AN INNOVATIVE APPROACH TO DETERMINE THE SUSTAINABLE DEVELOPMENT OF REGIONS BY HARMONIZATION OF THE ECONOMIC, SOCIAL AND ENVIRONMENTAL COMPONENTS

Olha Popelo, Chernihiv Polytechnic National University
Svitlana Tulchynska, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"
Viktoriia Marhasova, Chernihiv Polytechnic National University
Nataliia Ivanova, Chernihiv Polytechnic National University
Halyna Samiilenko, Chernihiv Polytechnic National University

ABSTRACT

The study is devoted to determining the state and dynamic changes in the sustainable development of regions by the harmony of economic, social and environmental components. Stages of the sustainable development assessment of the regions are proposed, including: grouping of statistical assessment data on the economic, social and environmental components of the sustainable development; calculation of integrated indices of the components of sustainable development; calculation of integrated indices to determine the harmonization of sustainable development by determining the angle between the ideal vectors of the components of sustainable development on the basis of integrated indices.

The results of the calculations are of practical importance, which is to provide more detailed information on the processes of sustainable development of regions and to propose measures that can give a synergistic effect to ensure positive dynamics of the sustainable development due to increasing harmonization of its components.

Keywords: Sustainable development; Economic development; Social development; Ecological development; Regions; Harmonization.

INTRODUCTION

For more than a decade, the world community has focused its development on achieving the sustainable development goals. This paradigm orientation makes it possible to achieve the global goals of humanity, as well as specific states and its regions.

Today, as evidenced by the analysis of publications in the field of the sustainable development research, there are different directions for methodological approaches to assessing the sustainable development of regions. It should be noted that not all methodological approaches to evaluation can be used and adapted to specific assessments, which is primarily due to the peculiarities of statistical assessments of the performance of national economies and their regions.

Citation Information: Popelo, O., Tulchynska, S., Marhasova, V., Ivanova, N., & Samiilenko, H. (2021). An innovative approach to determine the sustainable development of regions by harmonization of the economic, social and environmental components. *Journal of Management Information and Decision Sciences, 24*(S4), 1-9.

The proposed innovative approach to the definition of the sustainable development of regions by harmonization of the economic, social and environmental components makes it possible to carry out a deeper analysis of the sustainable development of regions.

LITERATURE REVIEW

Quite a few scientists have devoted their research to the study of various issues of the sustainable development of the regions, among which: De Laurentis (2020); Shiyan et al. (2020); Shkarlet et al. (2020); Paulus et al. (2020); Aguado et al. (2021); Álvarez-Lorente and Entrena-Durán (2021); Nejati et al. (2011); Popelo et al. (2021); Prus & Sikora (2021); Salamzadeh et al. (2021); Surówka et al. (2021); Tulchynska et al. (2021); Vovk et al. (2021); and Zhang & Wang, (2020).

Prus and Sikora (2021) identified the factors influencing the effectiveness of the concept of the sustainable development of rural areas. De Laurentis (2020) notes that the national governments of Italy and the United Kingdom have built regulatory and administrative relations on the organization and regulation of economic, social and environmental issues and the transfer of responsibility at the subnational level. Surówka et al. (2021) focused on the concept of a systematic approach to improving the technical infrastructure in the context of the sustainable development and cooperation strategies. According to Álvarez-Lorente and Entrena-Durán (2021), the actors should participate in the development policy, which, in turn, should take into consideration socio and economic, cultural, environmental and geological resources available in the area.

Aguado et al. (2021) examines the issues of sustainable development, the reasons for governments' decisions, and the motives of people to work together for sustainability are outlined. The purpose of the work by Paulus et al. (2020) was to formulate a strategy for sustainable local economic development through a systematic approach, namely the long-term analysis. The study of Zhang and Wang (2020) looked at a regional afforestation project based on the Sustainable Development Guide, with Fujian Province in China as an example for assessing benefits.

MATERIALS AND METHODS

To ensure the sustainable development of regions, it is important to measure it by determining, for example, its integrated indices of economic, social and environmental components, as well as the degree of harmonization of the sustainable development of regions. In this regard, we propose to determine not only the integrated indices of the sustainable development, but also to calculate the degree of harmonization of the sustainable development (G).

Integral indices are calculated using the correlation analysis, but this is preceded by the use of statistical grouping. The method of statistical groupings makes it possible to distribute statistical evaluation data selected to assess the sustainable development of regions in relation to the economic, social and environmental components of the sustainable development. However, the grouping method is not sufficient for the calculation of integral indices, as it allows to establish only the presence of a certain relationship between the studied processes and phenomena. However, the method of statistical groupings does not allow to determine

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comparative quantitative parameters. This shortcoming eliminates the method of correlation analysis, the essence of which is to determine the correlation of certain processes.

