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Differences in development levels of urban gminas in the Warmińsko-Mazurskie voivodship in view of the main components of sustainable development

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Abstract. The aim of this study was to evaluate various components of sustainable development (social, spatial-environmental, economic) in urban gminas (administrative region of the 3rd order in Poland) of the Warmińsko-Mazurskie voivodship (administrative region of the 1st order in Poland). The results were used to rank the analyzed gminas in terms of their sustainable development levels. The analysis was performed with the use of Hellwig's composite measure of development. The results were used to determine the overall value of the composite measure, calculated as the median of composite measures for each of the three components of sustainable development. The above approach was used to rank gminas in view of their sustainable development levels.
Data for the analysis was supplied by the Local Data Bank of the Central Statistical Office and the Local Government Analysis System for 2010 covering 16 gminas in the Warmińsko-Mazurskie voivodship. The results of the analysis point to variations in the value of the main components of sustainable development in the evaluated urban gminas in the Warmińsko-Mazurskie voivodship.

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1. Introduction

The main goal of sustainable development is to stimulate economic and social growth while minimizing its adverse impacts on the natural environment. Sustainable development promotes the rational use of natural resources without compromising the ability of future generations to satisfy their needs (Hopwood et al., 2005; Pawlewicz, Pawlewicz, 2011). The term sustainability as used here refers to a particular relationship between human and environmental systems – one that ensures meeting human needs in the long term (Alberti, 1996). Sustainability, first defined over 30 years ago, is widely accepted as a valid conceptual framework within which to position urban policy and development, providing the context for a considerable literature on planning, architecture and urban design (Williams et al., 2000 cited in Dempsey et al., 2011) Sustainable development is gradually emerging as the main concept in development strategies of all territorial units (Sharachchandra, 1991). A review of the literature that has sprung up around the concept of sustainable development indicates, however, a lack of consistency in its interpretation. Based on a review of the literature (Borys, 2005; Adamowicz, Dresler, 2006; Adamowicz, Smarzewska, 2009; Mierzejewska, 2010; Dempsey et al., 2011; Matuszczak, 2011) and deductive reasoning, we assumed that sustainable development can be characterized by its three main components: social, spatial-environmental and economic, which were defined as follows: (a) social development – man's ability to improve quality of life, promote development and self-actualization; (b) spatial-environmental development – implementation of ecological infrastructure for using environmental goods and services without compromising their contribution to human welfare; (c) economic development – achievement of economic progress through generation of higher incomes from human activity and enterprise.

Effective implementation of sustainable development policies requires specific tools for analyzing present levels of development and predicting future changes. Sustainable development is monitored with the application of analytical indicators that generate comprehensive information about the levels of development in a territorial unit and describe its relations with other territorial units (Korol, 2007). The aim of this study was to evaluate various components of sustainable development in urban gminas of the Warmińsko-Mazurskie voivodship (administrative region of the 1st order in Poland). This approach was used to rank the analyzed gminas (administrative region of the 3rd order in Poland) in terms of their sustainable development levels.

2. Materials and methods

Sustainable development is a complex concept that cannot be measured or expressed by a single trait. It combines three major components – social, spatial-environmental and economic that are also complex phenomena. In evaluations of sustainable development levels, the analyzed objects, such as gminas, are classified in view of the examined structural aspect – a complex phenomenon that cannot be quantified or expressed by a single trait (Wysocki, 2010). Complex phenomena are described with the use of synthetic variables where a set of multiple indicators is replaced by a single composite variable (Cieślak, 2001).

Hellwig's composite measure of development is one of the oldest and the most popular methods of determining synthetic variables (Hellwig, 1968; Strahl, 1984; Malina, Zeliaś, 1997; Sojka, 2008; Pomianek, 2010; Wysocki, 2010). Diagnostic variables are selected from a set of potential variables characterizing the investigated phenomenon. The following indicators were identified based on a review of the available literature (Bossel, 1999; Bell, Morse, 2003; Kistowski, 2003; Audyt …, 2004; Borys, 2005, 2008; Korol, 2007). Fifteen indicators were selected for every component to produce a total of 45 components describing sustainable development levels. Variables were chosen subject to their availability and completeness.

