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# ASSESSMENT OF ECONOMIC SECURITY OF TERRITORIAL SYSTEMS BASED ON THE MEMBERSHIP FUNCTION

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## Abstract

Strategic management of regional development requires deep and comprehensive monitoring of the territorial system functioning. The exposure of open socio-economic systems to external influences and the internal destabilizing factors means the emergence of risks and threats to economic security that are different in terms of control. The economic security of the region is based on the ability of the spheres and elements of the system to function in compliance with the requirement to ensure admissible risks, maintain stability under the influence of threats and a negative impact of a combination of factors. Among the most important and controlled areas of the territory economic security are the population life level, production and financial components, budget and infrastructure, investment potential. The article presents the results of the study aimed at developing an approach to assess the economic security of territorial systems based on the membership function. The approach proposed by the authors is adapted to solve the problem of assessing the system membership in different levels of economic security and risk. Application of this method made it possible to identify the probable distribution of regional economic security indicators by risk levels. The estimates of the membership functions indicators coefficients by the region's levels of economic security are obtained. The results can be applied for the subsequent strategic planning of measures to control the dynamics of the territory development.



*Keywords:* Regional development, system risk, economic security threats, territory management, membership function

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## 1. Introduction

The development of socio-economic systems is accompanied with the emergence of new conditions, risks and threats, which are caused both by poorly controlled processes within the framework of global trends, and by purposeful actions or inertness of the government entities of states and territories. Ensuring economic security of territorial units is the most important task in the field of management, the solution of which is based on continuous monitoring processes and development of measures to manage the system risks in order to avoid threats.

It is of utmost importance for decision makers (governing bodies of socio-economic systems) to be able to quickly and accurately assess emerging threats. For these purposes the methods of risk assessment and analysis of the territorial systems security can be applied. A system of assessment indices can be proposed, which includes a certain set of individual indicators in various categories related to certain aspects of socio-economic development. An alternative approach to assess safety is the risks and threats analysis, implementation of which is measured in a probabilistic way, taking into account a quantitative measure of consequences.

## 2. Problem Statement

Currently, a legal institution of economic security has been established in the Russian Federation, the foundations of which are fixed in the National Security Strategy of the Russian Federation according to the Decree of the President of the Russian Federation dated December 31, 2015, No. 683 "On the National Security Strategy of the Russian Federation", the Economic Security Strategy of the Russian Federation (Decree of the President of the Russian Federation dated May 13, 2017 No. 208 "On the Strategy of Economic Security of the Russian Federation for the Period up to 2030"), Federal Law No. 390-FL dated December 28, 2010 "On Security", etc.

The territorial specifics of economic security policy is to a certain extent reflected in the strategies of the socio-economic development of the regions, which traditionally analyze competitive advantages, problems, priorities and directions of the territory development; identify risks and threats, strengths and weaknesses of the regional socio-economic sphere. However, at the same time, the indicators and key positions of ensuring the territorial economic security still lack coverage. The main problem of assessing the regional economic security level is a choice of a methodological approach that is different from those used in the analysis of the systems characteristics of the similar categories (stability, competitiveness, etc.), as well as the choice and justification of assessment indicators (Moiseev, 2015).

The authors Krivorotov et al. (2019) considered such indicators as the rate of economic growth; the level (rate) of inflation; the ratio of spending on science and scientific services to GDP; the ratio of resources involved in the shadow turnover to GDP (the scale of shadow economy spread); the ratio of per capita income to the subsistence minimum; life expectancy at birth, etc. When diagnosing the state of Russia's economic security, threshold values were set based on the world average and reference indicators.

In the work edited by Kolesnikov (2019) the authors propose a methodology for assessing the level of economic security of regions, based on the calculation of demographic security indicators (according to the region’s population density); saturation ratios of the region with organizations, funds and investments;

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ratio indicator of the country's GRP and GDP; coefficient of the production structure of the economy (based on the share of the industry's value added in the GRP). The authors assessed the level of economic security of the Russian Federation federal districts by summing these calculated indicators, reduced to comparable coefficients.

Analysis of research on the problems of economic security of territories showed that the most frequently used diagnostic tool is the method of indicative analysis. Within its framework production, financial and socio-demographic indicators of economic security are traditionally distinguished (Nazarov, 2017; Skomoroshchenko et al., 2020; Tsvetkov et al., 2019).

