

MULTY-CRITERIA FUZZY ANALYSIS OF REGIONAL DEVELOPMENT

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Abstract. The article presents the possibility of using multi-criteria fuzzy analysis for assessing the regional competitiveness. This estimation can be used for place marketing strategy development and based on results of socio-economic development. The proposed approach is characterized by comparative estimation, when the level of development of one region is determined by the development of other areas. The final evaluation is the level of the cluster which the object being analyzed belongs. This allows ignoring minor fluctuations in total indexes. The results of robust and fuzzy groups of regions are analyzed. This grouping is characterized by similar levels of development and helps to define the directions of further development of the regions.

Keywords: membership function, classification, fuzzy clusters, Grodno counties, regional economy, sustainable development, regional competitiveness, place marketing.

INTRODUCTION

Economic objects and processes are very difficult nowadays. Most of them we can describe as a system which includes different elements. The properties of the system are determined by the relationships between these elements and the nature of its interdependence. The characteristic of object includes not only criteria for the whole system but for its elements as well. As a result most of economic problems become multi-criteria. And the special methods of analysis are used for solving these problems. In this article the fuzzy methods of multi-criteria analysis will be described.

The proposed methodology is universal and it can be adapted to different objects. The test area in this chapter is regional socio-economic development evaluation. The results of this analysis are useful for place marketing strategy development. In this case the region's position is a base for subsequent economic growth. The comparative analysis of regional competitiveness lets to receive the position of estimated region between others and the degree of similarity of current situation with others. Based on this information we can work out place marketing strategy for the region including the result of previous development and the leaders of economic growth experience.

The purpose of this article is to show the benefits of fuzzy methods for analysis of economic objects and to determine the circumstances of its using. For this purpose we'll make multi-criteria analysis by different methods (robust and fuzzy) and compare results. The methods will be applied to regional socio-economic strategic decision-making. We'll take into analysis the results of economic growth and life quality of lower level of counties. The experimental calculations were carried out on the example of counties of Grodno region (Belarus) in 2008-2014.

The multi-criteria fuzzy sets are useful for region's marketing strategy development. It was found that multi-criteria fuzzy clusters can describe the comparative competitiveness. In this paper the estimation of the competitiveness is based on the values of the membership functions to a particular cluster. It's possible to use this result for identifying of membership function value and forecasting the future positions. Single fuzzy clustering (based on one integral criterion) is easier for interpretation and visualization, but it cannot make multi-faced analysis.

The article is structured as follows. In beginning the basic definition like local region, socio-economic development evaluation and regional competitiveness are clarified. Then the methodology of research is presented. Then the experimental part of the chapter is considered. It includes data collection based on system of indexes of regional evaluation and it analysis, single and multi-dimensional fuzzy clustering of Grodno counties in dynamic and as a whole over the period. At the end the conclusions are made.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The problem of regional competitiveness, its investment attraction and place marketing attracts more attention nowadays. Moreover the modern conditions require revising existing concepts and methods of its evaluations. Globalization and high-tech industry development lead to the regional competitive grows. It means that regions become active participants in the struggle for resources (labor, technological, investment) and markets (tourism, investors, products). The distinctive feature of this process is that regions act as goods and as producers simultaneously. Dijkstra [11] notes that it's impossible to

apply the firm's competitiveness concept to the regions level:

The framework describing a firm's capacity to compete, grow and be profitable is relatively uncontested, but applying the same concept to countries or regions has been subject to much debate.

Golovikhin S. [12] notes that the concept of regional competitiveness shouldn't lead to increase of regional separatism. There're different approaches to the regional competitiveness definition: based on productivity [26], rising income and improving livelihood [19], as an environment for firms [7]. Moreover Nasser [20] and Chukhray [33] claims that regional competitiveness on national or global level is not the end in itself:

Maintaining a high level of competitiveness is not a goal by itself, it is a goal within another: development and growth for the present and future generations [20].

This approach is close to the concept of sustainable development [30] which considers regional competitiveness not only from economic position but also take into account ecological (natural) and social (human) components. Serebryakov L. [27] noted that regional competitiveness can't be evaluated without taking into account system on regional infrastructure.

