Formation of Indicators for Assessing the Ecological and Economic Development of the City and the Development of a Model for Assessing Sustainable Development

Chulpan S. Zakirova[1] [1], Olga A. Fatkhutdinova[1] [2], Svetlana M. Nuryiakhmetova[2] [3], Konstantin L. Svechnikov[2] [4] and Maria A. Pugacheva[2] [5]

[1]Almetyevsk state technological university «Petroleum high school», Almetyevsk, Republic of Tatarstan, Russia
[2]Kazan Federal University, Kazan, Republic of Tatarstan, Russia
czakirova@yandex.ru, fathutdinovaoa@mail.ru, Svetanur-agni@mail.ru, svechnikov.k@mail.ru, , marusechka009@mail.ru

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Abstract: The purpose of this work is to develop ecological and economic indicators for assessing the sustainable development of small cities. The authors use methods of collecting and processing scientific material, systematization, as well as logical and project-based approaches. In accordance with the purpose, the authors solve the following problems in their work: the formation of indicators and models for assessing the ecological and economic development of the city; testing the model on the example of a specific city. The paper proposes an algorithm for the formation of a model for an integral assessment of the sustainable development of the city, reflecting the dynamics of the economic, social and environmental development of the city. The object of the study is a complex of relationships that arise during the assessment of the state of the city in order to ensure its sustainable development. The article presents a comprehensive assessment of the ecological, social and economic factors of Almetyevsk (Republic of Tatarstan) and Salavat (Republic of Bashkortostan).

1 INTRODUCTION

Cities around the world are increasingly suffering from the effects of climate change. Adaptation of cities to climate change is one of the most important tasks, the solution of which is necessary to implement a model of sustainable development and reduce environmental threats to the population. “A well-designed strategy for cities to respond to climate change and build resilience creates additional economic, social and ecological benefits that will ensure a better life for everyone in a rapidly urbanizing and changing world.” In addition, the COVID-19 pandemic has contributed to the fact that "faced with conditions of self-isolation and the need for social distancing, citizens have developed new behavioral patterns, which is reflected in the nature of citizens' demand for public spaces: the demand for increasing accessibility and development of local public spaces has increased, and the degree of integration of digital space into urban processes has also increased” (Ahmetzyanova, 2021). Cities that are more attractive in terms of the quality of the urban environment are more popular. This is confirmed by international ratings published annually, such as Anholt-Ipsos City Brand Index 2020, The World's 100 Best Cities and others, assessing million-plus cities according to various parameters (Glebova, Kuchukbaeva, Vorobyev, Abdulganiev, 2022).

According to the authors, city management through sustainable development is aimed at creating and maintaining an urban environment that meets the needs of present and future generations, while preserving resources and respecting environmental

[1] https://orcid.org/0000-0002-5063-1076
[2] https://orcid.org/0000-0002-3715-3524
[3] https://orcid.org/0000-0002-9970-6737
[4] https://orcid.org/0000-0001-9224-7876
[5] https://orcid.org/0000-0003-3156-6042

sustainability, social justice and economic prosperity. "Effective and efficient urban management and sustainable development is crucial and becomes increasingly difficult as population growth and economic development occur in urban areas” (Makartni, Avanesov, 2014). Consequently, urban projects and strategies should minimize negative environmental impacts, preserve natural resources and biodiversity, and reduce greenhouse gas emissions. Urban management should take into account the needs of all segments of the population, including vulnerable groups, and ensure equal access to services, housing, health care, education and employment opportunities, as well as promote economic development, job creation, attracting investment and supporting entrepreneurship, ensuring sustainable economic growth. The use of new technologies and innovations can help improve the quality of life of citizens, increase the efficiency of resource consumption and reduce the impact of the city on the environment.

Introducing the concept of sustainable development in cities such as Almetyevsk and Salavat can help improve the environmental situation, reduce waste and increase resource efficiency. Government authorities play a key role in creating the necessary conditions for the development of a green economy, including through the development of appropriate legislation, financial support and stimulation of innovation.