More complex methods for assessing the territory economic security include: methods of scenarios analysis and processing, multivariate statistical analysis; logical and probabilty modeling; methods of the theory of fuzzy systems and pattern recognition; methods of multi-criteria optimization, simulation and game theory (Arkhipov, 2015).

To calculate the weights of indicators during their integration, the method of pair-wise comparisons, the method of analyzing hierarchies and the method of clustering weights are used (Wang et al., 2020). Fuzzy logic models and the entropy method are also used (Zhou & Luo, 2017).

In the process of methods for assessing economic security development, many authors solve another problem: they justify approaches to the formation of threshold values of security level indicative markers. The author's approaches to determine threshold values are based on four groups of methods: expert (most often used); methods based on assessing the level of world or average Russian indicators, focused on reference values; statistical and mathematical assessment methods (rarely used due to their complexity and lack of information) (Ivanova et al., 2020; Khairullov & Saipullaev, 2014; Kolesnikov & Dolzhenko, 2018; Nam et al., 2015).

Thus, to assess the security level of objects and systems, complex methods of processing statistical and expert indicators are used in order to combine the advantages and overcome the disadvantages of objective and subjective indicators. There are no generally accepted and universal methods for assessing the economic security of a territory.

The main tool for ensuring the economic security of a territory (country or region) is a mechanism for identifying and preventing internal and external threats to the security of the economy and social sphere (Stankevičienė et al., 2013).

Activities to counter threats and challenges to economic security of socio-economic systems should be strategic and purposeful, based on the coordination of efforts of all entities empowered to ensure economic security. Monitoring and safety assessment create an information and analytical basis for these activities (Morozov et al., 2019).

The complex of unresolved theoretical and methodological issues determines the relevance of research in the field of assessing the level and ensuring the economic security of the country's regions.

## 3. Research Questions

The economic security of a socio-economic system can be defined as the ability of the system's elements to develop and sustainably satisfy their basic needs while meeting the requirement to ensure low risks of the system's functioning. At the same time, the following spheres should be subject to assessment

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and control: the territory population life level, production and financial components, budget and infrastructure, investment potential, etc.

The economic security of the territory is the state of the economy in which the existing socio-economic threats and risks are manageable and controllable; in the event of a negative scenario (threats), the regional system retains the necessary and sufficient level of parameters to ensure the progressive development of economic sectors, socio-demographic sphere, financial and budget components, etc. Economic security is a prerequisite for sustainable development of the territory.

The economic security of the state and the economic security of its constituent territories (regions), of course, are closely interrelated. This determines the uniformity of terms and indicators (indices) of economic security both for the state as a whole and for its individual territories (regions).

According to the Decree of the President of the Russian Federation dated May 13, 2017 No. 208 "On the Strategy of Economic Security of the Russian Federation for the Period up to 2030", "Economic security means the state of the national economy protection from external and internal threats, which ensures the country's economic sovereignty, the unity of its economic spaces, conditions for the implementation of strategic national priorities of the Russian Federation".

Based on this definition, we can give the following interpretation of the concept of "economic security of the region". The economic security of the region is the state of protection of the regional economy (the economy of the territory) from external and internal threats, which ensures sustainable economic growth, conditions for a high standard of living of the population and the implementation of the most important strategic goals and priorities of territorial development.

The structural elements of the economic security of the region are: socio-demographic, budgetary and financial, investment, production, infrastructural and environmental components.

System security is understood as the achievement of a certain range of values of key indicators corresponding to the maximum or minimum threshold values. A selection of particular indicators is made and their reduction into one general index (a system of integral indicators), which allows comparing territorial systems with each other or analyzing their dynamics over a number of years. Deviation from the established threshold values is interpreted as the realization of risks and security threats and requires immediate government intervention in order to eliminate the negative impact of factors on the territorial system.

Thus, economic security is closely related to the category of risk as a probabilistic event, the consequences of which can have both positive and negative impact on the development of the territory. The risk is assessed from the point of view of two approaches: as the probability of an event and as the scale (magnitude) of the consequences from the threat. Risk is also understood as possible deviations of the specified parameters from their expected level (for example, from the average or standard value).

The emerging socio-economic risks are usually divided into external and internal, systemic (characteristic of the entire system as a whole) and specific (inherent in a specific object, element of the system). After assessing the risk acceptable for the system (low) and controlling its value, it is possible to monitor the state of the system in order to timely diagnose the signs of threats to the economic security of the territory. In this regard, a toolkit for diagnosing the level of economic security is required, which makes

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it possible to assess the magnitude and likelihood of the risks, the degree of manifestation of security threats to the territory.