I. Social components:

x_1 – migration balance per 1,000 people (‰);
x_2 – infant deaths per 1,000 live births (‰);
x_3 – number of kindergarten pupils aged 3-6 per 100 children aged 3-6;
x_4 – gross scholarization index for primary schools (%);
x_5 – total expenditure on education on per capita (PLN);

x_6 – total expenditure on social security per capita (PLN);
x_7 – expenditure on health care per capita (PLN);
x_8 – expenditure on public roads per capita (PLN);
x_9 – expenditure on street lighting per capita (PLN);
x_{10} – total expenditure on housing per capita (PLN);
x_{11} – percentage of households with bathrooms (bathtubs and showers with a water outlet) in the total number of households (%);
x_{12} expenditure on sport and physical education per capita (PLN);
x_{13} – expenditure on culture and national heritage protection per capita (PLN);
x_{14} – percentage of women in municipal councils (%);
x_{15} – unemployment per 100 residents of working age.

II. Spatial and environmental components:

x_{16} – area of municipal parks, street greens and residential green spaces per 10,000 people (ha/person);
x_{17} – expenditure on municipal services and environmental protection per resident (PLN);
x_{18} – share of expenditure on municipal services and environmental protection in total expenditure (%);
x_{19} – expenditure on public green spaces per resident (PLN);
x_{20} – number of natural monuments per 100 km^2 of municipal territory;
x_{21} – percentage of land area covered by forests in municipal territory;
x_{22} – percentage of land area covered by municipal and private forests in total forest area (%);
x_{23} – annual production of municipal waste per resident (kg);
x_{24} – water consumption by industry and households per 1,000 residents;
x_{25} – water consumption per resident (m^3/year);
x_{26} – percentage of residents served by municipal wastewater treatment plants in the total number of residents (%);
x_{27} – volume of wastewater generated by residents who are served by municipal wastewater treatment plants (dm^3/year/resident);
x_{28} – percentage of residents with access to the municipal water supply system in the total number of residents (%);
x_{29} – percentage of residents with access to the municipal sewage system in the total number of residents (%);
x_{30} – electricity consumption per resident (MWh).

III. Economic components:

x_{31} – total revenues of the local government per resident (PLN);
x_{32} – self-generated revenues of the local government per resident (PLN);
x_{33} – local government expenditures per resident (PLN);
x_{34} – municipal investments per resident (PLN);
x_{35} – number of business entities per 1,000 residents;
x_{36} – number of self-employed persons per 1,000 residents;
x_{37} – total number of privately-owned businesses per 1,000 residents;
x_{38} – professional activity rate – percentage of professionally active residents in the total number of residents aged 15+ (%);
x_{39} – demographic dependency ratio – share of residents of non-working age in the total number of residents (%);
x_{40} – average number of persons per household;
x_{41} – average living space per person;
x_{42} – number of guests per hotel or tourist facility;
x_{43} – length of operable water supply network (km) per 100 km^2;
x_{44} – length of operable sewage network (km) per 100 km^2;
x_{45} – length of operable gas supply network (km) per 100 km^2.

Synthetic variables were developed based on the observation matrix that can be expressed as follows:

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1m} \\ x_{21} & x_{22} & \dots & x_{2m} \\ \dots & \dots & \dots & \dots \\ x_{n1} & x_{n2} & \dots & x_{nm} \end{bmatrix},$$

where: x_{ij} (i = 1,2, …, n; j = 1,2, …, m) – value of the j^{th} attribute (economic, social and spatial-environmental components of sustainable development) for the i^{th} object (urban gmina).

