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**A SYSTEMATIC APPROACH TO THE ESTIMATION OF SOCIO-ECONOMIC DEVELOPMENT OF THE REGION BASED ON DYNAMIC FUZZY MODELS**

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**Abstract**

The purpose of this article is to present a systematic approach of integral estimation of socio-economic development of the region, which takes into account the level of citizen's subjective satisfaction and objective statistical estimates.

In accordance with the applicable rules of economic development, systematic approach to summarize methodological knowledge and the results of the analytical method were used for the study of the behavior of complex systems. The study is based on the methods of expert estimation, economic and mathematical modeling, methods of decision making under uncertainty.

To carry out numerical experiments and we used data of regional statistics. Data processing, including the assessment of membership functions, carried out using computer algebra system Mathcad, the application package for solving technical computing Matlab 7 and created by the author software systems.

There are represented the assessment's level methodology of the socio-economic development of the region based on linguistic fuzzy modeling for calculated partial indicators. Some indicators are determined on the state statistics data, and others are determined on the basis of results of sociological polls of the population. Linguistic variable are used for describing evaluation indicators. Each sets of the linguistic variable characterizes evaluation cluster consists of five terms. Recognition of simulation results is performed using the comparing matrix which contained the estimates of

two integral indicators, calculated on the basis of objective and subjective evaluations. There are described ten alternative states of the comprehensive assessment.

**Key words:** Socio-economic indicators, dynamic fuzzy model, linguistic variable, the level of subjective satisfaction, integral estimation, relational data model.

## 1. Introduction

Many scholars studied the problem of analysis of socio-economic development. The diversity of methods of estimation of socio-economic development of the region based on mathematical tools can be summarized in two groups:

1. Calculation of the generalizing index of development of the region, based on which the ratings are formed regions;
2. The use of econometric models and their characteristics for a quantitative assessment of the level of development.

At the heart of nearly all proposed by various authors valuation methodologies is the Unified system of indicators of socio-economic status of municipalities, elaborated on quantitative statistical indicators (Belyayeva L.A., 2009; Sidorov A.A. and Silich M.P. 2008; Approval of a unified system of indicators characterizing the social and economic situation of the municipality,1998 ).

The official statistics contain information about macroeconomic indicators, demographic data, employment and unemployment, conditions of labour, the size and structure of cash income. Among the social indicators were assessed the health status of the population and the development of the health system, education, etc. (Regions of Russia, 2015; Social well-being of Russians: All figures are reduced, 2015).

But the most of the statistical indicators are devoted to the evaluation of consumption and material security.

We considered that the level of subjective satisfaction of the population is one of the most important social indicators of development outcomes in the region, which evaluation is carried out by the sociological research and application of expert methods. In accordance with the applicable rules of economic development for the study of the behavior of complex systems use a systematic approach to summarize methodological knowledge and the results of the analytical method. Socio-economic system is a complex system; it is characterized by heterogeneity, multicomponent subject-object structure and complex relationships. Thus our study is based on the methods of expert estimation, economic and mathematical modeling, methods of decision making under uncertainty.

The purpose of this note is to represent a systematic approach of integral estimation of socio-economic development of the region, which takes into account the level of citizen's subjective satisfaction and objective statistical estimates. To solve this problem, we use the concept of dynamic fuzzy sets and linguistic variable.

## **2. Application of fuzzy sets in the evaluation of qualitative and quantitative indicators**

Researchers are very interested in the theory of fuzzy sets and its application in solving various technical and economic challenges due to the versatility of the methods, opportunities for work with the alternatives and criteria of different types, with different scales of measurement.

For example, we solve the problem of selection of vibration of the protective system of the vehicle can be simultaneously investigated such quality criteria as quantitative: "durability", measured in number of years and quality: "the resistance to mechanical damage", with a dimensionless scale.

Another example for the analysis of attractiveness of investment projects can be analyzed by the criteria: "Net present value" and "Degree of risk".

For the Analysis of the socio-economic situation of territories is the most informative study of indicators of life-support complex of objective and subjective parameters, changing in time.

In general our analysis combines the study of quantitative and qualitative indicators of economic systems through the concept of dynamic fuzzy sets. This concept (Tereliansky & Kostikova, 2013) does not deny these advantages to the classical theory, but also allows to examine the changes of various indicators of complex systems in time.

An important advantage of fuzzy set theory which allows using it for solving problems under uncertainty is the linguistic variables used for processing quality evaluations specified in natural or formal language.

Linguistic scales are different from numeric that as a variable that measures a certain property of an object are not numbers, but words. As the variables of the Linguistic scales used are words of natural language.