## 4. Purpose of the Study

Diagnostics of the territorial system economic security level together with the assessment of risks and threats to sustainable development serves the purposes of developing strategic plans for the regions. At the heart of territorial strategizing is a set of interrelated goals and objectives, the achievement of which ensures the necessary and sufficient level of economic security of the region for sustainable growth in the population life level and territory development, effective use of the system potential.

The authors of the article set the following goal: to propose a methodological approach to assessing the level of economic security of a regional system, taking into account the relationship between socio-economic indicators of development and indicators of risk of the territory, as well as the probabilistic nature of the system forecasts and threats to its security.

## 5. Research Methods

To assess the level of territorial system security a set of criteria and assessment indicators can be developed based on a indicators system in compliance with the "Strategy for ensuring the economic security of the Russian Federation until 2030".

The system of indicators can be divided into different categories: production, social, demographic, financial, environmental, and others, based on the goals and focus of the study. The set of criteria and indicators should reflect characteristics and specifics of the territory, its weaknesses and strengths of socio-economic development. Each selected factor has a certain impact on the maximum level of system risk. In this regard, it is necessary to establish limits (ranges) of values of assessment factors depending on the level of risk.

The economic security of a territory (region) can be divided into several levels: I (safe level), II (low risk), III (medium risk), IV (high risk). Table 1 shows the relationship between the levels of safety, risk characteristics, consequences and measures to ensure the safety of the territory: where $\bar{X}$ the average value of the indicator of the system for the selected study period; $\sigma$ root-mean-square (standard) deviation of the system state indicator.

**Table 1.** Characteristics of the economic security levels of the territory and security measures

| Security level of the territory. Risk | Effects | Security measures |
|---|---|---|
| I. Zero risk level. System security ensured | Sustainable development of the socio-economic system. The indicators of the development and state of the system are at an average level: $X_i = \bar{X}$ | Regular monitoring of socio-economic indicators, regulation of ongoing processes (management of negative trends and maintenance of positive changes). Significant risk management measures and impact on the level of economic security are not required. |
| II. Low system risk | The risks are predictable and manageable. The emerging negative tendencies are of a selective nature and can be eliminated in a short period | To control indicators dynamics and risks impact, an extended list of accompanying indicators is required, signaling a possible |

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| Security level of the territory. Risk | Effects | Security measures |
|---|---|---|
| | of time. Deviations of indicators from average values vary within the standard deviation: $X_i = \bar{X} \pm \sigma$ | further deviation of the situation development from its expected state. Analysis of the system symptoms, indicating the facts of expected (predicted) threats, in order to prevent their further development. |
| III. Medium system risk | Threats to economic security that were not predicted or their magnitude exceeds the expected consequences of the impact are realized. Possible realization of associated risks, the relationship of which has not been assessed in advance. Crisis phenomena are observed in vulnerable areas and industries affected by threats. Deviations of indicators from average values vary within two standard deviations: $X_i = \bar{X} \pm 2\sigma$ | It is required to strengthen socio-economic processes monitoring in the region, to increase the frequency of analyzing trends in relation to "problem" areas and indicators that respond to the threat impact. To expand the possibilities of further risks forecasting, to increase the accuracy of forecasts. Introduce measures to support vulnerable areas, industries and categories of the population. |
| IV. High system risk | Threat exposure significantly exceeds expected and acceptable levels. Crisis phenomena are typical for a significant number of spheres and sectors of the economy. Associated systemic and specific risks affect the entire socio-economic system. Deviations of indicators from average values vary within three standard deviations (and more): $X_i = \bar{X} \pm 3\sigma$ | Scale up monitoring of support measures of the economy, social sphere and the effectiveness of their implementation. Provide feedback on the assessment of the sufficiency of the implemented support measures. Introduce emergency measures to remedy the situation in the most important strategic areas and industries. Expand support measures for priority sectors and vulnerable groups of the population. |

To assess the level of a system risk based on a set of indicators, it is convenient to use membership functions, “which allow the analytical representation in the form of some simple mathematical functions. This simplifies not only the corresponding numerical calculations, but also reduces the computing resources required to store individual values of these membership functions” (Leonenkov, 2005, p. 43).