Diagnostic variables can have different physical dimensions, and they cannot be directly compared. To enable such a comparison, the examined attributes have to be normalized by eliminating the effect of units of measurement. The analyzed parameters were standardized in line with the below formula:

$$z_{ij} = \frac{\left(x_{ij} - \overline{x}_j\right)}{S_j}; \quad \left(j = 1,2,\ldots,m\right),$$

where:

$$\overline{x}_j = \frac{1}{n}\sum_{i=1}^{n} x_{ij}, \quad s_j = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_{ij} - x_j\right)^2}$$

The above transformations produced a matrix of standardized parameter values – Z.

$$Z = \begin{bmatrix} z_{11} & z_{12} & \ldots & z_{1m} \\ z_{21} & z_{22} & \ldots & z_{2m} \\ \ldots & \ldots & \ldots & \ldots \\ z_{n1} & z_{n2} & \ldots & z_{nm} \end{bmatrix},$$

The resulting matrix was used to determine a "pattern of development" – an abstract object P_0 (urban gmina) with coordinates $P_0 = \left[z_{01}, z_{02}, \ldots, z_{oj}\right]$, where: $z_{0j} = \max\{z_{ij}\}$, when Z_j is a stimulant, and $z_{0j} = \min\{z_{ij}\}$, when Z_j is a destimulant. The above indicates that the "pattern of development" is represented by a hypothetical urban gmina with the most desirable values of the analyzed variables.

The Euclidean distance between every evaluated object P_i(urban gmina) and the identified "pattern of development" was calculated using the below formula:

$$qi = \sqrt{\sum_{j=1}^{m}\left(z_{ij} - z_{oj}\right)^2},$$

The resulting values of q_i were used to calculate the value of Hellwig's synthetic measure of development, which was applied to evaluate the examined urban gminas. The above indicator can be expressed with the use of the below formula:

$$S_i = 1 - \frac{q_i}{q_o}, \quad \left(i = 1,2,\ldots,n\right),$$

where:

$$q_0 = \overline{q}_0 + 2s_0, \quad \overline{q}_0 = \frac{1}{n}\sum_{i=1}^{n} q_i, \quad s_0 = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(qi = \overline{q}_0\right)^2}.$$

In most cases, Hellwig's synthetic measure of development S_i takes on values in the range of (0,1). The closer the value of the indicator is to one, the higher the value of social, spatial-environmental and economic components of sustainable development in the studied object.

The investigated gminas were classified based on the value of social, spatial-environmental and economic components of sustainable development using standard deviation and the arithmetic mean of Hellwig's synthetic measure of development.

Four classes (four values of social, spatial-environmental and economic components of sustainable development) have been identified (Wysocki, 2010):

— class I (high values of social, spatial-environmental and economic components of sustainable development) $S_i \geq \overline{S}_i + s_{s_i}$,
— class II (moderately high values of social, spatial-environmental and economic components of sustainable development) $\overline{S}_i \leq S_i < \overline{S}_i + s_{s_i}$, ,
— class III (moderately low values of social, spatial-environmental and economic components of sustainable development) $\overline{S}_i - s_{s_i} \leq S_i < \overline{S}_i$, ,
— class IV (low values of social, spatial-environmental and economic components of sustainable development) $S_i < \overline{S}_i - s_{s_i}$, ,

where:

S_i – value of the synthetic measure calculated based on Hellwig's pattern of development,
$\overline{S}_i$ – arithmetic mean of synthetic measure S_i,
s_{s_i} – standard deviation of synthetic measure S_i.

A compound measure illustrating variations in sustainable development levels of urban gminas in the Warmińsko-Mazurskie voivodship was determined. It was calculated based on the values of synthetic variables (S_i) as the median of composite measures representing different components of sustainable development.

3. Analyzed area

The Warmińsko-Mazurskie voivodship is situated in north-eastern Poland. It borders the Kaliningrad Oblast in the north, the Kujawsko-Pomorskie voivodship in the west, the Podlaskie voivodship

in the east and the Mazowieckie voivodship in the west. In Poland and in Europe, the evaluated region is renowned for the diversity and abundance of its natural resources, including varied land relief, numerous lakes, dense forests, rich fauna and flora and clean air (Brodzińska, 2012). Nearly all of Warmia and Mazury is situated in an area known as the Green Lungs of Poland. For this reason, sustainable development is a particularly important goal in the region where social and economic development should be closely linked with environmental protection.

