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Modeling Evaluation of the Size of Countries (Regions) Using Fuzzy Logic

Stojić Gordan[A]*, Ristanović Branko[B], Tanackov Ilija[A], Vesković Slavko[C], Dimanoski Kire[D]

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Abstract

Countries (regions) size rating is based on various parameters: area, population, population density, economic development (GDP, GDP per capita etc.), natural resources, markets, etc. The most common rating is based on the area of the country (km^2). The values defining at the transition between the levels (classes), has a large level of subjectivity present, and the classes are more often contradictory. Countries classification as "Small", "Medium" or "Large" more often is subject for discussions and mutual disagreements.

Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth- truth values between "completely true" and "completely false". As its name suggests, it is the logic underlying modes of reasoning which are approximate rather than exact. The importance of fuzzy logic derives from the fact that most modes of human reasoning and especially common sense reasoning are approximate in nature.

This paper presents a model for size evaluation of countries (regions) using Fuzzy logic.

Input and output variables are defined. Input variables are: area, population and population density of countries (regions) and the output variable is the size evaluation of the country (small, medium or large).

Keywords: modeling, evaluation, size of the country, fuzzy logic

Introduction

One of the key issues in solving real problems in deciding is the treatment of problems of uncertainty and unprecision present in every segment of life and environment ("a little waiting time", "high costs", "approximately 30 minutes" etc). Such is the problem with defining the size of the countries (regions), or the countries (regions) size classification.

How to determine the size of the countries (regions)? Which country is "big", which country is "medium" or "small", for example according to geographic (area, population etc.) or economical characteristics (GDP, GNP) etc.?

In the literature, the countries size notion is considered in many ways, the most common classification is by area or size of the population (Dinić, 1992), and often by the level of economy development, natural resources, capital and so on. In relation with the issues which are involved in this work, particularly interesting is the classification of the countries according to the size of the territory.

The history of the political geography knows the concept of the countries and its classification. From the former city states (polis) and the great countries that extend their territory on few continents, the way they shared their territory was the subject of interest of many researchers.

So Paunds divides countries as gigantic (over 6 million. km^2) huge (2,5 - 6 million km^2), very large

[A] Department of Traffic Engineering, Faculty of Technical Sciences, University of Novi Sad, Trg Dositeja Obradovića 6, 21000, Novi Sad, Serbia; gordan@uns.ac.rs, ilijat@uns.ac.rs

[B] Department of Geography, Tourism and Hotel Management, Faculty of Science and Mathematics, University of Novi Sad, Trg Dositeja Obradovića 3, 21000, Novi Sad, Serbia; brankoris@yahoo.com

[C] Department of Railway Transport and Traffic, Faculty of Traffic and Transport Engineering, University of Belgrade, Vojvode Stepe 305, 11000, Belgrade, Serbia; veskos@sf.bg.ac.rs

[D] Secondary Technical School "Vlado Tasevski" - Skopje, 3ta Makedonska Brigada BB, 1000, Skopje, Macedonia; kdimanoski@yahoo.com

* Corresponding author: Stojić Gordan, e-mail: gordan@uns.ac.rs

(1,25 - 2,5 million km^2), large (0.65 - 1.25 million km^2), medium (0,25 - 0,65 million km^2), small (0,125 - 0,25 million km^2), very small (0,025 - 0,125 million km^2) and micro state (below 0.025 million km^2).

De Blij uses a similar model for countries dividing, and according to De Blij they are divided as: very large (over 2.5 million km^2), large (0,35 - 2,5 million km^2), medium (0,15 - 0,35 million km^2), small (0,025 - 0,15 million km^2), and very small (below 0.025 million. km^2).

M. Schwind divides the countries as: transcontinental (7-25 million km^2), sub-continental (3-10 million km^2), makrotope (0,9 - 2,9 million km^2), mezotope (0.04 - 0.8 million km^2), mikrotope (0,001 - 0,04 million km^2), and minitope (below 0.001 million. km^2).

According to Racel the countries are divided as: mainland (over 5 milion. km^2), medium (0,2 - 5 million km^2), and low (below 0.2 million km^2).

There is interesting classification of countries according to O. Maul, he shared the countries by power, and in his typology differentiate giant countries, great powers, middle powers, small and dwarf countries.

In the above classifications, classes are mechanically defined, poorly satisfying and many of them are contradictory. However, based on them we can determinate some extremes and relations which are needed in order to solve many problems related to the economic functioning of the given countries.

The official classification of countries into small, medium and large is also performed by EU, with the Treaty of Nice, and it is according to the number of seats allocated in the EU Parliament.

In addition, in the literature can be found application of the Computable General Equilibrium (CGE) model, for impact evaluation of the regulatory measures for markets liberalization and establishing a balance (Balistreri, et al. 2009), (Feraboli, 2006). For evaluation of the traffic system state, in this paper (Balistreri, et al. 2009) the Benchmarking analysis is applied.