The socio-economic system is fairly active and values can change frequently, therefore, their numerical evaluation may not be enough information. And then, the expert consciously or unconsciously replaces a point in a numerical evaluation, qualitative characteristics of the situation expressed in natural language (Kostikova & Tereliansky, 2014).

L. Zadeh: each word  $x$  in a natural language  $L$  may be viewed as a summarized description of a fuzzy subset  $M(x)$  of a universe of discourse  $U$ , with  $M(x)$  representing the meaning of  $x$  (Zadeh, 1975; Lee & Zadeh, 1969).

Both groups of parameters of socio-economic systems: the objective and subjective can be measured not only quantitatively, but also qualitatively. Quality measurement is achieved if we define a linguistic variable.

We introduce first linguistic variables "the level of the index  $F_n$ ", where indicator  $F_n$  is determined on the basis of statistical data. Linguistic variables "the degree of the index  $F_n$ " is characterized by the following fuzzy subsets:  $B_{i1}$  – "Low level  $F_n$ ";  $B_{i2}$  – fuzzy subset "of the index below the average  $F_n$ ";  $B_{i3}$  – fuzzy subset "Average level of the index  $F_n$ ";  $B_{i4}$  – fuzzy subset "of the index  $F_n$  is above average";  $B_{i5}$  – fuzzy subset "High level of  $F_n$ ".

For subjective evaluation, we define a linguistic variable "The level of satisfaction indicator  $P_n$ ", where the index  $P_n$  is determined on the basis of results of sociological polls of the population. Linguistic variable "The level of satisfaction indicator  $P_n$ " characterized by the following fuzzy subsets:  $B_{i1}$  – fuzzy subset "is not satisfied";  $B_{i2}$  – fuzzy subset "Not satisfied";  $B_{i3}$  – fuzzy subset of "Partially satisfied";  $B_{i4}$  – fuzzy subset of "Satisfied";  $B_{i5}$  – fuzzy subset "Completely Satisfied".

An important requirement for the calculation of the level of socio-economic development of the region by the proposed method is the requirement of this correlation between the indicators calculated according to statistical data and questionnaire data, i.e., different indicators should Express similar characteristics, so that later comparison could be made. For example, the statistical indicator "the Availability of comfortable housing (m<sup>2</sup>/person)" can be mapped to "Level of satisfaction with the comfort of property". The amount of statistical and subjective indicators may not be equal, for example, the statistical indicator "per Capita money income (ruble, \$, €)" can be backed up by subjective rating on indicators "the Level of satisfaction with earnings" and/or "the Level of satisfaction with the material situation of the family."

Consider the process definition of the linguistic variable.

For example, use the phrase "high utility bills". The question is how to determine the value in monetary terms lies behind this phrase?

To obtain an objective assessment it is necessary to attract to poll a certain group of persons paying for housing and utilities and try to calculate some average rating. However, to build a specific dependency is unlikely to succeed, because, first, the respondents would be difficult to give strict answers as to the parameters "cost of services", "assessing the cost of services". Secondly the respondents use the services of housing and communal services at different scales: the larger the apartment, the greater the amount of energy consumed, the higher the share of overhead expenses in recalculation on square meter, etc. However, it is possible to define some average value of payments, around which are grouped all other amounts (*figure 1,a*)

And, the further to the right on the X-axis (amount of payment) we will move from a certain mean value, the more reason we get to say that this value is "high". So we can distinguish three groups of payments: "high", "medium", "low" and post all the payments in the selected classes (clusters) in two ways.