The second growth point of economic development is region's (or place) marketing. Arzhenovskij [4] make a conclusion that region's marketing is an important part of regional economy and that it's based on the regional competitiveness. The region in this meaning is the territory limited by the existing administrative-territorial segmentation. And region's marketing can be seen in following Kotler's view:

Place development means to develop for a place a systematic and long-term marketing strategy directed towards nurturing and developing the natural and potential attributes of an area or region.

One of the mistakes of regional governance in post-soviet countries [8] is strategy development based on allocable budget without taking into account territorial potential. It means that the first step in marketing strategy development should be analysis of current position and tendencies of economic growth. The level of socio-economic development is the result of previous economic growth and the factor of ensuing development. It's an important criterion for region's marketing strategy development that's why this topic is actual and important.

The relevance of this topic in Belarus can be revealed by Program of Socio-Economic development [23] and National Strategy of Sustainable development [21]. They confirm that sustainable development of regions and increasing their competitiveness is a priority of socio-economic growth.

The feature of approach to the assessing of socio-economic development proposed in article is the object of study, which are local regions. The increase of interest to local regional analyzes can be proof by a lot of research on this topic. L. Servillo and others [28] explores territorial attractiveness for migration and it impact to the socio-economic development. J. Mawson [18] presents the UK experience in local governance. B. Blazevic and A. Jelusic [6] developed a model of regional economic and tourism development. All of the researchers confirm

that local regional development as a system consists of complex and multidiscipline problems and needs special methods for evaluation.

Marquardt [17] used Analytical Hierarchy Process (AHP) by Saaty [25] for evaluating regional development concept elaboration process. Distinct disadvantages of this method are expert estimation and a large number of pairwise comparisons. Aivazyan [2] and Lialikova [16] applied the principal component method for evaluating regions by life-quality. This method aimed at decreasing of number of criteria through combining in principal components which preserve variation of benchmarks. But most of time it's difficult to interpret these components in its economic sense. Zhelezko [32] presents some elements of multi-criteria fuzzy ranking, which can be adopted to the regional estimation. Alves and others [3] offer a fuzzy decision approach for location selection among potential available areas based on some criteria. It allows include in analysis not only quantitative but also qualitative criteria.

This chapter presents the fuzzy clustering application for object evaluation. In this case the fuzzy clustering performs as a classification tool. Diaz B. and others [10] applied it to the economy sectors and received the key sectors of Spanish economy. The groups with similar level of development can be received when fuzzy clustering applied to regional evaluation.

THE MAIN RESULTS OF THE RESEARCH

In the beginning, we'll clarify the concept of local region and socio-economic development evaluation.

Kuznecova [15] noted that region can be present in two meanings. By one meaning, region is the territory limited by the existing administrative-territorial segmentation. By other, region is territory limited by any signs of interrelating (population, geographical conditions and others). In this paper region is considered in first meaning because only administrative segmentation has authorities and opportunities to manage of socio-economic development.

Most of countries have a multitier system of regions. And the facilities of evaluating of high regional development are always much bigger than at local level. There're more statistical data and indexes value at high level. Some of important criteria of economic development (like gross regional product) are not calculating in local level. That's why specific methods and technics should be developed.

From the previous analysis we can distinguish that region can be seen in two aspects [28]. In one side region is seen as an independent system with its own resources and goal to increase the life's quality of the local population. In other side the region is considered as a subsystem of the state (or the high regional formation). The aim of region's functioning in this aspect is to find out resources for national economic growth. These two aspects relate and condition each other. So, when we are talking about competitiveness of region we should take into account that they are not only fighters for each other because they are elements of one system. But they are interesting in individual results of the local and high region the same time.

The system of local government includes departments and agencies with dual subordination to the ministry and to the local executive committee. Therefore, the inter-departmental barriers may lead to a slowdown in decision-making although the linear submission to the chairman of the executive committee. Sometimes it leads to duplication of functions, data collection and absence of clear zones of control.

The most of problems and issues of socio-economic regional development is complex, complicated and multiplex. It means that in regional decision-making we should take into account a lot of factors, indexes and constrains.