Urban management should be open, transparent and take into account the opinions and interests of citizens, involving them in decision-making and project implementation. Understanding the environmental needs of society and taking them into account when making decisions at the level of public administration is an important step towards creating a sustainable and prosperous economy. "Civil society can play an important role in establishing cooperation between the population and government officials" (Kristi, 2023). It is also important to ensure that society is widely informed about the benefits of a green economy and that citizens are involved in the process of making environmentally oriented decisions.

In general, urban management through sustainable development helps to create cities that not only thrive today, but also remain viable and livable in the future. The main essence of sustainable urban development management is the integration of various aspects of development to achieve sustainable and harmonious development, which is achieved through the cooperation of city authorities, public organizations, the private sector and citizens to develop and implement joint strategies and projects, as well as achieving a balance between economic, social and environmental development, taking into account the needs of present and future generations.

2 METHODOLOGY

The algorithm for forming an assessment of the ecological, economic and social development of the city includes 5 stages (Figure 1). This algorithm is flexible, in other words, it is possible to make changes when the indicators vary. The model is capable of adapting to changing environmental conditions, adding new areas of activity, and so on.

Figure 1: Algorithm for the formation of an assessment of the ecological, economic and social development of the city. *Source:* compiled by the authors**.**

The first step is to develop evaluation indicators for a detailed study of the sustainability of the city. Such indicators may include: the ecological situation of the city, demographic potential, the quality of life of the population, the maintenance of cultural and scientific potential, the ability of the economy for sustainable growth and, in general, the stability of the financial system of the city.

At the second stage, an assessment of the sustainability of the city is carried out, which includes six blocks (Figure 2).

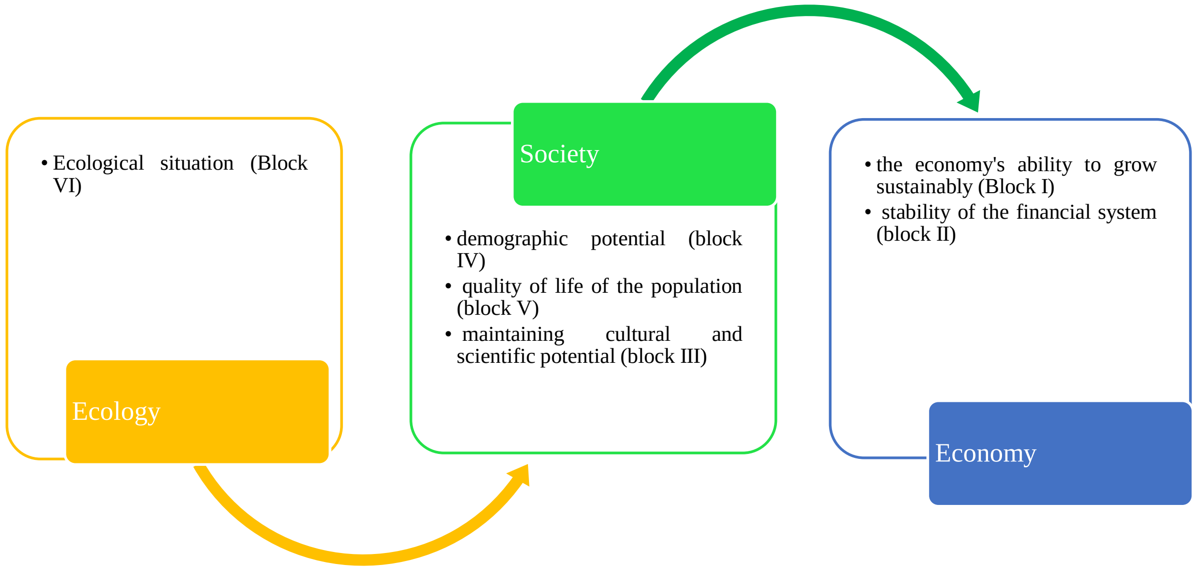

Figure 2: Assessment of the sustainability of the city.

