Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 182 (2017) 213 – 221

Procedia Engineering

www.elsevier.com/locate/procedia

7th International Conference on Engineering, Project, and Production Management

Assessment of the Interrelations between Economic and Ecological Development in Regions of Lithuania

Romualdas Ginevičius[a], Dainora Gedvilaitė[b], Andrius Stasiukynas[b,*]

[a]*Faculty of Management, Bialystok University of Technology, Wiejska 45A, 15-351 Bialystok, Poland*
[b]*Business Management Faculty, Vilnius Gediminas Technical University, Saulėtekio ave. 11, LT-10223 Vilnius, Lithuania*

Abstract

In order to analyse the interaction of three components of sustainable development – economic, social and environmental – they must be defined in quantitative terms. In this respect, the ecological development plays a special role, since both economic and social development goals must conform to environmental protection restrictions. The ecological development, just as the other components of sustainable development, is a complex thing that manifests itself in many different ways. The indicators that express them have various dimensions, and their manner of change can vary, i.e. one indicator rises as the situation improves while another may fall. Multi-criteria methods are well suited for the qualitative analysis of such manifestations. The goal of this paper is to perform a comprehensive analysis of Lithuania's regional economic and ecological development using the MDE method (Multi-criteria Different Evaluation), taking into account factors that both positively and negatively affect the ecological situation, and to determine the effect that economic development has on ecological development.

Peer-review under responsibility of the organizing committee of EPPM2016

Keywords: quantitative analysis; sustainable regional development; economic development; ecological development; MDE method; multi-criteria assessment

1. Introduction

Of the three components necessary for sustainable development, ecological development plays a special role. This becomes obvious when the interrelations between said components are analyzed in detail. We can see that the objectives of both economic and social development have to be compatible with the environmental limitations. Only

* Corresponding author. Tel.: +3-706-822-5390.
E-mail address: andrius.stasiukynas@vgtu.lt

Peer-review under responsibility of the organizing committee of EPPM2016
doi:10.1016/j.proeng.2017.03.169

in such cases will the main objectives of sustainable development – to meet the current needs of society by such ways and means that do not compromise the ability of future generations to meet their own needs – be achieved. However, in order to manage the process of sustainable development, its components must be assessed in a quantitative manner. Each one of these components is a complex phenomenon that is in reality expressed by many aspects. The indicators expressing them are multidimensional, as well as being different in the nature, i.e. an increase of the value of some indicators shows an improved situation, while an increase of another indicator may show a deteriorating situation. Therefore, multi-criteria methods are suitable for the quantitative assessment of such phenomena [1–3, 18]. An analysis of the literature shows that different views are applied in practice [4–7]. One of these is called the MDE (Multicriteria Different Evaluation) method, which allows for an assessment of the specific components of ecological development as a phenomenon [8].

This article describes an attempt to carry out a complex assessment of the economic and ecological development in the regions of Lithuania, employing the MDE method. To achieve this goal, an analysis of the literature, a multi-criteria analysis and mathematical statistics were employed.

1. Description of a multi-criteria assessment using the MDE method

This method was used for an analysis of the impact of economic development on the ecological development in Southeast European countries [8]. Its essential feature is that the factors responsible for improving the ecological situation and deteriorating it are integrated into one model. This model, in short form, is:

$$K_j = \sum_{i=1}^{l} w_i \widetilde{q}_i^{+} - \sum_{i=1}^{n} w_i \widetilde{q}_l^{-} \tag{1}$$

where:

K_j – value of the j country (region) using the multi-criteria MDE assessment method

w_i – weight of the indicator i ($i = \overline{1,n}$)

$\widetilde{q}_i^{+}$ – normalized value of the indicator i showing an improvement in the ecological situation

$\widetilde{q}_i^{-}$ – normalized value of the indicator i showing a deterioration of the ecological situation

m – number of indicators with the increase of their values, which shows an improving ecological situation ($i = \overline{1,m}$)

l – number of indicators with the decrease of their values, which shows a deterioration of the ecological situation ($i = \overline{1,n}$).

It is not difficult to notice when m or l = 0, i.e. when (1) formula does not contain indicators, the values of which show an improvement or deterioration of the situation, we have a multi-criteria assessment SAW (Simple Additive Weighting) method [9]:

$$K_j = \sum_{i=1}^{n} w_i \widetilde{q}_i \tag{2}$$

where:

$\widetilde{q}_i$ – normalized value of the indicator i.