The correlation analysis makes it possible not only to calculate integrated indices of components of the sustainable development, but also to determine the nature of changes in integrated indices from statistical indicators used in calculations by identifying the coefficients of the statistical indicators influence on the integrated index. Coefficients of influence are regression functions that determine the effect of the standardized indicators for assessing the sustainable development components on a given integrated index.

The unconditional reason for the correlation analysis use is that this method is suitable for the study of complex phenomena and processes which is the sustainable development, which depends on a large number of heterogeneous conditions and influences.

To determine the pairwise correlation of statistical indicators used to assess the components of the sustainable development, we use the Equation 1.

$$k_{xg,xp} = \frac{\operatorname{cov}(x_g, x_p)}{D[x_g^2] \cdot D[x_p^2]}, \quad (1)$$

Where:

$cov\ (\mathrm{x}g, \mathrm{x}p)$ – covariance between statistical indicators *xg, xp*;

$D[xg2], D[xp2]$ – variances of normalized statistical indicators used in estimating the components of the sustainable development that are not equal to zero.

The normalized indicators are used for the calculation in accordance with the requirements of economic and mathematical modeling. The matrix of normalized indicators for assessing economic (n = 1), social (n = 2), and environmental (n = 3) components of the sustainable development is as follows (Equation 2):

$$Yn = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{18} \\ x_{21} & x_{22} & \dots & x_{28} \\ \dots & \dots & \dots & \dots \\ x_{js} & x_{js} & \dots & x_{jk} \end{bmatrix}, \quad (2)$$

Where *Yn* is the matrix of the standardized indicators of the sustainable development components (n = 1, 2, 3), for a certain period (eight years, k = 8 (2013-2020);

x – the normalized values of statistical indicators for assessing the sustainable development components.

The correlation-regression analysis, as already noted, makes it possible to determine the degree of influence of individual factors on the component level of the sustainable development using the coefficients of influence (*Kn*) (Equation 3):

$$K_m = \left[(Y_m^T \cdot Y_m)^{-1} Y_m^T \right] \cdot I_m, \quad (3)$$

Where Yn - matrix of the standardized indicators of the sustainable development component;

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In is an indicator of the nth integral index of the corresponding component of the sustainable development of regions.

Calculations of integrated indices of the sustainable development components are carried out according to the Equation 4:

$$I_n = K_0 + \sum_{j=1}^{m} K_{n_i} \cdot x_i, \quad (4)$$

Calculations of integrated indices of economic (*Iecn*), social (*Isoc*) and environmental (*Iecl*) components of the sustainable development of regions make it possible to determine the degree of harmonization of the sustainable development. The harmonization of the sustainable development components is calculated by finding the angle formed between a certain ideal vector of the sustainable development component ($||1||$) and the vector calculated by the integral index of the sustainable development component ($||I_{SR}||$). The formulas for calculating the ideal and normalized vector are as follows (Equations 5-9):

$$||1|| = \sqrt{(1^2 + 1^2 + 1^2)} \quad (5)$$

$$\left||I_{SR}|\right| = \sqrt{(I_{ek}^2 + I_s^2 + I_{eco}^2)}, \quad (6)$$

The angle is determined by calculating the degree of the sustainable development harmonization (G):

$$G = \frac{ar\cos(f_1 + f_2 + f_3)}{ar\cos\frac{1}{\sqrt{3}}}, \quad (7)$$

Where f_1 – a system function of the integrated index of the economic component of the sustainable development;

f_2 – a system function of the integrated index of the social component of the sustainable development;

f_3 – a system function of the integrated index of the ecological component of the sustainable development.

$$G_1 = \frac{ar\cos f_0}{ar\cos\frac{1}{\sqrt{3}}}, \quad (8)$$

Where f_0 is a system function and is calculated as follows:

$$f_0 = \frac{f_0}{\sqrt{(f_1^2 + f_2^2 + f_3^2)} \cdot \sqrt{3}}, \quad (9)$$

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Since the degree of the sustainable development harmonization determines a certain balance between the economic, social and environmental components of the sustainable development, the angle of these components will be in the range from 0º to 90º. In this case, the higher the degree of the sustainable development harmonization, the smaller the angle and closer to 0º.

In addition to harmonization, there is a harmony indicator of the sustainable development, which shows the established density between the components of the sustainable development and their relationship. That is, the harmony of the sustainable development makes it possible to assess the interconnectedness of the selected components development of the sustainable development. To determine the harmony of the sustainable development, in the opinion of the authors, it is advisable to use the mathematical apparatus of the "golden section".