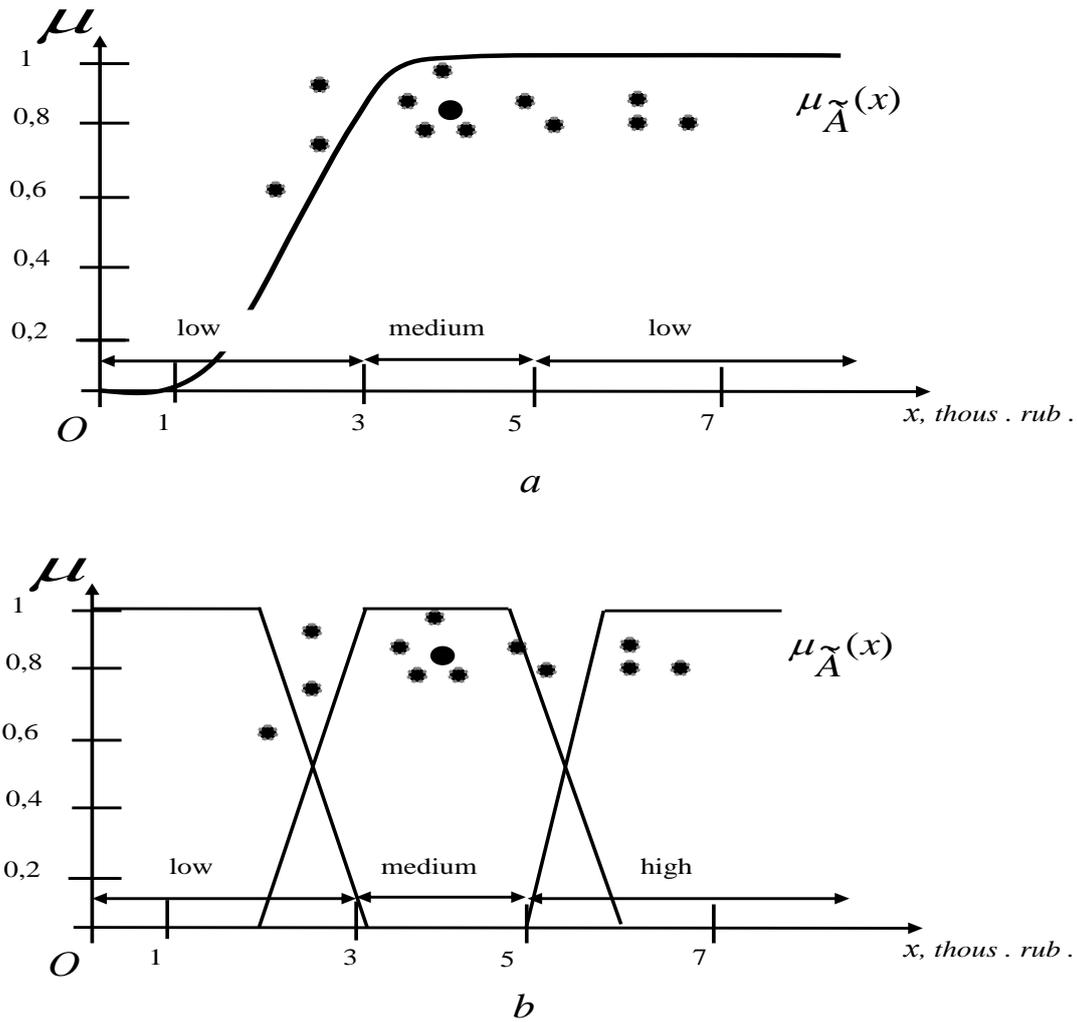


Figure 1. Fuzzy set "optimal payment of utility bills".

First, we can do this quite accurately by setting the corresponding intervals on the X-axis, and belonging to a particular interval will cause an unambiguous verbal assessment. If you do the same work to more carefully describe our confidence (uncertainty) in the classification. Then a clear set of intervals is converted into fuzzy subsets with blurred boundaries, and the grade of membership of a particular magnitude of payment for utility services to this subset will be determined by the membership function.

There are also several possible options, either we define the fuzzy set "optimal payment of utility bills" and construct a membership function (figure 1a).

Either we divide the interval of values to a set of concepts and construct several discontinuous terms, the union of which will enable us to more or less accurately determine where payments start low and where high (Figure 1, b).

We know that the estimates particular criteria level and quality of life significantly change over time.

Imagine a situation where the state implemented a social program on allocation of apartments for young families.

Respondents were asked to express their attitude to the new living conditions, answering the question: "How do they evaluate the availability of housing on a 10-point scale."

A Citizen "N", who has an average level of prosperity and has lived all his life in a communal apartment, answers that assesses the current situation in the 8 or even 10 points. Over time, with the growth of his total revenue and the addition to the family, Citizen "N" may change the needs significantly, and there is an objective need to expand the housing area. In such circumstances, when replying to questions "How do you evaluate the availability of housing on a 10-point scale", his score will be reduced to a mark of 4-5.

Linguistic characteristics quite useful for the recognition result evaluation of the integral index of socio-economic development, as they are understood by the people who does not have special skills of perception of complex mathematical evaluations, and experts - professionals in the field of socio-economic relations (Kostikova et al., 2015).