The analyzed region has the area of 24,173 km^2 and occupies 7.7% of Poland's territory. The Warmińsko-Mazurskie voivodship is the fourth largest Polish region. It is inhabited by 1.43 million people who represent 3.7% of the national population. The average population density in Poland is 122 persons/km^2, and Warmia and Mazury is the least densely populated Polish region with population density of approximately 60 persons/km^2. The analyzed region comprises 19 rural counties, 2 urban counties and 116 territorial units (16 urban gminas, 33 urban-rural gminas and 67 rural gminas) (Borawska et al., 2012).

The density and distribution of urban areas play an important role in a region's sustainable development. In Warmia and Mazury, the settlement network comprises the centrally located capital city of Olsztyn, two relatively large cities of Elbląg in the western part and Ełk in the eastern part of the region, as well as uniformly distributed county capitals and smaller towns. The existing settlement network supports effective management of the region (Brodziński, 2011).

4. Results

In line with the adopted procedure, Hellwig's composite measure of development was used to rank urban gminas in the Warmińsko-Mazurskie voivodship into four classes based on the respective values of sustainable development components. The results are presented in Tables 1, 2, 3.

Table 1. Social component in urban gminas of the Warmińsko-Mazurskie voivodship evaluated based on Hellwig's composite measure of development

Class		Range	Gmina	Place in ranking	Value of composite measure (S_i)
I	high value of the social component	≥0.198	Elbląg	1	0.244
			Lidzbark Warmiński	2	0.237
			Olsztyn	3	0.221
II	moderately high value of the social component	0.197-0.132	Iława	4	0.194
			Górowo Iławeckie	5	0.169
			Giżycko	6	0.157
III	moderately low value of the social component	0.131-0.066	Mrągowo	7	0.123
			Bartoszyce	8	0.121
			Lubawa	9	0.119
			Działdowo	10	0.117
			Szczytno	11	0.114
			Ostróda	12	0.093
			Kętrzyn	13	0.089
IV	low value of the social component	<0.066	Braniewo	14	0.065
			Ełk	15	0.042
			Nowe Miasto Lubawskie	16	0.008

Source: Own study

Social component values varied significantly across the analyzed urban gminas in the Warmińsko-Mazurskie voivodship. Hellwig's composite measure of development was determined in the range of 0.008 for Nowe Miasto Lubawskie to 0.244 for Elbląg. Three cities – Olsztyn, Elbląg (the largest urban centers that constitute urban counties) and Lidzbark Warmiński – were allocated to the group characterized by the highest value of the social component (class I). In comparison with the regional average, those cities were characterized by relatively high spending on social security, public roads, culture and national heritage protection as well as a high number of kindergarten pupils. Class II of territorial units with moderately high values of the social component covered 3 gminas of Iława, Górowo Iławeckie and Giżycko. The highest number of 7 gminas with moderately low values of the social component were allocated to class III. Class IV, characterized by low values of the social component, comprised 3 gminas of Braniewo, Ełk and Nowe Miasto Lubawskie. The main problems identified in class IV gminas were high unemployment and relatively low spending on health care, public roads and housing that was below the regional average.

Table 2. Spatial-environmental component in urban gminas of the Warmińsko-Mazurskie voivodship evaluated based on Hellwig's composite measure of development

Class		Range	Gmina	Place in ranking	Value of composite measure (S_i)
I	high value of the spatial-environmental component	≥0.301	Górowo Iławeckie	1	0.434
			Giżycko	2	0.337
			Olsztyn	3	0.308
II	moderately high value of the spatial-environmental component	0.300-0.201	Mrągowo	4	0.272
			Bartoszyce	5	0.226
			Braniewo	6	0.218
			Działdowo	7	0.214
III	moderately low value of the spatial-environmental component	0.200-0.100	Szczytno	8	0.194
			Elbląg	9	0.187
			Iława	10	0.182
			Ełk	11	0.162
			Lubawa	12	0.141
			Kętrzyn	13	0.140
			Ostróda	14	0.101
IV	low value of the spatial-environmental component	<0.100	Lidzbark Warmiński	15	0.091
			Nowe Miasto Lubawskie	16	0.003

