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Method and Criteria for Assessing Sustainable Development

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Abstract
The article is aimed at solving the urgent scientific task of creating new methods for an integrated assessment of the sustainable development of socio-economic objects, in particular, countries, regions and cities. A practical method of assessment is proposed, which allows to form ideas about the vector of sustainable development of objects. The construction of development models is based on the use of the principle of the corresponding states, according to which the positions of objects in multidimensional state spaces can be described by a single equation if an effective scale is constructed for comparing the states among themselves in a set of indicators. It is shown that the study of the features of sustainable development of countries, regions and cities can be performed by the method of cluster analysis of data with the subsequent construction of such scales. For comparison of objects it is suggested to use the reference vector of development, which is constructed for the control group of objects that are the most developed in terms of indicators of achieving the goals of sustainable development. Socio-econometric scales are proposed for assessing the development of regions, as well as criteria characterizing the stability of their development. As a realization of the method, a comparative analysis of the development of the regions of Russia on 13 indicators of sustainable development was carried out.

Keywords: Urgent scientific; Socio-econometric; Multidimensional.

1. Introduction

The concept of Sustainable development has been improving for almost three decades. However, it should be noted that very little progress has been made in the area of theoretical approaches during this period. The theories and models used mainly involve the use of expert methods and simple complex estimates.

The generally accepted concept of sustainable development is set out in the UN General Assembly Declaration. Sustainable development refers to development that promotes prosperity and economic opportunity, well-being and environmental protection

Since 1987, when the first formulation of sustainable development appeared, and to date, the concept of sustainable development remains a popular and beautiful idea. This concept is set out at a qualitative level without specific details, which would allow to create quantitative models of sustainable development of the analyzed objects.

The aim of this work is to develop a method and criteria for a comprehensive assessment of the development of countries, regions and cities, allowing to form ideas about the vector of sustainable development of both individual objects and groups of homogeneous

objects.

In recent years there has been rapidly developing the field of systematic research, based on the application of natural and physical methods in the economic and social sciences. In these methods, data that determine the entire course of research and model (Barceló *et al.*, 2015; Chakraborti *et al.*, 2015).

2. Methodology of Complex Assessment of Complex Objects Development

We assume that the position of each socio-economic object is determined by a set of values of its indicators, which are formed at a certain time. To describe the position of the object relative to all other objects of the studied class, we will use the natural science concept of the state space – an abstract space formed by state variables. As the state variables, we will take for socio-econometric analysis indicators that are considered significant among experts and that characterize the studied objects in a certain aspect

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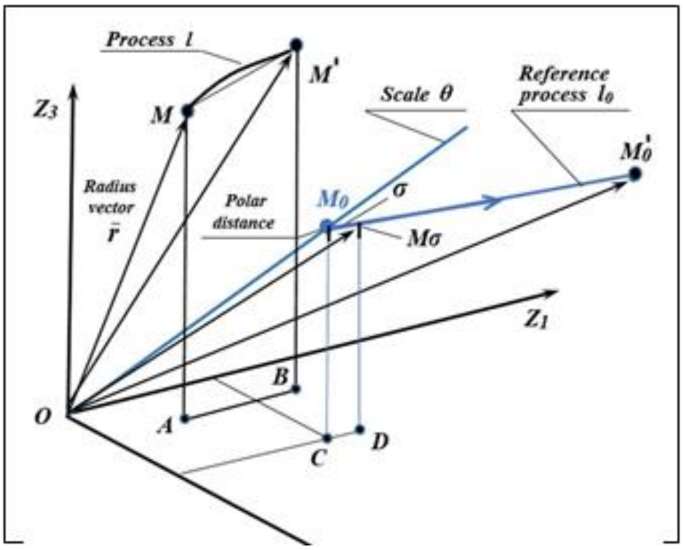
Suppose that for n socio-economic objects (countries, regions or cities) there are statistical data for the values of indicators $z_1, z_2, ..., z_n$, which will be considered as state variables. Let us form the n-dimensional state space in the form of a Cartesian coordinate system

The main idea of the work is related to the study of the possibility of creating models that differ in the description of geometric points (States) and lines (processes) in multidimensional spaces of States of socio-economic objects on the basis of available statistical information. Modeling is based on the hypothesis of the existence of different measures of similarity of object States $W = W(z_1, z_2, ..., z_n)$. This value is considered as a function of several variables (Crooks and Heppenstall, 2012).