For a set of indicators signaling the presence or absence of problems in the field of ensuring the territory economic security (set X), it is possible to construct a membership function μ, such that: $X^* \rightarrow [0, 1]$; a given fuzzy set is defined as:

$$\tilde{A} = \{(x, \mu_A(x)) | x \in X\} \quad (1)$$

The membership function quantitatively and probabilistically determines whether the elements of the initial set of observation indicators belong to a fuzzy set. In this case, the value 0 means that the element is not included in the specified fuzzy set; the value 1 characterizes an element that is completely (100%) in the desired set; values in the interval (0; 1) mean elements that are indistinctly included in the specified set, but the measure of their belonging to it is quantitatively determined by a relative indicator from 0 to 1 or up to 100% (Novoseltsev et al., 2019).

To construct a fuzzy set, the *fuzzy method* is applied which is a reduction to fuzziness, based on the use of data on values for quantitatively measurable indicators. “The method assumes that in the presence of data on the values of a measurable quantity, it is recognized that these values are known inaccurately, with an error or random error. The less confidence in the accuracy of measuring a feature, the larger the

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interval of the carrier of the corresponding fuzzy set should be. The method allows one to adequately represent the objectively present inaccuracy of the measurement results. As a rule, indirect methods for determining the values of the membership function are used in cases where there are no obvious measurable properties that can be used to build fuzzy models of the domain under consideration" (Leonenkov, 2005, p. 189).

Assessment of the territory economic security level, taking into account risk assessment, implies the use of the methodology for constructing the membership function for a set of local indicators by implementing several stages.

1) Determination of the safety level and risk indicators based on the statistical measure of their values variation. For this, it is proposed to use statistical assessment indicators, such as the mean and standard deviation (Table 1).

2) Calculation of the membership function coefficients of indicators to a set of assessments, for example, to such as "zero risk level" (the first level of assessment is a safe level), "low level of risk" (second level of safety), "average level of risk" (third level security) and "high level of risk" (fourth level of security).

3) Estimates of indicators can be represented in the form of a matrix of values $A = a_{ij}$, the elements of which show the degree of belonging of the element in the *i*-th row and *j*-th column to the set under consideration compared to the element in the *j*-th row and *i*- m column. The elements of the matrix are related by the $a_{ij} = 1/a_{ij}$ and are determined by the formula (2):

$$a_{ij} = \frac{n_i}{n_j}, \tag{2}$$

where ni is the number of the indicator observations for assessing the level of economic security falling into the range of the i-th security level ($i = \overline{1,4}$); nj is the indicator observations number for assessing the level of economic security falling within the range of the j-th security level ($j = \overline{1,4}$).

4) Finding the eigenvector $\lambda$ of the algebraic system of equations $Aw = \lambda w$ (or in another form $(A - \lambda E)\, w = 0$, where E is the identity matrix, that is, a matrix which main diagonal is filled with units, and all other members are equal to 0) in order to calculate the components of the eigenvector *w*, which characterize the membership function of a given element (indicator).

5) Based on the matrix of risk assessments (by mean values and standard deviations), determining the eigenvector *w* for which the condition $Aw = \lambda w$ is satisfied (finding the values $\lambda$ for which the determinant of the matrix $(A - \lambda E)$ is equal to zero).

After determining $\lambda_{max}$, it is required to proceed to finding the components of the eigenvector *w* corresponding to the found eigenvalue $\lambda_{max}$. For this purpose, the matrix equation is solved:

$$\begin{bmatrix} 1-\lambda_{max} & a_{1j} & a_{1j+1} \\ a_{2j-1} & 1-\lambda_{max} & a_{2j+1} \\ \dots & \dots & \dots \\ a_{ij-1} & a_{ij} & 1-\lambda_{max} \end{bmatrix} \cdot \begin{bmatrix} w_1 \\ w_2 \\ \dots \\ w_i \end{bmatrix} = 0, \tag{3}$$

which can be reduced to:

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$$\begin{cases} (1-\lambda_{max})w_1+a_{12}\,w_2+\ldots+a_{1j}\,w_j+a_{1j+1}\,w_{j+1}=0 \\ a_{21}\,w_1+(1-\lambda_{max})w_2+\ldots+a_{2j}\,w_j+a_{2j+1}\,w_{j+1}=0 \\ \ldots \\ a_{i1}\,w_1+a_{i+1\,2}\,w_2+\ldots+(1-\lambda_{max})w_{j+1}=0 \end{cases} \quad (4)$$

under $w_1 + w_2 + \ldots + w_j + w_{j+1} = 1$

The result of solving system (4) is the eigenvector of values at $\lambda_{max}$: $(w_1 ; w_2 ; \ldots; w_j ; w_{j+1})$, the components of which are the coefficients of the membership function.