Source: Own study

The value of the spatial-environmental component of sustainable development ranged from 0.003 to 0.434 in the group of 16 analyzed urban gminas. Similar to the evaluation of the social criterion, the lowest value of the spatial-environmental component was noted in Nowe Miasto Lubawskie, and the highest – in Górowo Iławeckie. Górowo Iławeckie, Olsztyn and Giżycko (a popular tourist destination in the region) were allocated to class I of gminas with high values of the spatial-environmental component. Those cities are characterized by high forest cover and a high percentage of residents who have access to municipal water supply and sewage networks. Four gminas of Mrągowo, Bartoszyce, Braniewo and Działdowo were ranked in class II of cities with moderately high values of the spatial-environmental component. Class III of cities characterized by moderately low values of the

spatial-environmental component covered 7 gminas, and class IV of the lowest-ranking cities – two gminas. The key challenges faced by the gminas with the lowest values of the spatial-environmental component were: sewage management problems, small area of municipal parks, street greens and residential green spaces and low forest cover that were significantly below the regional average.

Table 3. Economic component in urban gminas of the Warmińsko-Mazurskie voivodship evaluated based on Hellwig's composite measure of development

Class		Range	Gmina	Place in ranking	Value of composite measure (S_i)
I	high value of the economic component	≥0.316	Olsztyn	1	0.478
			Mrągowo	2	0.344
II	moderately high value of the economic component	0.315-0.211	Giżycko	3	0.294
			Elbląg	4	0.280
			Iława	5	0.275
			Ostróda	6	0.247
			Lidzbark Warmiński	7	0.241
III	moderately low value of the economic component	0.210-0.105	Szczytno	8	0.187
			Działdowo	9	0.184
			Bartoszyce	10	0.180
			Kętrzyn	11	0.154
			Lubawa	12	0.143
			Ełk	13	0.129
IV	low value of the economic component	<0.105	Nowe Miasto Lubawskie	14	0.096
			Górowo Iławeckie	15	0.076
			Braniewo	16	0.062

Source: Own study

The composite measure of the economic component of sustainable development in urban gminas of the Warmińsko-Mazurskie voivodship was determined in the range of 0.062 for Braniewo to 0.478 for Olsztyn. Class I comprised the gminas of Mrągowo and Olsztyn. It should be noted that the region's capital city was allocated to class I in the evaluations of all three sustainable development components. Mrągowo and Olsztyn were characterized by higher than average professional activity rates, a high number of business entities and self-employed residents, high levels of self-generated revenues and low demographic dependency ratios. Class II covered 5 gminas, class III – 6 gminas, and class IV – 3 gminas of Nowe Miasto Lubawskie (the lowest-ranking gmina in all evaluations), Braniewo and Górowo Iławeckie. The main problems of the gminas characterized by low values of the economic component were: low levels of self-generated revenue, low number of business entities, high demographic dependency ratios and low availability of water supply, sewage and gas supply networks.

The values of social, spatial-environmental and economic components were used to rank urban gminas of the Warmińsko-Mazurskie voivodship based on their levels of sustainable development. Figure 1 presents the ranking of the analyzed gminas and the overall value of the composite measure of development, calculated as the median of composite measures for every component of sustainable development in urban gminas of the Warmińsko-Mazurskie voivodship.