The MDE multi-criteria assessment method differs from the SAW method in the procedure for the normalization of the values of the indicators. The MDE method uses the following method of normalization [8]:

$$\widetilde{q}_i = \frac{q_{ij}}{\max q_{ij}} \tag{3}$$

where:

q_i – value of the variant j (maximizing or minimizing) of indicator i

$\max q_{ij}$ – highest value of all the values of the j variant of indicator i.

The SAW method requires the nature of the change in all indicators to be the same, i.e. they have to be either maximizing or minimizing. The maximization of the values of the indicators is done in the following manner [9]:

$$\tilde{\tilde{q}}_{lj} = \frac{\min q_{lj}}{q_{lj}} \tag{4}$$

where:

$\tilde{\tilde{q}}_{lj}$ – maximized value of the variant j of indicator l

$\min q_{lj}$ – lowest value of all possible values of the variant j of indicator l.

The minimization of the values of the indicators is done in the following manner [9]:

$$\tilde{\tilde{q}}_{jm} = \frac{q_{im}}{\max q_{im}} \tag{5}$$

where:

$\tilde{\tilde{q}}_{jm}$ – minimized value of the variant j of the maximizing indicator m.

Where the objective of a multi-criteria assessment is to determine the state of an individual phenomenon, the normalization is performed based on formula (3) applying the SAW method. Where the objective of the multi-criteria assessment is to determine a ranking, the normalization of the values of the indicators is done in the following manner [10–12]:

$$\tilde{q}_i = \frac{q_i}{\sum_{i=1}^{n} q_i} \tag{6}$$

We can see from formulas (1) and (2) that in the first case both positive and negative values may be obtained; whereas in the second case, the obtained values may only be positive.

3. Assessment of the economic and ecological development in the regions of Lithuania applying the MDE method

To carry out a multi-criteria assessment of the economic and ecological development in the regions of Lithuania, first of all, a system of indicators needs to be formed. In some cases, this system is formed on the basis of the literature and from interviews with experts [13], while in other cases previous studies are taken into account, as well as the availability of sufficiently accurate data and the accessibility of the data. In the present case, the latter circumstance has determined the choice [8]. In Lithuania, information about the indicators of ecological development in a cross-section of regions in the country is annually published by Statistics Lithuania [14–16]. Based on this publication, the following system of indicators for ecological development in the regions was formed (Fig. 1).

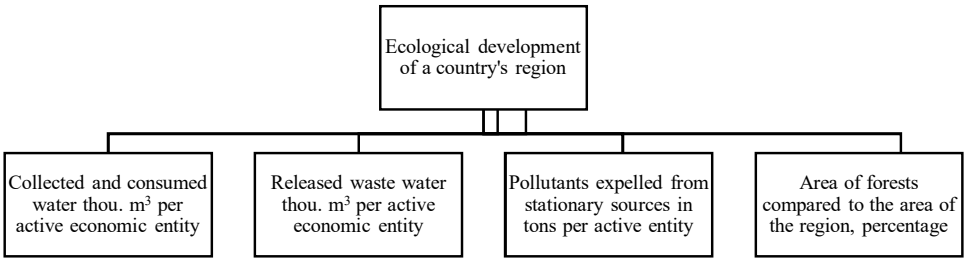

Fig. 1. System of indicators for ecological development in the regions of Lithuania.

From Fig. 1 we can see that the first three indicators are among those which show a deterioration of their situation when they increase, i.e. they are minimizing indicators. On the other hand, the fourth indicator for the area of forests compared to the total area of the region is a maximizing indicator, i.e. increasing its value signals an improvement of the situation. Thus, based on formula (1), the quantitative assessment of the ecological development in a region using the MDE model will be the following:

$$K_j = -w_1 q_1 - w_2 q_2 - w_3 q_3 + w_4 q_4 \tag{7}$$

where:

w_1, w_2, w_3, w_4 – respective weights of indicators one, two, three and four

q_1, q_2, q_3, q_4 – respective values of indicators one, two, three and four.