The socio-economic development of the region can be evaluated by multi-criteria analysis. The term of “the socio-economic development” includes an indication of the simultaneous control of several areas. The process can be characterized by next area:

- **Economic** (result of industry, agriculture, transport, trade and paid services).
- **Financial** (profitability, debt growth, investments).
- **Demographic** (population, nature and migration growth).
- **Social** (employment, crimes, salary, life’s quality, educational level, poverty).
- **Ecological** (emissions, water saving, waste products).

The complex of these fields leads to the effective socio-economic development named sustainable. But each of these fields is characterized by set of criteria. As a result the number of analyzed parameters ups to several dozen. The regional governance is interesting in evaluation of each area and of the whole system development. More over the estimation should be made in dynamic and in comparison with other counties. For this purpose the system of indexes should base on open source data.

The benchmark data for the analysis can be received from different sources: statistical data in official statistic collections, regional legislation, information of large enterprises and so on. But there’s not a single data source of regional socio-economic development for external users.

The results of estimation of regional socio-economic development can be used by following customers:

- **National governance** for development of socio-economic polity and strategy;
- **High region governance** for evaluating local regions composed the high region;
- **Local region governance** for comparing its level with others and receiving an experience of development;
- **Businessmen and investors** for identify objects of future investments.

We can make a conclusion that this concept lets to develop the region’s marketing strategy directed to the sustainable development based on local potential. Now we’ll formulate the methodology of this evaluation.

THE METHODOLOGY OF RESEARCH

Previously noted that the analysis of socio-economic regional development present the competitiveness estimation. The analysis of enterprise estimation by [14] has 7 steps and starts with information support and developing

indicators systems The methodology of this analysis includes only 5 steps:

1. The original data collection

a) **to form the system of indexes.** It must take into account all important parameters of competitiveness and based on those characteristics of the object, which are essential for competitiveness.

b) **to define the values of indexes for each object.** The original data are represented as a matrix in which the columns are recorded parameters and the rows - the objects (alternatives).

2. **To lead the data to comparable form.** The nominal model of object has the best results for this indicator and presents the most successful competitor in current market competition. If the prescriptive value of index is known it can be used instead of corresponding supremum. On the other hand, if the data gathering was carried out correctly and the prescriptive values weren’t received, may be they are not achievable for a given circumstances. Each alternative can be compared with this nominal model of object by different formulas [1], but we use the following:

$$z_{ij} = \frac{x_{ij}}{\max x_{ij}} \tag{1}$$

or

$$z_{ij} = \frac{1}{\max \frac{1}{x_{ij}}} \tag{2}$$

where: z_{ij} – comparable value, x_{ij} – original value of index.

If the proposed method is using then all comparable values are led to a common scale of measurement in the interval [0; 1] and reflect the level of the object compared with the most successful competitor in this aspect of activity.

3. **To calculate integral criterion.** This step is not obligatorily. The integral criterion can be calculated by additive convolution, principal component method or by special formula. Sometimes it’s necessary to receive not only one criterion, but some criteria which reflect the result of different spheres in the object development.

4. **To make multi-dimensional fuzzy sets.** The using of fuzzy sets in socio-economic development analysis can show gradual evolution of objects. The example of its using in economic objects is presented at [13]. The construction of membership functions often base on expert opinion. This gives the share of subjectivity and requires a lot of time. There is a method [29], which offers the construction of the membership functions using fuzzy clustering results. This conclusion is based on the assumption that membership function of a fuzzy cluster correspond to the membership function of congruent fuzzy set. Mathematically multidimensional fuzzy clustering procedure can be carried out by methods of fuzzy c-means, Gustafson-Kessel, with k-ellipsoids, etc. In this paper the fuzzy c-means method was used.

5. **To analyze the results.** The values of membership functions for different sets show the level of competitiveness of object. It's interesting to look at the cluster with maximum attitude and the degree of attitude to better clusters. If it's possible (when we have enough data) then it's useful to make the analyses in dynamic.

It can be assumed that the proposed methodology for constructing fuzzy sets with similar level of development is applicable to construct rankings of any objects and not only competitive, but its testing was carried out only in the assessment of the regional socio-economic development.