The construction of models is based on the use of the principle of the corresponding States, according to which the positions of objects in the state space can be described by a single equation of state, if you build an effective scale for comparing States with each other and use some of the variables. Typically, the equation of state is represented as: $F\left(z_1/z_{1_0}, z_2/z_{2_0}, ..., z_n/z_{n_0}\right) = 0$, where z_{k0} – the values of the indicators for the reference state. In this approach, the modeling object is the States of objects that can be characterized by a General equation that is valid for the entire multidimensional state space.

To construct the equation of state from a group of objects, a reference object or reference state is selected, and all other States are related to the selected point in the state space. The validity of the principle is verified on a case-by-case basis (Averin *et al.*, 2017; Tahavieva and Nigmatullina, 2017).

The principle of the corresponding States allows us to construct a scale for the relative comparison of the position of objects among themselves, in the form of an index θ (Averin *et al.*, 2016). In general, the content of the method is as follows (Fig. 1.). Select some linear reference process l_0 for some object and mark the reference state on it M_0. On the line of this process, we note the second reference state M'_0. The first reference state may correspond to the start time of statistical data collection, for example,



as in the example below, 2012, and the second reference state to the last year of data collection, for example, 2015. The resulting segment is divided into a given number of identical intervals, for example, 100, and set the length of the obtained segments σ, based on the measure of similarity of the States of objects W. Next, from the origin of the beam OM_0 and find the length of the segment OM_0 in the accepted system of measurement value W. The scale of measurements for the states of objects is formed in the form of an index θ applied to the beam OM_0 with a unit of measurement σ, the length of the segment OM_0 in this scale will be $\theta_0 = OM_0/\sigma$. For certainty, we set the appropriate unit of measure θ as a degree (°G), which is geometrically equal to the length σ.

Using various measures of similarity W, the resulting scale can measure each state in degrees of the index θ. Thus, the index θ as a whole characterizes the state of objects and is an empirical measure for their measurement. This is the main criterion for determining the position of countries, regions and cities on a set of different socio-economic indicators in a multidimensional space of States.

Figure 1. System of construction of the index scale θ in relation to the reference state and the reference process

The lengths of segments in the state space having Euclidean metric can be determined based on the Euclidean distance:

$$l_{ab} = \sqrt{(z_{1b} - z_{1a})^2 + (z_{2b} - z_{2a})^2 + ... + (z_{nb} - z_{na})^2}, \quad (1)$$

where a and b – the beginning and the end of a certain segment ab.

Now, to describe statistical data, we can search for a model of collective behavior of objects in the form of an equation of state.

$$\theta = f\left(z_1/z_{1_0}, z_2/z_{2_0}, ..., z_n/z_{n_0}\right). \quad (2)$$

For different periods of time, using a common scale of econometric measurements, it is possible to obtain different values of the complex index θ, as a function of time in the same state space of objects. This will allow you to study not only the state, but also the processes of development of objects (Averin and Zviagitrseva, 2017).

3. Sustainable Development Indicators

Today, 247 indicators recommended by the UN, 47 indicators proposed by the world Bank, and 35 national indicators recommended for use by the state statistics Service of Russia are used for sustainable development (Tan, 2007).

For example, 13 indicators were selected from the list of 35 national indicators for integrated assessment of sustainable development of Russian regions, which were grouped into two groups. The group that characterizes the socio-economic stability of the development of the regions include:

- gross regional product per capita, RUB/person, z_{1s};
- average per capita income of the population, RUB, z_{2s};

the average size of assigned pensions, RUB, z_{3s};

- volume of cargo transportation by rail and road, thousand tons/person, z_{4s};
- the volume of exports, converted at the exchange rate of the dollar, RUB/person,
- z_{5s};
- volume of imports converted at the dollar
- exchange rate, RUB/person, z_{6s};
- scope of work performed by types of economic activity "Construction", RUB/person, z_{7s}.