After performing an expert assessment of the importance of the indicators for ecological development in the regions, the compatibility of the expert opinions is verified using the value W, as the number of indicators which does not exceed 7 [17], thus:

$$W = \frac{S_f}{S_{\max}} \tag{8}$$

$$S_f = \sum_{i=1}^{n} \left| e_i - \bar{e} \right|^2 \tag{9}$$

$$S_{\max} = \frac{r^2 m\left(m^2 - 1\right)}{12} \tag{10}$$

where:

r – number of experts

m – number of indicators.

The result was W =0.86, which shows that the expert opinions are compatible. The final weights of the indicators for ecological development are as follows (Table 1).

Table 1. Weights of the indicators for ecological development in the regions of the country.

Name of the indicator	Collected and consumed water (thou. m^3) per active economic entity	Released waste water (thou. m^3) per active economic entity	Pollutants expelled from stationary sources of pollution (tons) per active economic entity	Area of forests compared to the area of the region (percentage)	Total
Weight of the indicator	0.25	0.15	0.5	0.1	1.0

Values of the indicators for ecological development in the regions of Lithuania are provided in Table 2.

Table 2. Values of the indicators for ecological development in the regions of Lithuania for 2010-2012.

No.	Name of ecological development indicators											
	Region	Collected and consumed water (thou. m^3) per active economic entity			Released waste water (thou. m^3) per active economic entity			Pollutants expelled from stationary sources of pollution (tons) per active economic entity			Area of forests compared to the area of the region (percentage)		
		2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012
1	Vilnius	31.027	21.16	26.824	15.731	10.7620	13.6709	8.10429	8.45289	7.9360	0.4369	0.44003	0.43900
2	Kaunas	2.9153	2.6081	2.7443	1.7678	1.98124	2.03469	0.62195	0.62956	0.63721	0.295957	0.29595	0.29694
3	Klaipėda	4.6939	4.2911	4.8110	3.3317	3.26283	3.46360	0.56430	1.45817	1.48850	0.26396	0.26396	0.26396
4	Alytus	6.5119	6.1906	6.1830	3.2803	2.93384	2.81866	3.42265	2.38313	2.45109	0.49106	0.49106	0.48995
5	Marijampolė	6.5678	6.5980	7.7927	4.1635	4.10132	4.63932	0.65104	0.74098	0.71204	0.21689	0.21689	0.21689
6	Panevėžys	4.0312	3.8472	4.1563	2.7545	2.49233	2.92926	3.46853	2.47811	1.58753	0.28194	0.28194	0.28194
7	Šiauliai	3.4868	3.3201	3.4321	2.7629	2.66661	435.338	1.78012	1.05586	1.07068	0.32400	0.32400	0.32400
8	Telšiai	5.8463	5.8306	6.3201	3.6779	4.24714	4.37913	7.2484	6.23043	5.22687	0.36092	0.36092	0.36092
9	Utena	74.404	69.882	58.475	36.888	35.2002	29.6232	0.69420	0.56684	0.68856	0.34106	0.34106	0.34106
10	Tauragė	380.63	280.63	274.49	190.08	140.008	136.516	1.36112	1.40081	1.44770	0.33008	0.33008	0.33008

Source: compiled by the authors, according to counties of Lithuania, 2010, 2011 and 2012.

To carry out a multi-criteria assessment of the ecological development in the regions of Lithuania by applying the MDE method, the data in Table 2 needed to be normalized using formula (3). The results are provided in Table 3.

Table 3. Normalized values of the indicators for ecological development in the regions of Lithuania.