This division into blocks makes it possible to analyze each indicator, so that the sustainable development of the city can be assessed. If any indicator turns out to be negative, then it is necessary to develop a project to increase the stability of this block. Accordingly, the higher the score for three factors (ecology, society, economy), the more sustainable the development of the city.

The sustainability assessment is based on the methodology of expert assessments, where the significance of sustainable development indicators is established, and the general characteristics of the social, ecological and economic sustainability of the region are assessed as the arithmetic mean of the integral indicators of the sustainability of local blocks, weighted by significance:

$$\mathrm{y}_{\text{total}} = \frac{\mathrm{y}_1 \mathrm{a}_1 + \mathrm{y}_2 \mathrm{a}_2 + \mathrm{y}_3 \mathrm{a}_3 + \dots + \mathrm{y}_m \mathrm{a}_m}{m}, \quad (1)$$

or as a geometric mean:

$$\mathrm{y}_{\text{total}} = \sqrt[m]{\mathrm{y}_1 * \mathrm{y}_2 * \mathrm{y}_3 * \dots * \mathrm{y}_m}, \quad (1.1)$$

where $\mathrm{y}_1, \mathrm{y}_2, \mathrm{y}_3, \dots, \mathrm{y}_m$ are the sustainability coefficients for local blocks;

$a_1, a_2, \dots, a_m$ — the levels of significance determined by stage 6, and they will determine the priorities of the economic, social and ecological development of the region;

m is the number of local blocks.

The use of the arithmetic mean is justified where some of the considered indicators may have negative values.

The calculated generalized indicator of city sustainability allows to:

assess the effectiveness of urban policy, both at this stage and in dynamics;

take measures for the operational management of the sustainable development of the subject of the Russian Federation.

At the third stage, it is proposed to use a system of sustainability indicators for urbanized areas. "The use of goals and indicators within the framework of the United Nations Millennium Development Goals and their adaptation for cities can be quite effective. In Russia, this system has been adapted at the national and regional levels and includes 25 indicators reflecting important economic, social and ecological urban priorities" (Bobylev, Kudryavceva, Solov'eva, 2014). Figure 3 shows only the main key (basic) indicators for urban sustainable development.

