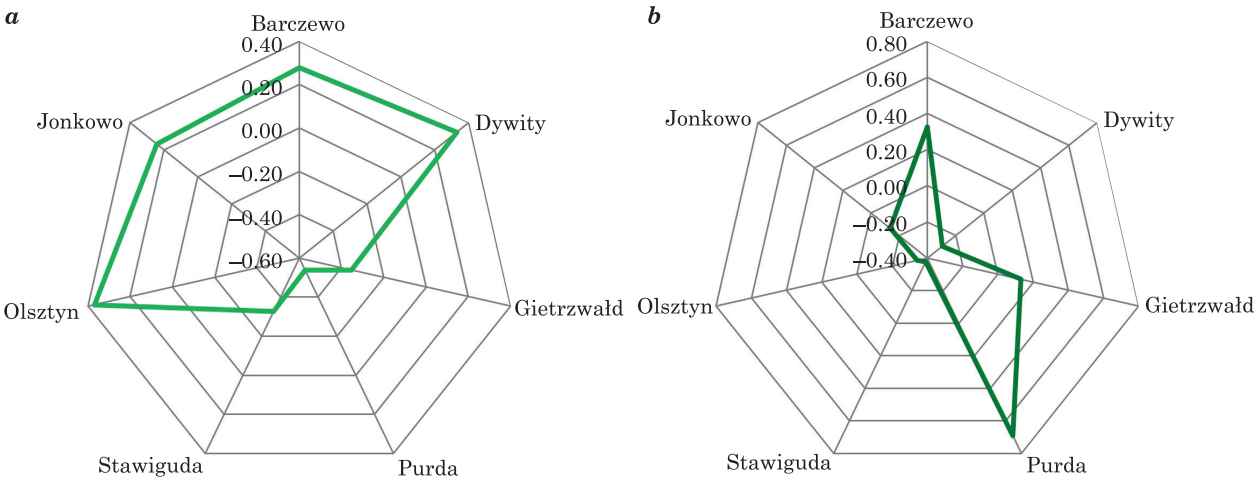

Fig. 4. Perkal's indicator in the environmental dimension (a) in the dynamic (2010–2019) and static (b) approach (2019)
Source: own elaboration.

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An analysis of the environmental dimension of spatial order in the functional urban area revealed that despite relatively unfavorable changes noted in Purda, this municipality was characterized by the most satisfactory environmental status. It should be noted that most municipalities where positive environmental changes had occurred in the examined period (Olsztyn, Jonkowo, Barczewo and Dywity) ranked last in the analysis of 2019. These findings suggest that urbanization processes exerted the greatest impact on the current environmental status of the studied territorial units. In most municipalities, waste production, wastewater generation and water consumption continued to increase steadily in the evaluated period. These changes exert a negative impact on the natural environment.

Spatial order in the Olsztyn Functional Urban Area

The evaluation of spatial order in each of the analyzed dimensions (social, economic and environmental) revealed certain differences between territorial units that constitute the Olsztyn functional urban area. Between 2010 and 2019, visible changes occurred in every dimension in all municipalities (Fig. 5). The most even changes were observed in the municipalities of Jonkowo and Dywity. Dywity ranked third in the social dimension, first in the economic dimension, and second in the environmental dimension, whereas Jonkowo occupied the second, third and third position in the above ranking, respectively. The most diverse changes in the examined dimensions of spatial order were noted in the city of Olsztyn and in the municipality of Stawiguda. Olsztyn experienced the most profound changes in the environmental dimension, whereas its economic performance remained most stable in the analyzed period relative to the remaining territorial units. Olsztyn also ranked second to last with respect to changes in the social dimension. In turn, Stawiguda was characterized by the most profound changes in the social dimension, but it lagged behind the remaining municipalities in the ranking based on economic and environmental indicators. In the social and economic dimensions, the most rapid changes took place in the external zone of the functional urban area.

An analysis of spatial order data for 2019 (Fig. 6) revealed that the city of Olsztyn and the municipality of Stawiguda clearly outranked the remaining territorial units in social and economic dimensions. These municipalities were characterized by the most

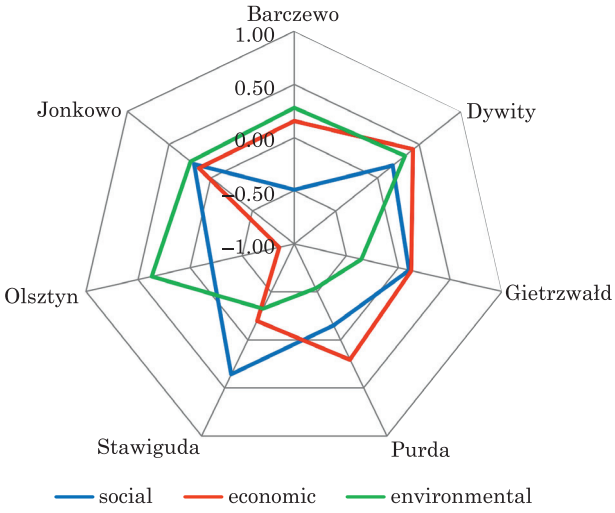

Fig. 5. Changes in spatial order in the Olsztyn Functional Urban Area between 2010 and 2019
Source: own elaboration.