No.	Name of ecological development indicators											
	Region	Collected and consumed water (thou. m^3) per active economic entity			Released waste water (thou. m^3) per active economic entity			Pollutants expelled from stationary sources of pollution (tons) per active economic entity			Area of forests compared to the area of the region (percentage)		
		2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012
1	Vilnius	0.0939	0.1232	0.1023	0.1123	0.18409	0.1488	1	1	1	0.8898	0.8960	0.8960
2	Kaunas	0.0076	0.0092	0.0099	0.0093	0.01415	0.0149	0.3993	0.3660	0.3560	0.6026	0.6026	0.6060
3	Klaipėda	0.6210	0.6077	0.5704	0.5306	0.60721	0.5874	0.4401	0.5029	0.4644	0.5375	0.5375	0.5387
4	Alytus	0.4476	0.4213	0.4438	0.5389	0.67530	0.7218	0.5877	0.6014	0.5029	1	1	1
5	Marijampolė	0.4438	0.3952	0.3521	0.4246	0.48307	0.4385	0.3815	0.3109	0.3186	0.4416	0.4416	0.4426
6	Panevėžys	0.7231	0.6779	0.6602	0.6418	0.79493	0.6946	0.5301	0.4819	0.3861	0.5741	0.5741	0.5754
7	Šiauliai	0.8360	0.7855	0.7996	0.6398	0.74297	0.0046	0.3184	0.2182	0.2119	0.6598	0.6598	0.6612
8	Telšiai	0.4986	0.4473	0.4342	0.4806	0.46648	0.4646	0.0306	0.0272	0.0285	0.73498	0.73498	0.7366
9	Utena	0.0391	0.0373	0.0469	0.0479	0.05628	0.0686	0.3578	0.4065	0.3294	0.6945	0.6945	0.6961
10	Tauragė	1	1	1	1	1	1	0.6878	0.5749	0.5067	0.67218	0.67218	0.67370

Source: compiled by the authors, according to counties of Lithuania, 2010, 2011 and 2012.

After obtaining the weights of all the indicators for ecological development and the normalized values for all regions, we were able to perform a multi-criteria assessment of the ecological development. The results of the calculations are presented in Table 4.

Table 4. Results of a multi-criteria assessment of the ecological development in the regions of Lithuania, using the MDE method.

No.	Regions	Year		
		2010	2011	2012
1	Vilnius	-45.1365	-46.8814	-45.83
2	Kaunas	-14.2735	-12.7187	-12.2152
3	Klaipėda	-40.1201	-44.0747	-40.9067
4	Alytus	-38.6622	-40.7345	-37.0716
5	Marijampolė	-32.1263	-28.2609	-26.8875
6	Panevėžys	-48.4734	-47.2288	-40.4794
7	Šiauliai	-39.8227	-35.0979	-24.0425
8	Telšiai	-13.8594	-12.1936	-11.8883
9	Utena	-12.6441	-15.1577	-11.717
10	Tauragė	-67.6707	-62.0236	-58.6008

In the same way, i.e. by applying formula (1), the values of the economic development in the regions of Lithuania have been determined. All of the indicators are maximizing, thus formula (1) coincides with formula (2), i.e. the MDE method coincides with the SAW method. The results of the calculations are presented in Table 5.

Table 5. Results of a multi-criteria assessment of the economic development in the regions of Lithuania.

No.	Regions	Year		
		2010	2011	2012
1	Vilnius	37.33	42.44	38.44
2	Kaunas	30.13	43.84	35.89
3	Klaipėda	43.96	57.09	47.94
4	Alytus	27.16	44.47	31.18
5	Marijampolė	45.42	41.25	33.69
6	Panevėžys	27.56	44.37	33.1
7	Šiauliai	35.3	48.52	44.17
8	Telšiai	38.55	58.65	46.58
9	Utena	28.95	44.81	29.52
10	Tauragė	28.38	42.92	34.23

A quantitative assessment of the ecological development in each region of the country is not self-serving. As was already mentioned, it is necessary to determine the impact of the other components necessary for sustainable development (firstly, of economic development as the basis for all other development) on the ecological development. This is illustrated in Figs. 2–4. The dots represent the intersection of the values for economic and ecological development in an individual region.

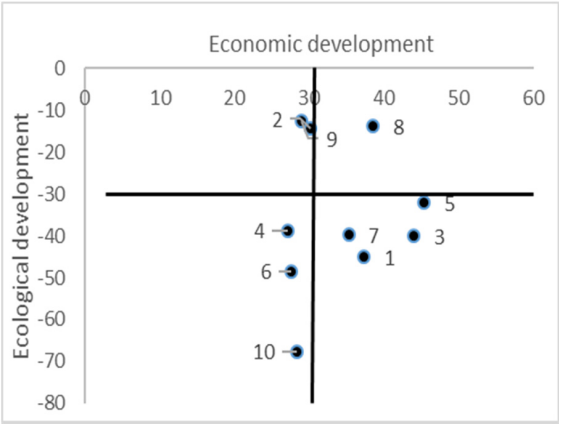

Fig. 2. Distributions of the regions of Lithuania, according to the impact of the economic development on ecological development in 2010.