### 3. Dynamic fuzzy modeling of socio-economic development of the region

Suppose that at each time  $t_n$  the level of socio-economic development of the region is characterized by a set of indicators  $F_n$ . During the period of time  $t_0$  the coefficients  $F_1 \dots F_n$  with values  $f_{v1(t_0)} \dots f_{vn(t_0)}$ . Also we know the level of public satisfaction with the socio-economic status indicators on the  $P_1 \dots P_m$ , which change over time  $t_n$ .

First, we select the system of indicators to assess the socio-economic indicators in the region according to the statistics and calculation of values.

For a comprehensive description of the socio-economic processes often selected indicators of the following blocks:

1. The level of economic welfare (provision of material goods and services);
2. Population quality (reproduction, health, education);
3. Livelihood (income and employment);
4. The level of development of the social sphere (provision of social and spiritual infrastructure);
5. The level of safety of life (the degree of environmental pollution, crime rates, working conditions).

Dynamic fuzzy modeling of socio-economic development of the region will include:

1. Construction of fuzzy definitions for calculated according to statistical data indicators;
2. Construction of a linguistic variable "satisfaction" for each subjective indicators derived from the data of a sociological survey of residents in the region.

3. Formation of linguistic variables for the two integral indices of socio-economic status on the basis of objective ( $S_{st}$ ) and subjective ( $S_{sub}$ ) estimates, respectively.
4. Value recognition of integral indicators  $S_{st}$  and  $S_{sub}$  with subsets of linguistic variables "level of socio-economic development of the region", defined in Step 3, and the determination of their class.
5. Comparison of the results of integrated indicators  $S_{st}$  and  $S_{sub}$ .
6. Analysis of the results and the formation of a system of fuzzy rules for subsequent iterations.

Integral indicator is formed by convolution of criteria values. As a result, the cluster distribution is determined by the integral index, to which the cluster belongs to the value of the quality of life in the region during the selected time period.

$$QL = \sum_{i=1}^N Y_i \times \beta_i, \tag{1}$$

where  $Y_i$  - intermediate factor, which takes into account the number of indicators for each level of linguistic variable;

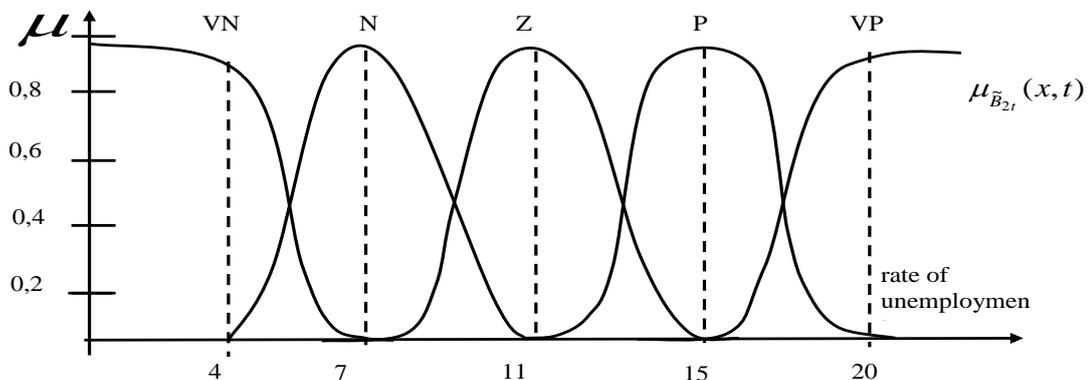
$\beta_i$  - the arithmetic mean of the absolute confidence zone;  $N$  - the number of indicators.