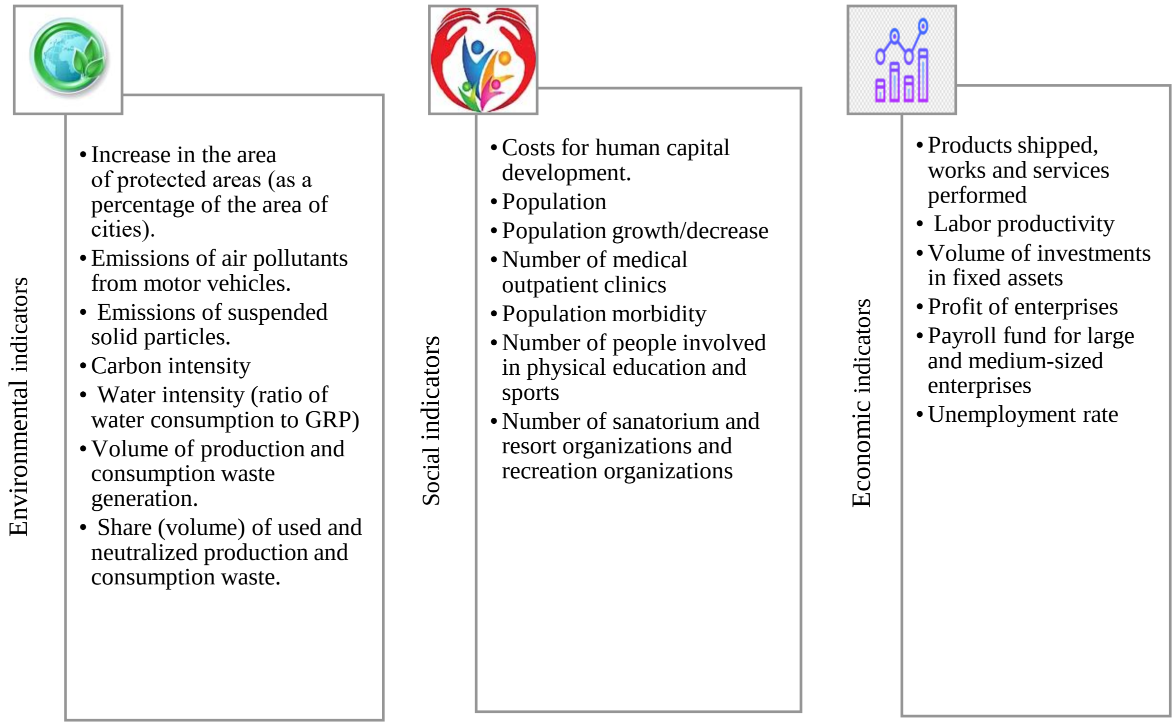

Figure 3: System of sustainable development indicators for cities. Source: compiled by the authors based on the source (Bobylev, Kudryavceva, Solov'eva, 2014).

The presented blocks on sustainability assessment (Fig.2) and a system of sustainable development indicators for cities (Fig.3) make it possible to more adequately assess the trends in the formation of urbanized space.

To compare the indicators, various data processing methods are used, including the Harrington desirability function method:

$$d = \exp(-\exp\{-y\}), \qquad (2)$$

where y is the coded value of the indicator, which allows to convert natural values into a single dimensionless numerical scale with fixed boundaries [8].

Any comprehensive assessment includes a stage associated with combining previously heterogeneous (multi-criteria) assessments into one whole, taking into account their contribution to the overall assessment. To do this, the generalized desirability function D is calculated:

$$D = \sqrt[n]{\Pi_{i=1}^{n} d_i}, \qquad (3)$$

where di is a private desirability function (Gelashvili, Lisovenko, Zaznobina, Korolev, 2009).

The boundary values of the function are from -1 to 1, which corresponds to the values “decrease - no change - increase”.

The relationship between the quantitative value of the dimensionless scale and the psychological perception of a person is shown in Table 1.

Table 1: The relationship between the quantitative value of the generalized indicator and the psychological perception of a person.

Desirability	**Marks on the desirability scale**
Very good	1.0-0.8
Good	0.8-0.6
Satisfactory	0.6-0.3
Bad	0.3-0.2
Very bad	0.2-0.0

Source: compiled by the authors

The fourth stage is the approbation of the model. Using the city as an example, we implement our model and analyze the indicators. The higher the integral indicator, the more harmoniously the city develops.

The fifth stage is the development of directions (strategies) for the work of the model blocks in the direction of improving lagging indicators. Programs will be proposed that will contribute to the growth of indicators.

Thus, thanks to the algorithm, it will be possible to analyze any city for its sustainable development, identify problems and eliminate them. Such a model will be relevant due to rapidly changing conditions and an unstable economy.

3 RESULTS

The study carried out a comprehensive assessment of the state of the cities of Almetyevsk (Republic of Tatarstan) and Salavat (Republic of Bashkortostan).

The description of the designated cities is presented in Table 2.

Table 2: Main characteristics of Almetyevsk and Salavat.