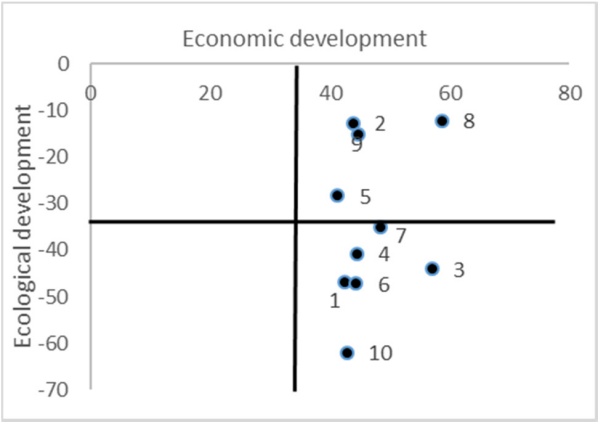

Fig. 3. Distribution of the regions of Lithuania, according to the impact of the economic development on ecological development in 2011.

1* - number of the region

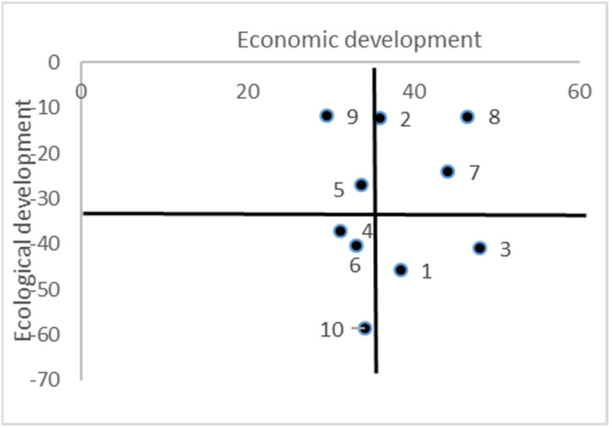

Fig. 4. Distribution of the regions of Lithuania, according to the impact of the economic development on ecological development in 2012.

Based on Figs. 2–4, all of the regions in Lithuania may be relatively placed into four groups, according to the impact of economic development on their ecological development (Table 6).

Table 6. Grouping of the regions of Lithuania into categories, according to the impact of economic development on their ecological development.

Group of the region	Level of development in the region			
	economic		ecological	
	low	high	low	high
I		+		+
II	+			+
III		+	+	
IV	+		+	

The positioning of the regions in the groups may be seen in Table 6.

Ecological development	Economic development: low	Economic development: high
high	Utena	Kaunas Telšiai
low	Alytus Panevėžys Tauragė	Klaipėda Marijampolė Šiauliai Vilnius

Fig. 5. Distribution of the regions of Lithuania, according to the impact of the economic development on ecological development in 2010.

Ecological development	Economic development: low	Economic development: high
high		Kaunas Marijampolė Telšiai Utena
low		Alytus Klaipėda Panevėžys Šiauliai Tauragė Vilnius

Fig. 6. Distribution of the regions of Lithuania, according to the impact of the economic development on ecological development in 2011.

Ecological development	Economic development: low	Economic development: high
high	Marijampolė Utena	Kaunas Šiauliai Telšiai
low	Alytus Panevėžys Tauragė	Klaipėda Vilnius

Fig. 7. Distribution of the regions of Lithuania, according to the impact of the economic development on ecological development in 2012.

From Fig. 5–7, we can see that during the analyzed period, the negative impact of economic development on the ecological development in the regions of Lithuania did not decrease. Also, the situation did not differ much in individual regions – where the majority of regions remained in the same group throughout the three years. All of this suggests serious measures are required to improve the regional policies in Lithuania, i.e. to increase the level of sustainable development in the regions.

4. Conclusion

In order to carry out a quantitative analysis of the interrelations between the components necessary for sustainable development (economic, social and environmental), these components need to be expressed in a quantitative manner. All of them are complex phenomena, expressed in reality by many aspects. Thus, the indicators expressing them must be multidimensional and able to change in different directions. Therefore, multi-criteria methods are suitable for a quantitative assessment of the state of such phenomena.

One such method is called the MDE (Multicriteria Different Evaluation), which allows for an assessment of the specific components for economic and ecological development of the regions in a country, expressed in a manner where some factors improve the ecological situation, while others show a deterioration of the situation.