6) The results obtained allow us to construct a function $\mu(x_{ij})$, characterizing the degree of belonging of the indicator $x_{ij}$ to one of the gradations: “zero level of risk”, “low level of risk”, “average level of risk”, “high level of risk”.

The degree of belonging of the studied indicator $x_{ij}$ to a zero level of risk is $w_3$ %, to the low level -$w_2$ %, to the middle level $w_3$ % and to the high level -$w_4$%.

The indicator can be represented as: $x_{ij} = w_1$ "zero level" + $w_2$ "low level" + $w_3$ "middle level" + $w_4$ "high level". The summing of indicators in the form of a membership function makes it possible to obtain the integral assessment of the membership level of a system of indicators to a certain level of risk. Since the $w_i$ range from 0 to 1 (normalized), they can be summed up.

## 6. Findings

In Table 2, the application of the method is shown by the example of the following indicators for assessing the level of economic security: real money incomes of the population (as a percentage of the previous year); consumer price index (percentage) - risk indicator; index of the physical volume of the gross regional product (in constant prices; as a percentage of the previous year); index of gross regional product per capita (in percent); the degree of depreciation of fixed assets (at the end of the year; in percent) is a risk indicator. We used the annual data of the indicators of the Krasnoyarsk Territory for the period from 2010 to 2019. The eigenvalues of the matrices were estimated using SPSS Statistics.

**Table 2.** The results of evaluating the coefficients of the membership functions of the Krasnoyarsk Territory economic security indicators

| Indicator for assessing the level of security of the territory | Territory security level (lower limit of the indicator) | | | | Eigenvalue $\lambda_{max}$ | Eigenvector of values $w_j$ |
|---|---|---|---|---|---|---|
| | I | II | III | IV | | |
| Real money income of the population (% of the previous year) $X_1$ | 100.65 | 97.70 | 94.76 | 91.81 | 3.904 | (0.14; 0.26; 0.49; 0.11) |
| Consumer price indices (%) $X_2$ | 106.01 | 108.76 | 111.50 | 114.25 | 3.712 | (0.15; 0.22; 0.36; 0.27) |
| Index of the physical volume of the gross regional product (in constant prices; % of the previous year) $X_3$ | 102.73 | 100.12 | 97.51 | 94.89 | 2.651 | (0.21; 0.37; 0.36; 0.06) |
| Index of gross regional product per capita (%) $X_4$ | 109.23 | 102.71 | 96.19 | 89.68 | 3.109 | (0.27; 0.39; 0.30; 0.04) |

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| Indicator for assessing the level of security of the territory | Territory security level (lower limit of the indicator) | | | | Eigenvalue $\lambda_{max}$ | Eigenvector of values $w_j$ |
|---|---|---|---|---|---|---|
| | I | II | III | IV | | |
| Depreciation of fixed assets (at the end of the year, %) $X_5$ | 40.20 | 42.94 | 45.67 | 48.41 | 1.917 | (0.24; 0.41; 0.21; 0.14) |

*Source:* calculated and drawn up by the authors.

The degree of indicator membership of the Krasnoyarsk Territory population real money income (growth index) for the period under study in the first level of economic security (high degree of security) is 14%, the second level (low risk) - 26%, the third level (medium risk) - 49 % and the fourth level (high risk) - 11%.

The membership functions on the example of the selected indicators for economic security assessment are as follows:

$$x_1=0.14\langle zero\ risk\rangle+0.26\langle low\ risk\rangle+0.49\langle medium\ risk\rangle+0.11\langle high\ risk\rangle$$

$$x_2=0.15\langle zero\ risk\rangle+0.22\langle low\ risk\rangle+0.36\langle medium\ risk\rangle+0.27\langle high\ risk\rangle$$

$$x_3=0.21\langle zero\ risk\rangle+0.37\langle low\ risk\rangle+0.36\langle medium\ risk\rangle+0.06\langle high\ risk\rangle$$

$$x_4=0.27\langle zero\ risk\rangle+0.39\langle low\ risk\rangle+0.30\langle medium\ risk\rangle+0.04\langle high\ risk\rangle$$

$$x_5=0.24\langle zero\ risk\rangle+0.41\langle low\ risk\rangle+0.21\langle medium\ risk\rangle+0.14\langle high\ risk\rangle$$

The graphical view of the membership functions is shown in Figure 1.