This group in relation to the regions was based on the principle "the higher the value of the indicator, the better".

The group that characterizes the environmental sustainability of the regions include:

- investments in fixed capital aimed at environmental protection, RUB/person, z_{8s};
- emissions of air pollutants from stationary and mobile sources, kg/person, z_{9s};
- water intake from natural water bodies, m3/person, z_{10s};
- discharge of contaminated wastewater into surface water bodies, m3/person, z_{11s};
- the energy intensity of the GRP, kg of standard fuel/10 thousand RUB, z_{12s};

infant mortality, the number of children who died before the age of 1 year per 1,000 births, z_{13s}.

The group of indicators of environmental sustainability of regional development was organized according to the principle "the lower the value of the indicator, the better".

Data on the above indicators were collected for the period 2012–2015 for 80 regions of Russia. The study of the features of sustainable development of regions was carried out by the method of cluster data analysis, followed by the construction of socio-econometric scales for comparing the States of objects. Clustering was carried out by the k-means method using the Statistica program separately for groups of indicators characterizing the socio-economic and environmental sustainability of regional development. The clustering technique involved the use of the nearest neighbor method, where Euclidean

distance was used as a clustering measure. The studied indicators were previously standardized by bringing them to the form: $z_k^{st} = \left(z_k - z_k^{sr}\right)/\sigma_k$,

where z_k^{sr} – average k-indicator, σ_k – standard deviation.

The above seven indicators $z_{1s}, \ldots, z_{7s}$, were used for the analysis of socio-economic sustainability and six $z_{8s}, \ldots, z_{13s}$, for the analysis of environmental sustainability. The number of clusters was determined by the method of hierarchical clustering in the Statistical software product by building dendrograms.

Clustering of regions according to the observations of the values of socio-economic stability indicators allowed to identify three groups of regions. The characteristics of the clustering areas by standardized indicators are given in table 1.

Table-1. Characteristics of clustering areas by standardized indicators of socio-economic sustainability

Clusters	Statistics	Standardized indicators						
		z_{1s}	z_{2s}	z_{3s}	z_{4s}	z_{5s}	z_{6s}	z_{7s}
The first cluster	Average	2.668	2.433	2.076	0.4	1.737	1.077	2.426
	Standard deviation	1.467	1.077	1.455	1.684	2.782	1.849	1.343
The second cluster	Average	0.128	0.204	0.344	0.700	0.155	0.274	0.249
	Average	0.330	0.644	0.847	1.104	0.403	1.290	0.571
The third cluster	Average	-0.468	-0.475	-0.499	-0.450	-0.344	-0.312	-0.499
	Standard deviation	0.248	0.430	0.271	0.416	0.162	0.221	0.345

The first cluster contained 7 regions, the second 26 and the third 47 regions: the first cluster – Moscow and St. Petersburg, Tyumen and Tomsk regions, the Republic of Sakha (Yakutia), Sakhalin region and Chukotka Autonomous Okrug; the second cluster – Belgorod, Kaluga, Lipetsk, Moscow regions, Republic of Karelia, Republic of Komi, Arkhangelsk, Vologda, Kaliningrad, Leningrad, Murmansk, Novgorod regions, Republic of Tatarstan,

Perm, Samara, Sverdlovsk regions, Republic of Altai, Republic of Khakassia, Krasnoyarsk region, Irkutsk, Kemerovo, Tomsk regions, Kamchatka, Primorsky Krai,

Khabarovsk Krai, Amur oblast; the third cluster –

all remaining regions of Russia.

Table 1 shows that for the regions of the first cluster, there are high indicators of socio-economic stability, since six of the seven clustering indicators have the highest average. These regions, in the context of the country as a whole, can be seen as examples of sustainable socio-economic development.

Clustering of regions according to observations of the values of environmental sustainability indicators also allowed us to identify three groups of regions: the first cluster (12 regions) – Lipetsk region,

Republic of Karelia, Republic of Komi, Arkhangelsk, Vologda, Murmansk regions, Perm region, Tyumen,

Chelyabinsk regions, Krasnoyarsk region, Irkutsk and Kemerovo regions;

the second cluster (12 regions) – Kostroma, Tver, Leningrad regions, Republic of Dagestan, Republic of Ingushetia, Karachay-Cherkess Republic, Republic of North Ossetia-Alania, Chechen Republic, Republic of Tuva, Republic of Khakassia, Jewish Autonomous region, Chukotka Autonomous region;

the third cluster (56 regions) – all remaining regions of Russia.