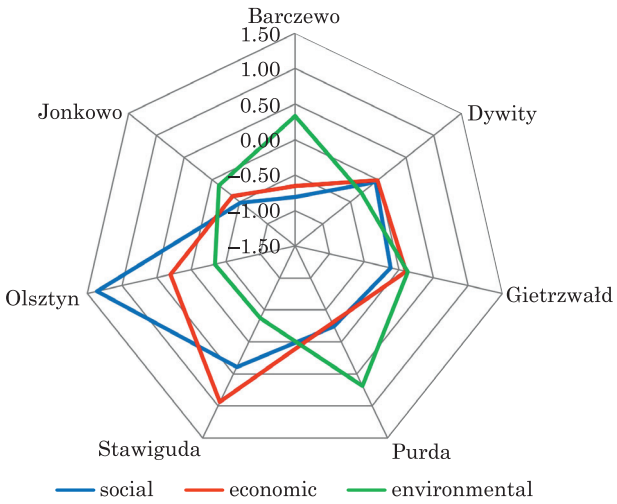

Fig. 6. Spatial order in the Olsztyn Functional Urban Area in 2019
Source: own elaboration.

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satisfactory social and economic status, but relatively unfavorable values of environmental indicators in comparison with the remaining territorial units. The values of social and economic indicators were also relatively satisfactory in Dywity and Gietrzwałd, and they were least favorable in Purda, Jonkowo and Barczewo. At the same time, Purda and Barczewo emerged as the leading municipalities in the environmental dimension.

The study demonstrated that municipalities with the highest ranking in the social and economic dimension were characterized by the least satisfactory performance in the environmental dimension (Olsztyn and Stawiguda), which can be largely attributed to urbanization and the development of suburban zones. At the same time, municipalities with the most favorable environmental status ranked last in the social and economic dimensions of spatial order (Purda and Barczewo). Considerable and largely positive changes were noted in all territorial units between 2010 and 2019. The highest levels of development were observed in the municipalities surrounding the urban core. The most positive changes occurred in the economic dimension. The performance of all territorial units improved in the examined period, with Olsztyn and Stawiguda as the main drivers of economic growth in the functional urban area. However, economic growth and social development were accompanied by a decline in the environmental dimension.

The preservation of spatial order in all analyzed dimensions is a very important goal that promotes sustainable development not only in individual units of territorial administration, but also in the entire functional urban area. Special emphasis should be placed on environmental protection because the relevant indicators were below the optimal values in the studied area. Socioeconomic development should be balanced with environmental protection to promote spatial order and improve the quality of life.

CONCLUSIONS

Spatial order and sustainable development should be the pillars of spatial policy at both the local and central levels of administration. Various methods, diagnostic attributes, criteria and approaches can be applied to measure spatial order. However, regardless of the adopted research methodology, changes in space should be regularly monitored and development goals should be set in a manner that promotes the preservation of spatial order and sustainable development of entire regions. The achievement of these goals requires well-planned implementing actions, strategies and political decisions at the local, regional and national level. Acts of local law, documents, programs and strategies that aim to improve the quality of life in an environmentally-friendly manner and protect the existing resources for future generations contribute to the preservation of spatial order. A functional approach to urban development that extends beyond the administrative boundaries of urban areas is becoming increasingly popular. These areas are experiencing growing urbanization pressure, which is why the implemented strategies and programs should be geared towards the achievement of sustainable development goals.

The current study demonstrated that multi-dimensional comparative analyses support measurements of spatial order in the static and dynamic approach. Both approaches were combined to identify the full spectrum of changes in space. The study revealed positive changes in the economic and social dimension of spatial order in the Olsztyn Functional Area, whereas the environmental dimension requires special attention. The results of the presented analyses indicate that changes in the social, economic and environmental dimensions of space should be regularly monitored to ensure that local policies and strategies contribute to the preservation of spatial order. Regular monitoring efforts also facilitate early identification of the emerging problems and conflicts.

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The municipalities belonging to functional urban areas should be regarded not only as distinct territorial units, but also as members of a cohesive area whose development in every dimension of spatial order contributes to an improvement in the quality of life for local communities.

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