Indicator	Almetyevsk	Salavat
1. Industry	one of the most important industrial centers of the Republic of Tatarstan. The city is known for its oil refineries, chemical and petrochemical industries. The oil refinery in Almetyevsk plays a key role in the economy of the region	one of the largest industrial centers in the Republic of Bashkortostan. The oil refining, chemical and petrochemical industries are developed here. There is a large oil refinery on the territory of the city, which plays an important role in the economy of the region
2. The economy of the city	is based on industry, as well as on transport and trade. Oil refining and related industries play an important role in shaping the economy of Almetyevsk	is based on industry, especially the oil refining and chemical industries. The city also has developed trade, transport and infrastructure base
3. Population	amounts to several hundred thousand people. Almetyevsk is one of the largest cities in the Republic of Tatarstan	amounts to several hundred thousand people. Salavat is a large city of the Republic of Bashkortostan
4. History	has a rich history associated with the development of the oil industry in the region. It was founded in the 19th century and has been actively developing since then as an industrial and economic center	The city has a rich history associated with the development of industry and the oil industry in the region. It was founded in the 19th century and has been actively developing since then as an industrial center
5. Culture and sightseeing	There are various cultural and historical sights such as museums, parks, monuments and architectural structures. The city also offers a variety of cultural and entertainment events	There are various cultural and historical sights such as museums, parks, monuments and architectural structures reflecting the history and culture of the region

As can be seen from the presented data, the city of Almetyevsk is an important industrial and economic center of the Republic of Tatarstan and plays a significant role in the development of the region and the whole country. The city of Salavat also plays a significant role in the economy and socio-cultural life of the Republic of Bashkortostan, and its industry is important for the whole country.

In order to conduct a comprehensive assessment of the ecological, social and economic situation in Almetyevsk and Salavat (Tables 3-4), data collected from different sources and having different units of measurement were calculated as relative values so that they could be compared.

For an analytical assessment of the ecological, social and economic situation, 3 groups of indicators have been identified:

1) the state of the ecological situation;
2) maintenance of scientific, cultural and demographic potential;
3) the ability of the economy for sustainable growth, the stability of the financial system of the city and the quality of life of the population.

Table 3: Comprehensive assessment of ecological, social and economic factors of Almetyevsk.

ECOLOGICAL FACTORS			**SOCIAL FACTORS**			**ECONOMIC FACTORS**		
Indicators	Indicator values	Points (di)	Indicators	Indicator values	Points (di)	Indicators	Indicator values	Points (di)
Ecological situation (block VI)			**Demographic potential (block IV)**			**The ability of the economy for sustainable growth (block I)**		
						Products shipped, works and services performed	20.3	1
						Labor productivity	17.6	1
Increasing the area of specially protected natural zones	6.3	1	*Population size*	0.1	1	*Volume of investments in fixed capital*	84.3	1
Emissions of harmful substances into the atmosphere	63.3	-1	*Population growth/decline*	30.7	-1	**Sustainability of the financial system (block II)**		
Emissions of air pollutants from motor vehicles	29.3	1	*Number of outpatient medical organizations*	93.8	1	*Profit of enterprises*	73.2	1
Particulate matter emissions	0.2	-1	*Population morbidity*	68.7	-1	*Balanced financial result*	41.7	1
Carbon intensity	1.1	1	**Maintenance of scientific and cultural potential (block III)**			**Quality of life of the population (block V)**		
Water intensity (ratio of water consumption to GRP)	50.2	1	*Human capital development costs*	42	1	*Wage fund for large and medium-sized enterprises*	120.4	1
Volume of generation of production and consumption waste	23.1	1	*Number of people involved in physical education and sports*	45	1	*Average monthly salary*	19.4	1

Share (volume) of used and neutralized production and consumption waste	15.3	-1	*Number of sanatorium and recreation organizations*	10	1	*Unemployment rate*	2.7	1
	∑	**2**		∑	**3**		∑	**8**

Source: compiled by the authors on the basis of data from indicators of municipalities of the Federal Statistics Service.

Table 4: Comprehensive assessment of ecological, social and economic factors of Salavat.