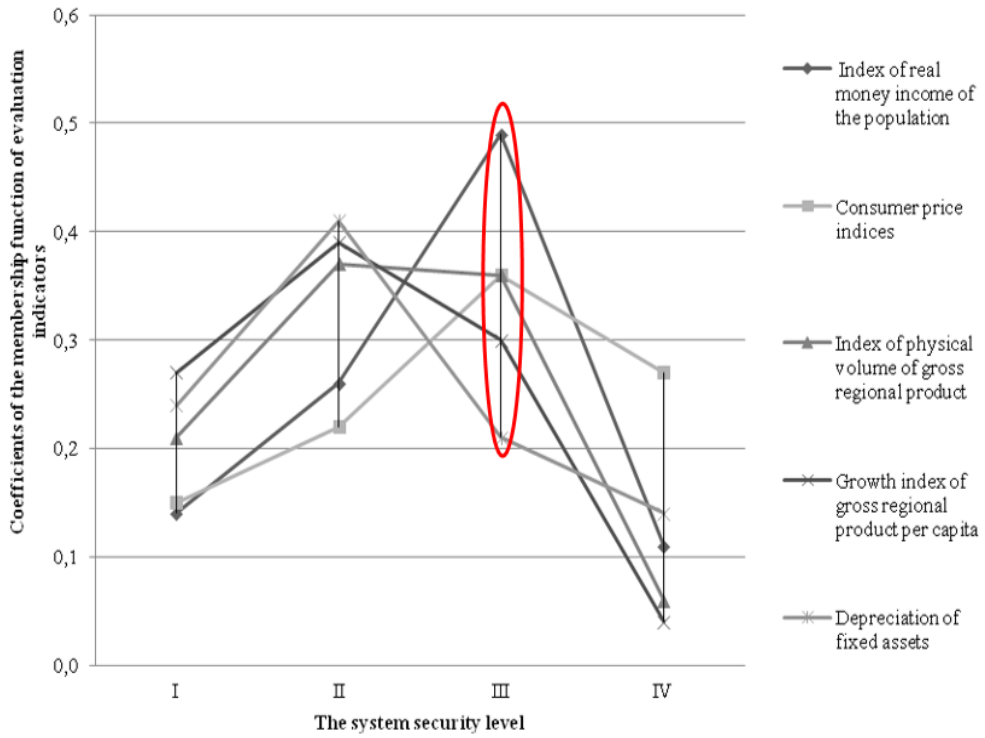


**Figure 1.** Membership functions of the regional economic security level evaluation indicators

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Based on the results of the membership functions coefficients' values, it can be concluded that within the considered time interval the level of economic security of the Krasnoyarsk Territory is mainly in the range of the "average level of the system risk". The indicators used for the assessment belong to the specified level cumulatively at 1.72. In case of the optimistic scenario the most probable level of economic security of the territory is the second level and low system risk (the cumulative membership of indicators is 1.65). The probability of the system assessment indicators belonging to the first security level - "zero risk" - is 1.01, which is higher than the probability of the system belonging to the fourth security level ("high risk") - 0.62. At the same time, a number of indicators are assessed as the most at risk and determine the general belonging of the system to the established range: the index of the population real money incomes (belonging to the third level of security is 49%), the consumer price index (belonging to the third level of security is 36%, to the fourth - 27%), the index of the physical volume of the gross regional product (belonging to the third level of security is 36%).

## 7. Conclusion

The method of constructing membership functions of a region's economic security indicators makes it possible to assess the relative distribution of assessment indicators by levels of system risk. The proposed method has an important advantage: the assessment of the security level of an object is carried out independently without comparison with other objects of assessment (other territories), which makes its results more reliable and objective with respect to rating methods.

The choice of the method for assessing the qualitative state of the territorial system largely determines the results of the study and the basis for the development of management measures.

Measures to ensure a certain basic (minimum required) level of economic security are: emergency measures to manage the system risks in order to avoid threats; ongoing activity of the management bodies to maintain the system secure functioning; capacity management activities, which are aimed at building the potential of the territory in order to create a "safety margin" for the system, which is necessary in the event of existing or newly emerging threats. These measures should be combined with programmatic measures to manage the socio-economic development of the territory in order to achieve maximum effect.

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