During the 2007th the company IBM Business Consulting Services, for Deutsche Bahn AG, performed an evaluation study for the market level liberalization in 27 EU countries (IBM, 2007). In the study the Benchmarking method is also applied.

One of the methods for evaluation that is often applied in various segments is the SWOT analysis (Business Monitor International, 2009) (SEETO 2009) (Yang, et al. 2007) etc. In the literature can be found applicated hybrid models such as A'WOT analysis (combining the SWOT analysis and the Analytic Hierarchy Process - AHP). A'WOT analysis is applied for strategic planning of rural tourism (Kajanus, et al. 2004).

Certain elements in the analysis are often insufficiently precise, and the assessment of their value is subjective. The methods: Computable General Equilibrium and Dynamic General Equilibrium Analysis, use statistical database. The comparative Benchmarking method is based on the concept of innovative way of utilization of the best practice and experience. In applying this method, basic danger comes with the process of reduction to a simple method of comparison, or innovating with copying.

The SWOT analysis is a widely applied method of analysis. The application of this analysis for the evaluation of size of the country also implies the use of intuition and subjective evaluation. However, the SWOT analysis is not only used as a direct research method. Results of SWOT analysis is too often only a superficial and imprecise listing or an incomplete qualitative examination of internal and external factors (Chang, Huang, 2006).

Conventionally, a mathematical model of a system is constructed by analyzing input–output measurements from the system. However, an additional important source of information about engineering systems is human expert knowledge, known as linguistic information. It provides qualitative instructions and descriptions of the system. While a conventional mathematical model fails to include this type of information, a fuzzy model can conveniently incorporate it (Qiao, et al. 2009).

The countries sizing is given according to the experience, intuition and subjective attitude or particular institutions of experts. However, uncertainty, regarding the input data necessary for the certain decision making, is also present. This implies that all parameters of evaluation are characterized by uncertainty, subjectivity, inaccuracy and ambiguity. Fuzzy sets theory (scattered – inarticulate sets), is a very suitable tool for uncertainty, subjectivity, ambiguity and inaccuracy treatment (Teodorović, Kikuchi, 2000). Modeling with uncertainty requires more than probability theory.

A substantial result in the application of the theory of "fuzzy" sets in geography appears at the end of the last century. So in the book (Burrough, Frank, 1996), fuzzy logic is applied in several aspects. (Lynn Usery, 1996) gives a conceptual framework and fuzzy set implementation for geographic features. (Fisher, 1996) is applying fuzzy logic to define a region, (Sarjakoski, 1996) to determinate the number of lakes, islands and rivers in Finland. (Openshaw, 1996), defines the fuzzy logics as a new scientific paradigm for doing geography.

At the beginning of this century, (Wenbao, et al. 2001), is focused on some issues of fuzzy uncertainty of positional data, including new mathematical expressions and methods of formal description of fuzzy points, lines and polygons in GIS.

In his work (Boreiko, 2002) estimates the readiness of the Accession Countries of Central and East Europe for EMU or for unilateral euroisation using a fuzzy clustering algorithm.

The computation of areas of fuzzy geographical entities in Geographical Information Systems are presented in the paper (Fonte, Lodwick, 2004).

The theory of "fuzzy" sets can be implemented also in modeling the fuzzy spatial extent of geographical entities (Fonte, Lodwick, 2005a) and for computation of the area and perimeter of fuzzy geographical entities (Fonte, Lodwick, 2005b).

Particularly significant is the application of the fuzzy logic in geology. As in the book (Demicco, Klir, 2004) fuzzy logics are used in Hydrology and Water Resources (Bogardi, et al. 2004), Earthquake Research (Bělohlávek, 2004), Formal Concept Analysis in Geology (Huang, 2004) etc.

The analyzed effects of the country size, where the Relative Gross National Product (GNP), the domestic investment and saving where included, and the data from the panel of OECD 21 countries for the years between 1970 and 2003, are presented in the paper (Ozkan, et al. 2009). Using fuzzy logic, clustering of the countries based on their relative sizes lead to groups such as, "small", "medium", "large" and "very large" countries.

In this paper is presented fuzzy model which allows assessment of the size of the EU member states and aspirants for membership. Evaluation is made based on the following parameters: area, population and population density of countries.

Fuzzy model for evaluation

Fuzzy sets are sets whose elements have degrees of membership. In classical set theory, the membership of elements in a set is assessed in binary terms according to a bivalent condition — an element either belongs or does not belong to the set. By contrast, fuzzy set theory permits the gradual assessment of the membership of elements in a set; this is described with the aid of a membership function valued in the real unit interval [0, 1].

The core technique of fuzzy logic is based on three basic concepts: (1) fuzzy set: unlike crisp sets, a fuzzy set has a smooth boundary, i.e., the elements of the fuzzy set can be partly within the set. Membership functions are employed to provide gradual transition from regions completely outside a set to regions completely in the set; (2) linguistic variables: variables that are qualitatively, as well as quantitatively, described by a fuzzy set. Similar to a conventional set, a fuzzy set can describe the value of a variable; (3) fuzzy "if-then" rules: a scheme, describing a functional mapping or a logic formula that generalizes an implication of two-valued logic. The main feature of the application of fuzzy "if-then" rules is its capability to perform inference under partial matching. It computes the degree the input data matches the condition of a rule. This matching degree is combined with the consequence of the rule to form a conclusion inferred by the fuzzy rule (Qiao, et al. 2009).