Characteristics of clustering areas by indicators of environmental sustainability are given in table 2.

Table-2. Characteristics of clustering areas by standardized indicators of environmental sustainability

Clusters	Statistics	Standardized indicators					
		z_{8s}	z_{9s}	z_{10s}	z_{11s}	z_{12s}	z_{13s}
The first cluster	Average	1.190	1.656	0.156	1.500	0.934	-0.391
	Standard deviation	1.911	1.496	0.567	1.442	1.564	0.338
The second cluster	Average	-0.506	-0.217	1.133	-0.376	0.602	1.509
	Standard deviation	0.162	0.743	2.158	0.643	1.158	1.439
The third cluster	Average	-0.147	-0.308	-0.276	-0.240	-0.329	-0.240
	Standard deviation	0.560	0.416	0.278	0.601	0.547	0.641

From the above data it is clear that the regions included in the first and second clusters have low indicators of environmental sustainability. From a large group of regions of the third cluster, 12 regions were selected according to the values of environmental indicators, which can be considered as regions of sustainable environmental development in the context of the whole country: Belgorod, Voronezh, Ivanovo, Kursk, Tambov, Kirov, Penza, Kurgan, Novosibirsk regions, Republic of Mordovia, Udmurt Republic, Chuvash Republic.

Thus, on the basis of the results of cluster data analysis, two control groups of regions were formed, which are distinguished by indicators of socio-economic and environmental sustainability.

4. Integrat Assessment Criteria

Criteria for comparing regions by indicators of sustainable development in a multidimensional state space are based on the choice of support vectors.

If we take two control groups of regions and average their values for 2012 and 2015, then in the state space we can construct vectors characterizing the directions of the most sustainable development for the entire group of 80 regions of Russia for a given period of time.

Due to the fact that the indicators have different dimensions and different values of numbers, the analysis will be carried out on standardized values of indicators: $z_k^{st} = \left(z_k - z_k^{sr}\right) / \sigma_k$.

We will form a basic vector $\vec{F}_{1s}$ of social and economic stability of the regions. For this vector, the reference state M_0 corresponds to the observed values of the indicators $z_{1s_0}, \ldots, z_{7s_0}$ in 2012. The second reference state M'_0 for this vector corresponds to the observed values $z_{1s*}, \ldots, z_{7s*}$ of the selected group of 7 regions in 2015. According to this data, we find the vector

module $\left|\vec{F}_{1s}\right|$ and divide it into 100 identical parts. This allows you to set the length of a line

σ as a dimensionless unit socioeconomically scale to compare regions among themselves, which amounted to 0.01398.

Similarly, we will form the second reference vector $\vec{F}_{2y}$ of environmental sustainability of the regions. For this vector, the first reference state M_0 corresponds to the values of the indicators in 2012 – $z_{8s*}, \ldots, z_{13s*}$, and the second reference state for the 2015 data . We find the module of the vector $\left|\vec{F}_{2s}\right|$ and divide it into 100 equal parts and set the length of the segment $\sigma = 0.00976$ as a unit of socio-econometric scale for comparing regions with each other in terms of environmental sustainability.

The vectors of sustainability defined for the selected small control groups of regions, which will be considered as examples of sustainable development in the context of the whole country, can be used to form criteria for integrated assessment. The value of the vector module will be used as one of these criteria. On its basis, we will create an appropriate socio-econometric school. Measurements on this scale allow you to compare the regions of Russia with each other.

The index θ , as a measure of similarity of States, will be along the length of the vector characterizing the development of each region in a certain period of time, for example, in 2012–2015. This index determines the level of sustainable development of the region in relation to the reference vector, which characterizes the most developed group of regions in this respect.

It should be noted that the vector $\vec{F}_s$ can be characterized not only by the length, but also by the direction of development in the space of object States. Therefore, the second criterion for sustainable

development of the region in relation to the most developed group of regions can be the angle φ between the reference vector and the vector of development of the region.