Experimental research at Belarusian regions

Previously noted that the analysis of socio-economic regional development present the competitiveness estimation. The proposed methodology was applied to this evaluation. The first step of the procedure connects with data collection. There're different approaches to system of indexes for regional socio-economic development evaluation. But most of them were developed for high regional development and they don't take into account local regional particularities. It's interesting to descry the European Union experience in this sphere. The whole territory of European Union is divided into 3 levels of regions (NUTS-1, NUTS-2 and NUTS-3) [24]. The current classification characteristics are represented at the table 1.

Table 1. The NUTS characteristics

Level	Number of regions	Minimum population	Maximum population
NUTS-1	97	3 millions	7 millions
NUTS-2	270	800 000	3 millions
NUTS-3	1294	150 000	800 000

The smallest region (NUTS-3) level corresponds to the high regional level in the country (in most of cases). Moreover European commission doesn't use analyses which include data from only NUTS-3 level. For example the evaluation of coherence in Europe includes 4 groups of factors (25 criteria) and only 3 of them belong to the local level [9]. That's why the system of indexes was developed for this analysis. It includes economic evaluation, demographic indexes, social criteria and sustainable development. This system includes only quantitative criteria because the evaluation of qualitative obtains experts' measurement. The using of fuzzy theory can help to convert the qualitative estimates to the numeric but it also requires experts' participation. The structure of this system in local regional level [22] is shown in table 2.

Table 2. System of criteria of regional socio-economic development evaluation

Social	Economic	
Demographic 1) population 2) natural increase 3) migration rate	Source 1) budget 2) investments 3) direct foreign investments 4) receivables and payables 5) employment 6) unemployment rate 7) percentage of population in working age 8) import	Results 1) industrial production 2) productivity of yield and livestock capita 3) retail trade and paid services 4) goods turnover 5) value of constructions 6) profitability 7) small business production 8) export
Life quality 1) availability of housing 2) crimes 3) salary		
Sustainable development 1) emissions		

We didn't add any indexes of education [5] because in local regions (of Grodno county) there's not high education institutions and the secondary education is mandatory in Belarus. We haven't open data about population with high education in local regions and there're very small property of PhD's in region.

Some of criteria (like productivity of yield and livestock capita) include more than one index. As a result all system is based on 28 criteria.

For experimental check of our methodology we apply it to the evaluation of socio-economic development of Grodno's local region (Belarus). We received the data for 28 indexes value of 17 Grodno's local regions and city Grodno in 2008-2014. All of them were led to the comparable form. It was interesting to estimate the correlation between these indexes. The following result was received by correlation analysis: there is a strong relationship between the value of the population (one of the main demographic indicators) and the majority of economic indicators (regional budget (0.95), turnover (0.93), retail trade (0.97), paid services (0.97), the volume of industrial production (0.9), the number of employed in the economy (0.99)). It mean that population (or the number of employed in the economy) is the determining factor for economic growth in Belarus regions. The absence of indexes for evaluating information and communication technologies at local regional level doesn't let us to characterize local economy as post-industrial.

The methodology provides an opportunity of using an integral criterion for assessment and building a rating of regions by this criterion. The strong correlations between indexes allow to use the principal components analysis. Using it we received factors which have the greatest impact for general variance. In this analysis we didn't take into consideration city Grodno. We received that first principal component retains 51.99% of the variance. This is not enough for using the value of this component as a ranking value of regional development estimation [2]. This component is determined by following indexes: regional budget, investments, retail trade, paid services, receivables and payables, employment value, industrial production, goods turnover and value of constructions. All of these indexes are important factors of economic development in industrial society. It reaffirms that Belarusian economy is not at the post-industrial step yet. The second principal component retains 13.3% of the variance. This component is mostly determined by rural factors (livestock capita and productivity of yield).

Let's try to adopt the known at national level methods for calculating the integral criterion. For the national economic development this criterion is gross domestic product (GDP). By [31] GDP is the total value of goods and services (counted without duplication) that are newly produced in the economy during an accounting period, generated net incomes to the economy and are available for domestic final uses or for exports.