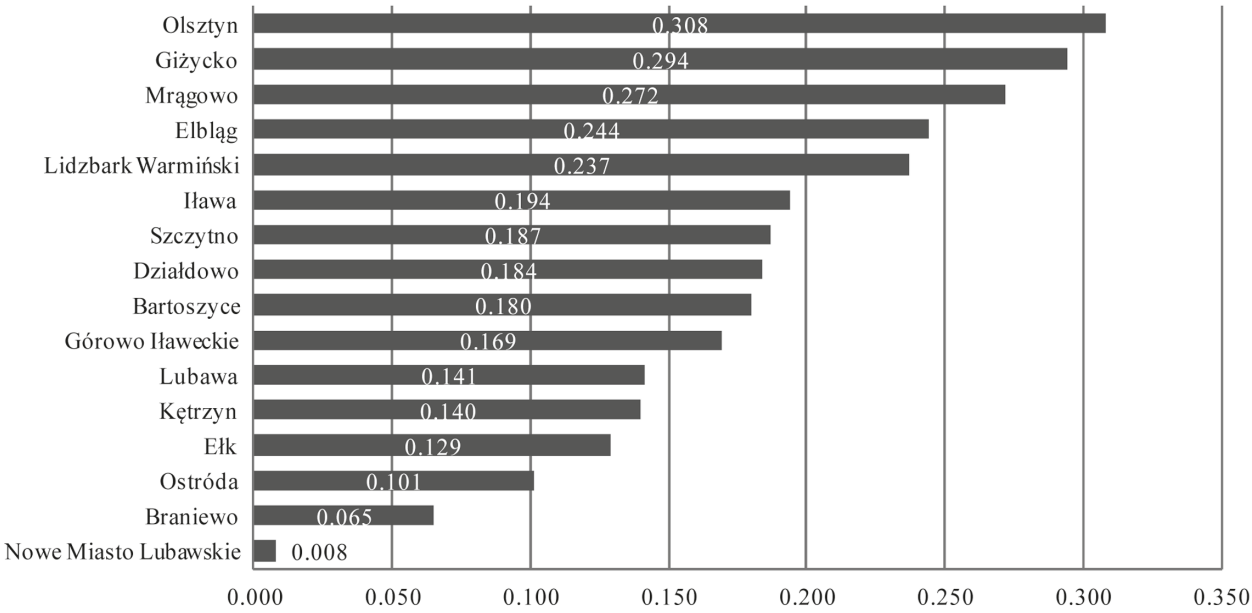

Fig. 1. Ranking of urban gminas of the Warmińsko-Mazurskie voivodship based on the values of the composite measure of sustainable development

Source: Own study

The leader in the sustainable development ranking of urban gminas was Olsztyn, followed by Giżycko, Mrągowo, Elbląg and Lidzbark Warmiński. Nowe Miasto Lubawskie was characterized by the lowest level of sustainable development, and it was allocated to class IV in all evaluated categories.

5. Conclusions

Urban gminas in the Warmińsko-Mazurskie voivodship were characterized by significant variations in the values of social, spatial-environmental and economic components of sustainable development.

Olsztyn, the capital city of the analyzed region, was the most highly developed urban gmina that was allocated to class I representing the highest values of sustainable development components in all three rankings.

The reported results can be attributed to: (a) financial status of the analyzed gmina which reported high revenues, including self-generated revenues, high capital expenditures, high spending on education, social welfare, healthcare, public roads, greens, municipal services and environmental protection; (b) local residents' enterprising and proactive attitudes, expressed by high rates of professional activity, low unemployment, a high number of business entities and self-employed residents; (c) a high percentage of urban greens, including parks, street greens, residential greens and forests in municipal area; (d) availability of products and services that improve local quality of life, expressed by a high percentage of local residents with access to wastewater treatment plants, sewer networks and water supply networks, as well as a high share of dwellings with bathrooms and a low average number of tenants per dwelling; (e) level of environmental awareness, expressed by low per capita consumption of electricity and water; (f) demographic factors, including low demographic dependency ratio, low emigration rate and high kindergarten enrollment in comparison with other cities in the region.

The lowest values of the analyzed components were reported in the gmina of Nowe Miasto Lubawskie that was characterized by the lowest level of sustainable development and was allocated to class IV in all three classifications.

The main problems faced by the gmina of Nowe Miasto Lubawskie are: (a) low revenues, including self-generated revenues, low capital expenditures and low spending on healthcare, public roads and greens; (b) high unemployment, a low num-

ber of business entities and self-employed residents; (c) small area of municipal greens – parks, street greens, residential greens and forests; (d) low access to water supply and sewer networks, a low percentage of the local population disposing their effluents to a wastewater treatment plant; (e) demographic problems, including high demographic dependency ratio and low kindergarten enrollment.

In general, urban gminas in the Warmińsko-Mazurskie voivodship were characterized by average values of sustainable development components. In most cases, most problems could be attributed to low availability of funds from the municipal budget due to low levels of municipal revenue, including self-generated revenue, which decreases spending in many strategic areas for sustainable development, including healthcare, culture, physical education, education, protection of national heritage, municipal services and environmental protection. Other municipal issues include low levels of professional activity, a low number of self-employed residents and an ageing society.

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