ECOLOGICAL FACTORS			**SOCIAL FACTORS**			**ECONOMIC FACTORS**		
Indicators	Indicator values	Points (di)	Indicators	Indicator values	Points (di)	Indicators	Indicator values	Points (di)
Ecological situation (block VI)			**Demographic potential (block VII)**			**The ability of the economy for sustainable growth (block I)**		
						Products shipped, works and services performed	23.36	1
						Labor productivity	10.3	1
Increasing the area of specially protected natural zones	0.1	0	*Population size*	-0.2	-1	*Volume of investments in fixed capital*	33.8	1
Emissions of harmful substances into the atmosphere	1.1	-1	*Population growth/decline*	-0.2	-1	**Sustainability of the financial system (block II)**		
Emissions of air pollutants from motor vehicles	7.5	-1	*Number of outpatient medical organizations*	1.5	1	*Profit of enterprises*	23.4	1
Particulate matter emissions	2.3	1	*Population morbidity*	81.3	1	*Balanced financial result*	16.54	1
Carbon intensity	0.01	0	**Maintenance of scientific and cultural potential (block III)**			**Quality of life of the population (block V)**		
Water intensity (ratio of water consumption to GRP)	3.7	1	*Human capital development costs*	1.2	1	*Wage fund for large and medium-sized enterprises*	22.8	-1
Volume of generation of production and consumption waste	3.8	-1	*Number of people involved in physical education and sports*	32.9	1	*Average monthly salary*	27	1
Share (volume) of used and neutralized production and consumption waste	75.9	-1	*Number of sanatorium and recreation organizations*	4	1	*Unemployment rate*	0.97	1
	∑	**-2**		∑	**3**		∑	**6**

Source: compiled by the authors based on data from indicators of municipalities of the Federal Statistics Service.

The unfavorable state of the environment in the territory of the analyzed cities is due to the presence of environmentally hazardous and harmful industries and the imperfection of the solid waste disposal system. Thus, in Almetyevsk, the situation with the disposal of solid household waste is estimated as "bad" (di = -1), while the load on the environment due to the disposal of household waste is estimated as "decrease" (d = -1). The data in Table 4 show that emissions of harmful substances into the atmosphere and emissions of pollutants from motor vehicles increase annually in Salavat (di = -1). In Salavat, in contrast to Almetyevsk, there is a positive trend in terms of particulate matter emissions (di=1).

The demographic potential in both cities has a negative dynamics in terms of population growth/decline (d = -1), which is due to high mortality against a background of low birth rates. In Salavat, the population indicator has a minimal value, and in Almetyevsk, the birth rate is lower than the death rate of the population. In general, the acceleration of population decline from 2017 to 2022 is a direct consequence of the system-wide crisis in the country that unfolded during the transition period, as well as the Covid-19 pandemic. It should be noted that in terms of population morbidity, Almetyevsk has a negative value (di = -1), while in Salavat this indicator has a positive value.

In terms of economic factors, Almetyevsk has a more favorable situation in all indicators than Salavat – in terms of the ability of the economy for sustainable growth, the stability of the financial system, as well as the quality of life of the population. The city of Salavat lags behind Almetyevsk in terms of the Wage Fund for large and medium-sized enterprises (di = -1).

In general, the calculation results show that the generalized indicator on the desirability scale for the city of Almetyevsk is D=0.56 points, for the city of Salavat - D=0.38 points, which assesses the ecological, social and economic situation in these cities as "satisfactory".

4 RESULTS AND DISCUSSION

The cities of Almetyevsk and Salavat are located in the oil regions of Russia, so they often face a number of environmental problems related to the extraction, transportation and processing of oil and petroleum products. Some of the most common problems include:

1. Water pollution: industrial processes such as oil extraction and refining often lead to contamination of surface and groundwater. Emissions of petroleum products and chemicals can have serious consequences for the ecosystems of rivers, lakes and water intake areas, as well as for human and animal health.
2. Air pollution: the operation of oil refineries, transportation of oil and petroleum products, as well as waste incineration can lead to emissions of harmful substances into the atmosphere. This can cause air pollution and increased levels of pollution in the cities of the oil regions.
3. Specific types of pollution: in oil regions, there are often problems with soil contamination with petroleum products and chemicals. This can have a negative impact on agriculture, vegetation and human health.
4. Environmental accidents: Oil pipelines, oil depots and refineries pose a potential threat to the environment due to possible oil leaks and spills. Environmental accidents can lead to catastrophic consequences for nature and people.
5. Destruction of natural ecosystems: the development of the oil industry can lead to the destruction of natural ecosystems, including forests, swamps and animal migration routes, leading to loss of biodiversity and disruption of ecological balance.