It can be calculated by 3 approaches: the production (or output or value added) approach, the income approach, or the expenditure approach. The analog of this criterion on regional level is gross regional product (GRP). But it's determined only by value-added approach

and in Belarus only for high Regional County. It's possible to adopt the expenditure approach to the local regions and calculate analog of GRP at local level. In this case, the GRP will be formed as sum of household expenditure (C), investment (I), government expenditure (G) and net exports (Xn). The formula of calculating is:

$$GRP = C + G + I + Xn. \quad (3)$$

Household expenditure as a statistical measure is not published in open sources. But it's possible to find data of the value of retail sales and the cost of paid services to the population. Household expenditure spends to pay for goods and services. Therefore, we can assume that these values reflect the approximate level of household's expenditure.

The value of investments in fixed capital is a statistical measure, which is estimated at the level of high and local regions of the republic and published in statistical yearbooks.

Government expenditure can be estimated as the regional budget. The value of regional budget can be found in regional legal acts.

The value of net exports is the difference between exports and imports in goods and services. Each of these values shall be published in statistical yearbooks.

This method allows receiving the integral result of economic development. Moreover all factors (except export) which assumed in GRP were included in first principal component. So we used the most influential factors in this method.

To test this method of calculating GRP we compare results of official data of GRP and calculated by this method at high level of regional economy. We received that the degrees of each region in total GRP by official and calculated values have not a significant discrepancy between two samples. So we can use this methodology for evaluating the share of each local region in the economic reward of high region.

We should include in integral criterion that regions have different size. For this aim we calculated GRP per Capita by dividing the value of GRP to the average population.

One-dimensional Fuzzy Clusters

Let's try to evaluate the regional economic growth with this criterion by fuzzy clusters analysis. One of the important questions is how many clusters should we have. In this research we make 4 clusters: low, medium, high and top of socio-economic development. It's interesting to use fuzzy clusters because it's impossible instantaneous transition from one group to another. The membership function shows the degree of membership of each local region to each group. The calculations were made in MS Excel. The author's software was used for construction of membership functions.

The research confirms that there is a high degree of differentiation of Grodno's local regions development. The membership functions of clusters and corresponding value of GRP are presented on fig.1. The results of regions attitude to fuzzy clusters are presented on the map

of region at fig.2. The darker color means the higher the level of economic development of region. Some regions refer to two clusters with different degree simultaneously. It is reflected as double color.

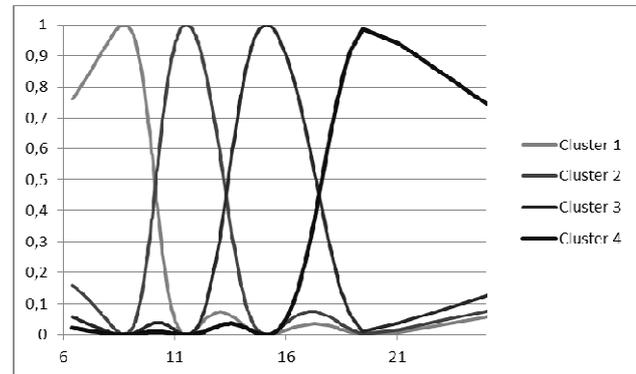


Fig.1. Membership functions and GRP

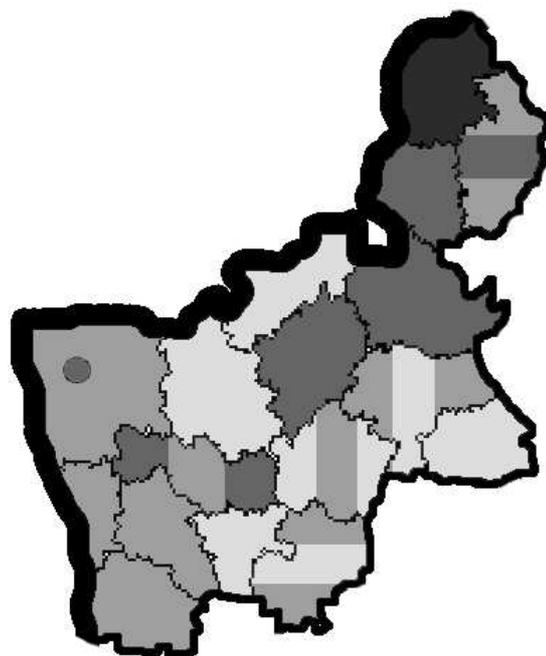


Fig.2. Regions attitude to fuzzy cluster in 2014

We can make a math model of each membership function for every year and compare its dynamics. It's possible to use this membership functions for predict results of regional socio-economic development in stable conditions. When economic conditions greatly change (for example in financial crisis) there's a shift in membership functions and changes in models of GRP.