The smaller the angle φ , the more the direction of development of the analyzed region corresponds to the indicators of sustainability priority development of the most developed control group.

5. Comparison of Russian Ergions in Terms of Sustainable Development

We will carry out a comprehensive assessment of the socio-economic and environmental sustainability of the regions according to the above indicators of achieving sustainable development goals. We will use the method of integrated assessment of the development of socio-economic objects, given earlier. Table 3 presents a comparison of Russian regions by a set of indicators based on the created scales of socio-economic and environmental sustainability.

Table-3. Comparison of Russian regions in complex terms of socio-economic and environmental sustainability

Subjects of the Russian Federation	Value of the quantities θ, °G		Region rank in group	
	Socio-economic sustainability	Environmen-tal sustainability	Socio-economic sustainability	Environmental sustainability
1	2	3	4	5
Sakhalin Region	598.28	64.47	1	33
Belgorod Region	499.37	40.17	2	15
Kaliningrad region	432.99	81.90	3	44
Republic of Altai	262.08	44.70	4	16
Tyumen Region	259.12	312.50	5	77
Moscow	214.16	17.56	6	3
Saint-Petersburg	206.95	61.39	7	30

Kaluga Region	171.79	90.35	8	52
Smolensk Region	141.46	32.22	11	7
Leningrad Region	138.76	89.10	13	51
Irkutsk Region	135.33	79.95	14	41
Primorsky Krai	134.48	339.31	15	78
Orenburg region	120.21	90.45	18	53
Krasnodar region	113.41	9.22	20	1
Samara region	85.86	33.25	24	9
Moscow region	81.37	53.90	25	22
Republic of Tatarstan	78.96	58.02	27	25
Rostov region	76.13	54.27	28	23
Voronezh region	70.75	35.40	32	11
Vologda region	70.34	154.75	33	69
Krasnoyarsk region	69.11	93.76	34	55
Arkhangelsk region	68.91	60.22	35	28
Novosibirsk region	68.28	33.26	36	10
Kemerovo region	67.86	107.42	37	59
Volgograd region	65.51	180.31	38	71
Kursk region	60.94	81.05	43	43
Tula region	45.91	80.30	48	42
Saratov region	45.63	82.25	49	45
Nizhny Novgorod region	44.96	10.60	50	2
Vladimir region	39.51	108.49	53	60
Astrakhan region	34.46	132.55	57	66
Altai territory	30.38	36.94	59	14
Perm territory	29.52	292.63	60	75
Ivanovo region	29.26	48.15	61	17
Ulyanovsk region	24.01	60.88	66	29
Stavropol territory	19.75	32.42	72	8
Omsk region	19.69	64.26	73	32
Tomsk region	16.99	115.29	75	61
Ryazan region	16.09	74.56	77	39
Kirov region	13.55	69.06	78	35
Chuvash Republic	11.91	68.16	79	34
Tver region	6.42	273.13	80	74

The value of θ is taken for the reference vectors equal to 100.

As can be seen from the data obtained, the five regions that have a high level of socio-economic stability in terms of specific indicators (related to the population) include the Sakhalin, Belgorod, Kaliningrad regions, the Republic of Altai, the Tyumen region.

In turn, the five regions that have a high level of environmental sustainability in terms of specific indicators include the Krasnodar territory, Nizhny Novgorod region, Moscow, Sverdlovsk region and the Kabardian-Balkar Republic. The presence of Moscow in this group is explained by a significant number of the population (12.3 million people) and the fact that the integrated assessment considered specific indicators of environmental sustainability (related to the number of the population).

6. Conclusions and Prospects

The above example shows that the study of the features of sustainable development of countries, regions and cities can be performed by cluster analysis of data, followed by the construction of econometric scales to compare the States of objects among themselves on a set of indicators. For comparison of objects it is offered to use a basic vector of development which is under construction for control group of objects which are the most developed on indicators of achievement of the purposes of sustainable development.

The article proposes socio-econometric scales for assessing the development of regions, as well as criteria characterizing their sustainability, which are based on a relative comparison of the vector of development of each region with the reference vector of development of the control group of regions.

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