After performing a quantitative assessment of the economic and ecological development, all of the regions were grouped according to the impact of economic development on their ecological development. The calculations showed that the negative impact of economic development on the ecological development in the regions of Lithuania is not decreasing. This shows that the current regional policies for sustainable development are ineffective.

Acknowledgements

7th International Conference on Engineering, Project, and Production Management (EPPM2016) was financed in the framework of the contract no. 712/P-DUN/2016 by the Ministry of Science and Higher Education from the funds earmarked for the public understanding of science initiatives.

7th International Conference on Engineering, Project, and Production Management (EPPM2016) finansowana w ramach umowy 712/P-DUN/2016 ze środków Ministra Nauki i Szkolnictwa Wyższego przeznaczonych na działalność upowszechniającą naukę.

7th International Conference on Engineering, Project, and Production Management (EPPM2016) was co-organised by the Agency for Restructuring and Modernisation of Agriculture (Poland).

References

[1] Boggia A, Cortina C. Measuring sustainable development using a multi-criteria model: A case study. *Journal of Environmental Management* 2010;91:2301–2306.
[2] Ferrarini A, Bodini A, Becchi M. Environmental quality and sustainability in the province of Reggio Emilia (Italy): using multi-criteria analysis to assess and compare municipal performance. *Journal of Environmental Management* 2001;63:117–131.
[3] Kevin FRL. Evaluating environmental sustainability: an integration of multiple-criteria decision-making and Fuzzy logic. *Environmental Management* 2007;39:721–736.
[4] Babu S, Datta SK. Revisiting the link between socio-economic development and environmental status indicators – focus on panel data, Environment. *Development and Sustainability* 2015;17(3):567–586.
[5] Golusin M, Munitlak OI. Definition, characteristics and state of the indicators of sustainable development in countries of Southeastern Europe. *Agriculture, Ecosystems and Environment* 2009;130:67–74.
[6] Kondyli J. Measurement and evaluation of sustainable development – a composite indicator for the islands of the North Aegean region, Greece. *Environmental Impact Assessment Review* 2010;30:347–356.
[7] Zhou J, Xiao H, Shang J, Zhang X. Assessment of sustainable development system in Suihua City, China, Chinese. *Geographical Science* 2007;17(4):304–310.
[8] Golusin M, Munitlak OI, Teodorovic N. The review of the achieved degree of sustainable development in South Eastern Europe – The use of linear regression method. *Renewable and Sustainable Energy Reviews* 2001;15:766–772.
[9] Hwang CL, Yoon K. *Multiple attribute decision making – methods and applications. A state of the art survey*. Berlin, Heidelberg, New York: Springer Verlag; 1981.
[10] Ginevičius R, Podvezko V. Complex evaluation of the use of information technologies in the countries of Easters and Central Europe. *Journal of Business Economics and Management* 2004;5(4):183–191.
[11] Ginevičius R, Podvezko V. Complex assessment of sustainable development of state regions with emphasis on ecological and dwelling conditions. *Ekologija* 2007;53(Supplement):41–48.
[12] Ginevičius R, Butkevičius A, Podvezko V. Complex evaluation of economic development of the Baltic States and Poland. *Ekonomický Časopis* 2006;9(54):918–930.
[13] Ginevičius R, Gedvilaitė D, Bruzgė Š. Assessment of a country's regional economic development on the basis of Estimation of a Single Process (ESP) method. *Entrepreneurial Business and Economics Review* 2015;3(2):141–153.
[14] Counties of Lithuania 2010, http://osp.stat.gov.lt/services-portlet/pub-edition-file?id=14761 (retrieved 20.01.2016).
[15] Counties of Lithuania 2011, http://osp.stat.gov.lt/services-portlet/pub-edition-file?id=2068 (retrieved 20.01.2016).
[16] Counties of Lithuania 2012, http://osp.stat.gov.lt/services-portlet/pub-edition-file?id=2068 (retrieved 20.01.2016).
[17] Kendall M. *Rank correlation methods*. London: Griffin and Co; 1979.
[18] Komarovska A, Ustinovichius L, Shevchenko G, Nazarko L. Multicriteria evaluation of commercial industrial zone development. *International Journal of Strategic Property Management* 2015;19(1):84–95.