RESULTS

The proposed stages of the sustainable development assessment make it possible to test the proposed approach on the example of the regions of Ukraine using the software package MathCad-15.

The obtained results of integrated indices of the sustainable development components are presented in Table 1.

TABLE 1
ARITHMETIC MEAN VALUES OF INTEGRATED INDICES OF THE SUSTAINABLE DEVELOPMENT COMPONENTS OF UKRAINE'S REGIONS FOR 2013-2020

Regions	$I_{ecn.\ avg}$	The rank of the region by value $I_{ecn.avg}$	$I_{soc.\ avg.}$	The rank of the region by value $I_{soc.avg.}$	$I_{ecl.\ avg.}$	The rank of the region by value $I_{ecl.avg}$
Vinnytsia	0,286	7	0,195	10	0,226	9
Volyn	0,087	22	0,123	15	0,069	20
Dnipropetrovsk	0,330	3	0,194	11	0,285	3
Donetsk	0,059	25	0,079	21	0,040	24
Zhytomyr	0,127	15	0,123	16	0,095	15
Transcarpathian	0,091	21	0,074	23	0,063	22
Zaporozhye	0,316	5	0,235	5	0,216	11
Ivano-Frankivsk	0,198	11	0,197	9	0,279	4
Kiev	0,939	1	0,288	1	0,596	1
Kyrovohrad	0,191	12	0,201	8	0,230	6
Luhansk	0,044	24	0,052	25	0,033	25
Lviv	0,221	10	0,185	12	0,231	5
Mykolaiv	0,111	16	0,105	17	0,089	17
Odessa	0,187	13	0,227	6	0,226	10
Poltava	0,274	8	0,162	14	0,229	7
Rivne	0,110	17	0,096	19	0,091	16
Sumy	0,106	18	0,077	22	0,083	18
Ternopil	0,100	19	0,099	18	0,065	21
Kharkiv	0,327	4	0,256	3	0,286	2

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Kherson	0,086	23	0,083	20	0,056	23
Khmelnytsky	0,314	6	0,245	4	0,212	12
Cherkasy	0,096	20	0,064	24	0,078	19
Chernivtsi	0,175	14	0,204	7	0,228	8
Chernihiv	0,246	9	0,264	2	0,156	14
Kyiv city	0,774	2	0,195	13	0,157	13
The arithmetic mean value of the integrated index of the sustainable development component for all regions	0,231	-	0,123	-	0,168	-

Source: calculated by the authors.

The calculations and the results given by the values of the average integrated indices by region allow us to conclude that not all regions have the same degree of economic, social and environmental component of the sustainable development. And there are regions where there is a certain asymmetry in the development of the sustainable development components. The only region in which the average integrated indices of the sustainable development components have the same rank is the Kyiv region, which occupies a leading position at the same time in terms of three values of integrated indices. There are also regions in which there is a small difference of no more than two steps in the ranks of the arithmetic mean values of integral indices. Such regions include: Zhytomyr (15-16 rank), Transcarpathia (21-23 rank), Luhansk (24-25 rank), Mykolaiv (16-17 rank), Ternopil (18-21 rank), Kharkiv (2-4 rank) and Kherson (20-23 rank) regions.

At the same time, there are regions in which there is a fairly high discrepancy in the values of the ranks of the arithmetic mean of the integral indices. For example, Dnipropetrovsk region ranks 3rd in terms of the values of integrated indices of the economic and environmental components of the sustainable development and 11th in terms of the value of the integrated index of the social component of the sustainable development. Ivano-Frankivsk region ranked 11th in terms of the economic development index, 9th in terms of the social development index and 4th in terms of the value of the integrated index of the environmental component of the sustainable development. This is due to a number of objective reasons related to the peculiarities and resource capabilities of the regions of Ukraine, but in any case, such asymmetry needs to be eliminated.

Calculations of integrated indices of the sustainable development components make it possible to determine the degree of the sustainable development harmonization in accordance with the proposed methodological approach (Equations 7-9). In Table 2, presents the results of calculations of the degree the sustainable development harmonization are presented.

Harmonization of the sustainable development involves determining the angle formed between the ideal vector and the vector of the calculated integrated index, with the smaller the defined angle the greater the degree of harmonization of the sustainable development, and vice versa, the greater the degree of degrees approaching 90º indicates unsatisfactory harmonization of the sustainable development.