Solving these problems requires a comprehensive approach, which includes strict regulatory measures, monitoring and control of production processes, as well as the introduction of technologies to reduce the negative impact on the environment. In addition, it is important to ensure the active participation of society and citizens in solving environmental problems in the cities of the oil regions.

Based on the results of the analysis, it can be concluded that the social and economic strategy prevails in the city of Almetyevsk (Figure 4). This means that much attention is paid to the system of stable connections and relationships between companies, social groups, people (economic entities) that arise in the process of production, distribution, exchange and consumption of goods in relation to property.

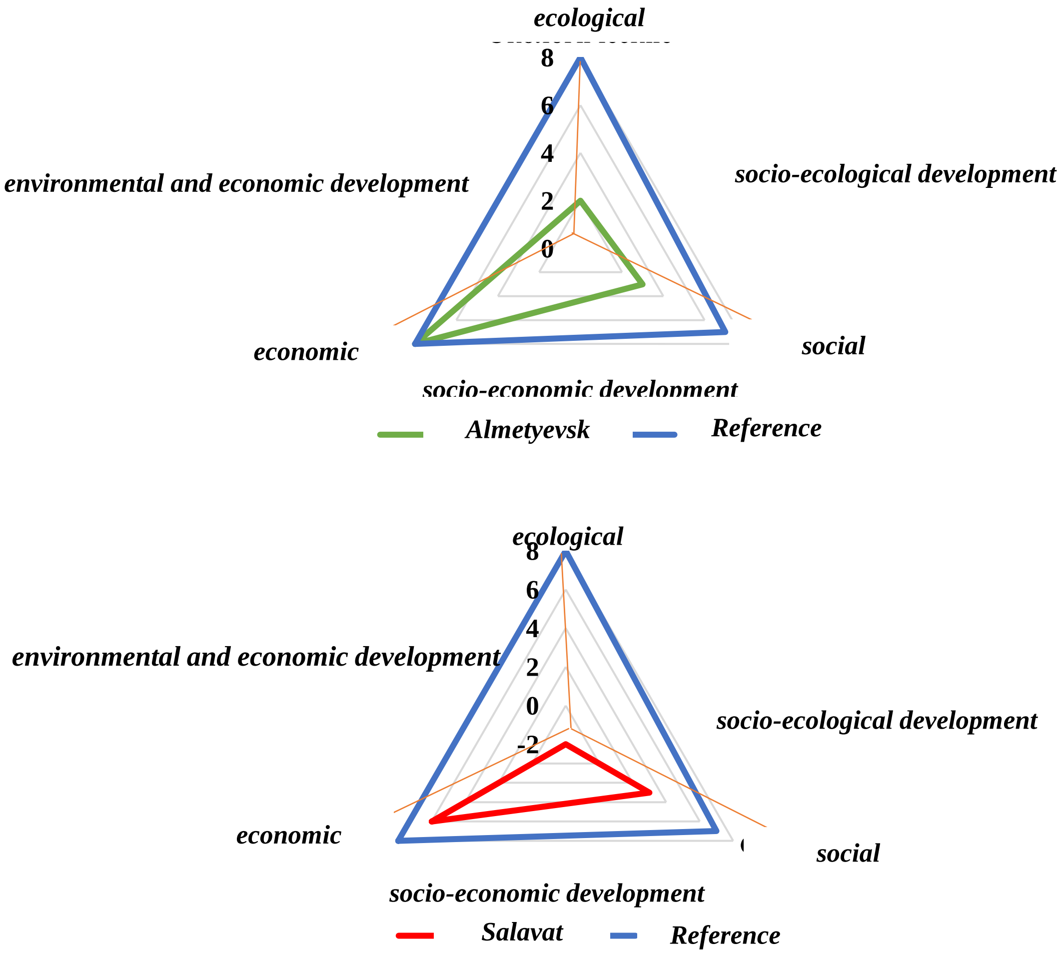

Figure 4: Comprehensive assessment of ecological, social and economic factors in Almetyevsk and Salavat. *Source:* compiled by the authors.