Also this type of analysis lets us to make historical conclusions. We can see the relative magnitude of the recession or growth of real GRP (at constant prices).

Multi-dimensional Fuzzy Clusters

Often there's not possibility to calculate an integral criterion. Then we have a multi-criteria problem. The c-mean fuzzy clustering procedure lets to work with multi-dimensional spaces. Membership functions are based on the set of indexes. We can't receive an analytical form of the functions, but only a set of points in the multi-dimensional space. The graphical display of the results

based on the value of input data is impossible and their interpretations become difficult. But it's possible to represent these functions based on case number.

We made this procedure and compared results of one-dimensional and multi-dimensional fuzzy clustering. For this analysis we used all the indexes presented in table 2.

The result was some different from one-dimensional clustering. At first the system of indexes doesn't contain the GRP per capita. Most of used indexes are in absolute form. It means that they were not adjusted by population, employment and so on. At second the system combines indexes from different spheres (not only economic characteristics, but also social). Moreover it includes agricultural estimation, construction volume and freight turnover. This allows making multilateral estimation of economic growth.

In this conditions city Grodno attitude to the top cluster for more than 0,99 throughout the period under review. City Grodno is one object which significant attitude to this cluster. This can be explaining by large role of city Grodno in socio-economic development of region. Its impact to the GRP is more than 33%. It's interesting that we have in our system some rural indexes, and city Grodno, which hasn't agriculture, anyway belongs to the top cluster absolutely.

The cluster with high level of development always includes Lida's region with the highest degree of attitude. Only this one region belongs to this cluster with significant degree (more than 0,2). But there're two more regions which attitude to this cluster regularly. It's Volkovysk's and Slonim regions. Volkovysk's region is two times smaller than Lida's (by population number), but has a very good indexes in rural and social spheres. The attitude to this cluster of Slonim's region can be explained by the value of regional budget.

We had also compared these results with previous researches. The analysis of competitiveness of Grodno's region was made by V. Lialikova [16]. She used principal component analysis for receiving the integral index and then made 4 robust clusters with homogeneous groups of regions. In this methodology the number of clusters is chosen as large as possible which preserves the significant differences between the groups. But the absence of gradual transitions leads to sharp jumps of regional competitiveness rating. V. Lialikova received more optimistic results. 6 regions are in the high development cluster in 2011. We received only 3 regions with more than 70% of membership and 1 with 50% membership to better cluster. So the fuzzy clusters can show the slow progressive in regional development.

One more particularities of fuzzy clusters using is that it helps to find out the most important factor in the system. We mentioned above that visualization of membership functions can be done by graphic representation based on case number. For this purpose all cases should be ranked. All possible cases were explored, but only sorting by population gave acceptable results (noises are negligible). In other cases, the trend is not visible.

The benchmark data were ranked by population. We can see on fig.3. that there's high inhomogeneity in regional socio-economic development.

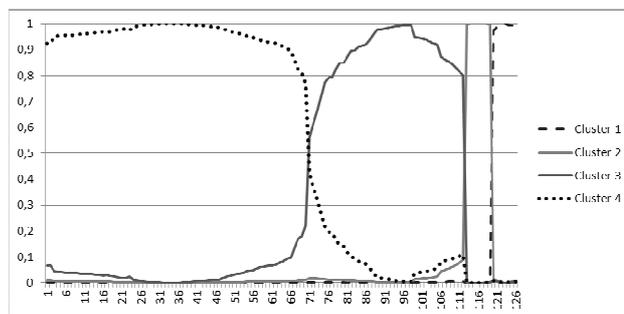


Fig.3. The membership functions of multi-criteria fuzzy clusters of Grodno local regions in 2008-2014

The top cluster includes only result of city Grodno with significant membership function value. The analysis of membership functions values of other cases of city Grodno testify that it can be used for historical research.