According to the data presented in Table 2, it can be noted that the regions with the best degree of harmonization of the sustainable development include Khmelnytsky (average value of the harmonization degree is 9º), Poltava (G_{avg} = 11º), Kirovohrad (G_{avg} = 14º), as well as Ivano-Frankivsk, Kiev, Chernivtsi region and the city of Kyiv, in which the average value of the harmonization degree is 15º. However, it should be noted that the harmonization degree over the years in each region had quite significant fluctuations. For example, in Khmelnytsky region in

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2013 the harmonization value of the sustainable development was 3º, and in 2017-2018 G_{avg} = 12º. In the Poltava region in 2013 G_{avg} = 6º, and in 2018 the harmonization value of the sustainable development was G_{avg} = 15º.

TABLE 2
THE VALUES OF THE DEGREE THE SUSTAINABLE DEVELOPMENT HARMONIZATION OF UKRAINE'S REGIONS (G) FOR 2013-2020, THE ANGLE IN DEGREES

Regions	G								$G_{avg.}$ the average for 2013-2020	Rank of the region
	2013	2014	2015	2016	2017	2018	2019	2020		
Vinnytsia	11	13	17	19	19	19	18	18	17	**3**
Volyn	20	28	58	71	75	85	60	59	57	6
Dnipropetrovsk	31	19	24	34	39	38	32	27	31	17
Donetsk	77	69	64	68	78	83	63	68	71	13
Zhytomyr	10	16	15	20	19	20	25	28	19	19
Transcarpathian	46	27	31	54	64	51	44	57	47	8
Zaporozhye	17	16	15	15	15	15	15	16	16	16
Ivano-Frankivsk	11	14	16	19	17	13	13	16	15	5
Kiev	10	17	21	19	14	13	14	13	15	4
Kyrovohrad	12	8	14	11	18	14	18	17	14	4
Luhansk	62	70	66	74	90	88	80	63	75	3
Lviv	14	12	12	15	18	19	18	17	16	20
Mykolaiv	16	18	22	23	23	22	23	27	22	5
Odessa	18	18	26	17	17	14	24	8	18	9
Poltava	6	9	10	10	14	15	13	13	11	7
Rivne	15	21	25	28	29	24	14	35	24	2
Sumy	16	20	24	29	30	29	28	26	25	10
Ternopil	19	26	66	85	82	77	70	57	60	11
Kharkiv	40	36	33	31	34	39	37	32	35	18
Kherson	31	35	39	41	44	50	55	55	44	14
Khmelnytsky	3	8	10	11	12	12	10	9	9	15
Cherkasy	20	26	27	26	24	26	29	32	26	1
Chernivtsi	14	10	13	17	18	13	15	18	15	12
Chernihiv	13	12	11	13	19	23	23	20	17	4
Kyiv city	22	22	18	14	15	9	9	7	15	6
The arithmetic mean of the harmonization degree for all regions ($G_{avg.}$)	22	23	27	31	33	33	30	30	28	4

Source: calculated by the authors.

The regions with the worst harmonization of the sustainable development on average are Luhansk (average harmonization value of the sustainable development is 75º), Donetsk (G_{avg} = 71º), Ternopil (G_{avg} = 60º), Volyn, (G_{avg} = 57º), Transcarpathian (G_{avg} = 47º) area. It should be noted that these regions are outsiders in terms of gross regional product and are recipients of

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government subsidies. Variation in the values of harmonization of sustainable development in these regions is also quite high. Thus, the harmonization value of the sustainable development in 2013 was $G_{avg} = 19^o$, and in 2016 $G_{avg} = 85^o$.

The values of the harmonization angle of the sustainable development are followed by some trends in certain regions, but mostly these are negative trends characterized by an increase in the harmonization angle of the sustainable development. Thus, in Zhytomyr oblast the value of the angle increased from 10º in 2013 to 28º in 2020, in Mykolayiv oblast from 16º to 27º, and in Kherson oblast from 31º to 55º. And only the city of Kyiv shows positive results, i.e. a decrease in the angle from 22º in 2014 to 7º in 2020. If we consider harmonization in general for all regions, it should be noted that the arithmetic mean of the harmonization degree tended to increase in the studied period and only two recent years have illustrated a slight improvement in the harmonization of the sustainable development.

CONCLUSIONS

Thus, there is no region that occupies the same rating for all arithmetic mean values of harmonization of sustainable development components. However, there is a clear relationship between the ranks of the regions by the arithmetic mean of the harmonization of the sustainable development components and the ranks of the integrated indices of the its components.

The calculations allow us to conclude that in general, regions that have higher values of harmonization of the sustainable development components also have higher values of the integrated indices of the sustainable development.

The authors consider the processes of improving the sustainable development harmonization, which can be defined as reducing the angle between the calculated and ideal vector, as well as increasing the density of the relationship between the components of sustainable development, which is determined by the harmony of the economic, social and environmental components of the sustainable development.

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