Ecological and economic development is present in Almetyevsk, but it is developing slowly. Therefore, to develop this area, the city administration needs to create attractive conditions to attract small businesses, offer government support, grants, create eco-projects, popularize eco-products, showing that it can be both profitable and useful for society, the city and the world at the same time. For example, these could be projects such as ecotourism, motivating entrepreneurs to build residential eco-districts, eco-taxi, and create smart heating for buildings. The socio-ecological development of the city can be considered satisfactory. The lack of environmental priorities in determining the development strategy of many cities and the irrational approach to the use of individual geosystems and components of the natural environment lead to the emergence of a number of complex, intractable, and sometimes dead-end environmental problems. These include problems related to pollution of atmospheric air, soils, transformation of the hydrological and hydrochemical regime of water bodies, the decrease in the area of green spaces and deterioration of their condition observed in many cities, etc.

Only socio-economic relations are mainly developing in Salavat. Unfortunately, this is a common model of small cities. Lack of attention to environmental and social factors can ultimately lead to negative consequences. The significant deterioration of the environmental situation in cities leads to a number of serious social problems, including a decrease in life expectancy and the period of intense activity of urban residents, an increase in morbidity and mortality rates, a deterioration of mental and social health, which is expressed in the wide spread of various forms of deviant behavior (drug addiction, alcoholism, etc.) and the increase in crime, etc. In many cities, conditions for sports and recreation are deteriorating significantly, and there are fewer and fewer opportunities to meet many other material and spiritual human needs.

It can be concluded that the city of Almetyevsk is developing more steadily in all directions than the city of Salavat. Every city must develop all spheres of life in order to achieve the goals of sustainable development.

5 CONCLUSION

The analysis of the ecological and economic environment revealed the relevance of the model for Russia as a whole and for the city of Almetyevsk in particular due to the growing problem of resource depletion, negative climate changes, accumulation of large amounts of production and consumption waste, and deterioration of the overall environmental situation.

Methodological approaches for assessing the sustainable development of the city were formed. An algorithm for the formation of an assessment of the ecological, economic and social development of the city was developed: evaluation indicators were developed, indicators were divided into blocks, the model was tested using the example of a city, and strategies for the operation of model blocks in the direction of improvement were developed.

A comprehensive assessment of the ecological, social and economic factors of Almetyevsk and Salavat shows that they are in a satisfactory state on the desirability scale. However, the city of Almetyevsk is at a borderline value, and with an increase in integral values, its condition may become “good” on the desirability scale. In this regard, programs were proposed to ensure the sustainable development of the city.

Rational use of land, development of urban infrastructure, preservation of green and public spaces play a key role in managing the sustainable development of the city. Sustainable development of the city includes measures to reduce social and economic inequality, ensuring access of all segments of the population to basic services and opportunities. The sustainability management of the city strives for the efficient use of natural resources, reduction of waste and emissions, and the transition to environmentally friendly and energy-efficient technologies. An important component of managing the sustainable development of a city is the involvement of citizens in decision-making and project implementation, as well as ensuring transparency and openness of city government.

Thus, the development of the principles of circular economy in Almetyevsk can be promising in terms of economic, ecological, and social effects. However, the state will have to create conditions for the successful implementation of the concept through reforming the legislative framework, creating financial support mechanisms, and stimulating scientific research. In general, urban sustainable development management aims to create cities that provide a high standard of living for their residents, while preserving natural resources and respecting the principles of justice and equality.

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