$$Y_i = \sum_{i=1}^N k \times y_i, \tag{2}$$

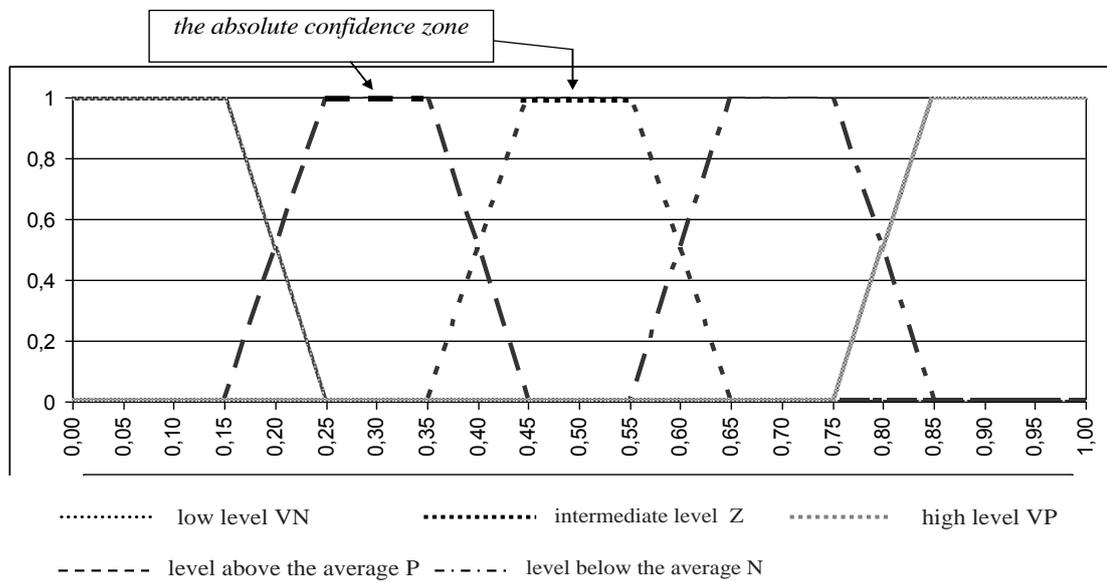
where  $k$  - weight value of the indicator;  $y_i$  - the number of values of the indicators for each level of linguistic variable.

Term-value set of indicators is organized as follows:  $T = \{\text{a low level; The level below the average; Intermediate level; The level above the average; High Level}\} = \{\text{VN, N, Z, P, VP}\}$ .

For example, term-value set of linguistic variable "rate of unemployment" (Figure 2). Term-value set of integral indicators of socio-economic status on the basis of objective ( $S_{st}$ ) and subjective ( $S_{sub}$ ) (Figure 3).



**Figure 2. Term-value set of linguistic variable "rate of unemployment".**



**Figure 3. Term-value set of integral indicators.**

Comparison of integrated indicators Sst and Ssub values by means of a matrix, which indicates the cell to one of the ten levels of socio-economic development of the region (Table 1). The number of rows and columns of the matrix depends on the number of linguistic variable values, which constitute its term-set. We suppose the optimal number of subsets equal to five (Egorova & Kostikova, 2014).

We used the term set values of the linguistic variable "index level» consisting of the five subsets:  $T = \{\text{Low-level indicator; index level is below average; The average level of the indicator; index level is above average; The high level of the indicator}\}$ .

How to recognize the results of the matrix? For example, "The absolute prosperity" is achieved at the highest estimates of both integral indicators. The combination of good objective conditions of life with positive subjective assessments indicates the presence of a stable social environment and favorable prospects for sustained social development of the region ('relative prosperity' field). The "socio-economic adaptation" means that the population of the region has adapted to the existing conditions of life. The "socio-economic tensions," shows that the dissatisfaction of the population can develop into active forms of social protest. If you get into this field, it is necessary to take steps to search for the most realistic and best in this situation how to improve life. This state is unstable and transient. The "economic and social discord" refers to serious contradictions in the minds of people in the region and does not match their ideas with current conditions of life, which is the real source of the protest and said the need for immediate social change. The worst situation is recognized by ingestion of the "socio-economic deprivation": the population exists in conditions of prolonged deprivation or significant restrictions meet the vital needs of possibilities.

**Table 1 - Matrix of integral objective and subjective indicators.**

Interval parameter values $S_{st}$	Interval parameter values $S_{sub}$				
	low level	level is below average	average level	level is above average	high level
low level	The absolute socio-economic deprivation	The relative socio-economic deprivation	Socio-economic tensions	The relative socio-economic adaptation	The absolute socio-economic adaptation
level is below average	The absolute socio-economic deprivation	The relative socio-economic deprivation	Socio-economic tensions	The relative socio-economic adaptation	The relative socio-economic adaptation
average level	Socio-economic dissonance	Socio-economic tensions	The relative socio-economic adaptation	The relative socio-economic adaptation	The relative socio-economic adaptation
level is above average	The relative Socio-economic dissonance	The relative Socio-economic dissonance	Socio-economic tensions	The relative prosperity	The relative prosperity
high level	The absolute Socio-economic dissonance	The relative Socio-economic dissonance	The relative Socio-economic dissonance	The relative prosperity	The absolute prosperity

## Conclusions

As was stated in the introduction, the purpose of the method is the integration of different nature, some of which describe a set of time-varying statistical characteristics, measured with the help of tools, while others - a dynamic set of subjective indicators, the analysis of which requires the use of methods of expert estimation.

The developed technique will allow authors to analyze the complex structure of the socio-economic indicators characterizing the individual components of the population living conditions, taking into account the dynamics of their changes under the influence of objective and subjective factors.

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