Solutions and recommendations.

The local regional economy can characterize by strong correlation dependence between economic and social indexes. That's why regional governance should take into account a lot of criteria for decision-making.

In Belarus there're lacks of statistical data that characterize the current stage of development of the information economy. We didn't receive the impact of services and knowledge to the result of socio-economic development. The local regional development in Belarus in these circumstances can be characterized only as industrial. National statistical committee makes sense to reconsider the system of indexes and add the evaluation of knowledge society.

There're inequalities in regional socio-economic development in Belarus. When we considered fuzzy sets based of multi-criteria we received that city Grodno has huge results with maximum values of most of indexes. The same time most local regions have a low and medium contribution to the socio-economic development. For changing this situation the government should attract investments to local regions.

It was found that economy in the Grodno region is mostly time-consuming and result of socio-economic development is mainly determined by demographic factors. Insufficient attention is paid to the development of high-tech innovation. These negative trends in the development must be overcome through the development of investment activity of both local and foreign entrepreneurs.

A significant contribution to socio-economic development of local regions is made by regional budget. It reaffirms that regions should attract private capital and develop entrepreneurship.

FUTURE RESEARCH DIRECTIONS

One of the drawbacks of this concept is that we take all indexes as equivalent. It would be interesting in future to complete the software by adding a possibility to take into account the importance of indexes.

Moreover, it makes sense to develop integrated criteria for the various areas of regional socio-economic development and to construct a multi-dimensional

membership functions based on a smaller number of baseline factors.

One of the most important directions of this research is construction of analytical form of multi-criteria membership functions. It will allow to develop different scenarios of regional economic growth and predict future position of regions. It also can help to evaluate the influence of different factors to the result of socio-economic development.

It's interesting to apply this methodology to other objects. It can be used for evaluating of set of products for marketing strategy development or for comparative measure of solvency of enterprises or organizations.

CONCLUSION

1. The fuzzy logic argues that a sharp transition from one cluster to another is impossible, and there is the possibility of a piecemeal transition from one group to another. This process can be described by a membership function, which shows the degree of each region belongs to each fuzzy set.

The study was conducted comparative characteristic of the level of socio-economic development of the Grodno region, an analysis of the results robust and fuzzy multidimensional clustering and multi-dimensional and one-dimensional comparison of clustering.

2. The multidimensional fuzzy clustering is useful for group's construction based on several criteria. The goal of this analysis is to form a fuzzy group of regions with similar levels of socio-economic development based on multiple values of initial indices. The degree of membership to the fuzzy cluster will be a degree of group membership. This saves the standard rules of the group, in which the differences within groups are much smaller differences between the groups.

3. The methodology for these procedures can be easily automated. This allows carry out interregional comparisons operatively. The testing area of this method was the assessment of Grodno region in 2008-2014.

At first, a system of criteria, indicators that reflect different aspects of socio-economic development was developed. The system consists of 28 indicators combined into 5 groups.

Then, the database was collected. It includes the statistics of these indicators for the 17 counties of the Grodno region and city Grodno in 2008-2014.

In the next step the raw data were normalized, scaled and unified to the form "the more, the better."

4. Application of factor analysis and principal component analysis allowed form a single integral criterion, which retained most of the variance of initial data. On the basis of the criterion which is analog to GRP per Capita, all counties of the Grodno region were grouped into 4 clusters based on socio-economic development's level.

After that, using a multidimensional method of fuzzy c-means, the original set of counties was also grouped into 4 fuzzy clusters. So we obtained a degree of membership for each county to each cluster. It's known that the classical membership functions may be represented by a triangular, trapezoidal, etc. We tried to display the membership function on the chart with lowest

noises. As a result of streamlining counties by different parameters we revealed that the most representative view of the membership functions are in the ordering by the population. This suggests the priority of this indicator in determining the level of socio-economic development.

5. Multi-dimensional fuzzy clusters better reflect the comparative level of socio-economic development. But using of very informative criterion of GDP per Capita allows receiving interesting results. The difficulty of interpretation and using of the result of multi-dimensional fuzzy clustering in future leads to the need of building and using some integral criteria.

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