Defining fuzzy variable

Considering that in literature can't be found a model that assesses the size of countries according to the parameters: area, population and population density of countries, the author's proposed special type and values of fuzzy variables in the model.

In the model a fuzzy output variable A is defined and fuzzy input variables: B, C, D.

Fuzzy output variable A, assesses the level of the size of the countries (regions). It is presupposed that the country can be "Small", "Medium" or "Large" and the quantification of the scores is in range from 0 to 10. Membership functions belonging to fuzzy sets A_{SMALL}, A_{MEDIUM} and A_{LARGE} are shown in Figure 1 (a).

Fuzzy input variable B describes the country (region) area. It is presupposed that there can be "Small" (SA), "Medium" (MA), or "Large" (LA) area of the country. Membership functions belonging to fuzzy sets B_{SA}, B_{MA} and B_{LA} are shown in Figure 1 (b).

Fuzzy input variable C describes the number of inhabitants. It is assumed that the population

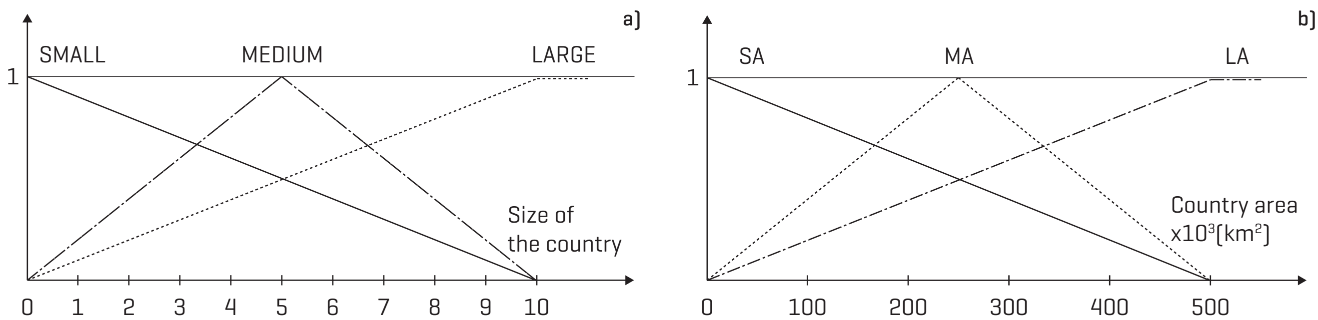

Figure 1 Functions belonging to fuzzy sets: a) A_S, A_M and A_L; b) B_{SA}, B_{MA} and B_{LA}

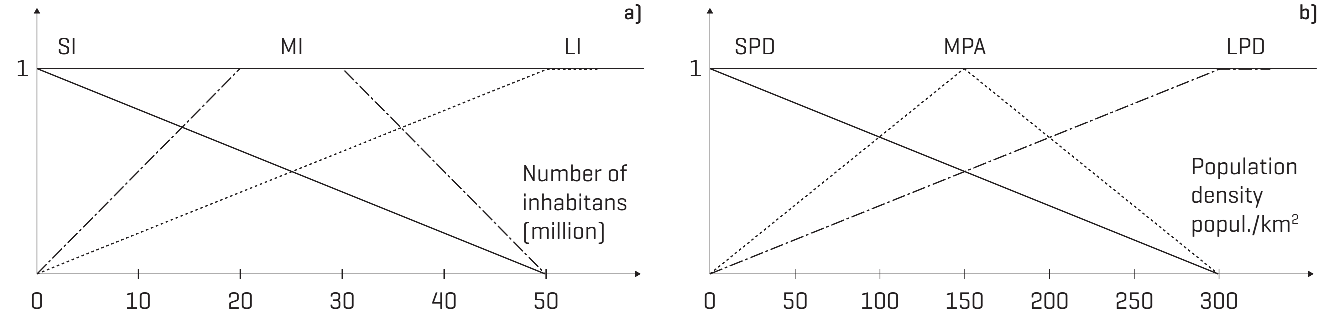

Figure 2 Functions belonging to fuzzy sets: a) C_{SI}, C_{MI} and C_{LI}; b) D_{SPD}, D_{MPD} and D_{LPD}

may be Small (SI), Medium (MI) or Large "Great" (LI). Membership functions are defined (5) and (6). Membership functions belonging to fuzzy sets C_{SI}, C_{MI} and C_{LI} are shown in Figure 2 (a).

Fuzzy input variable D represents population density. It is presupposed that there can be "Small" (SPD), "Medium" (MPD) or "Large" (LPD) population density. Membership functions belonging to fuzzy sets D_{SPD}, D_{MPD} and D_{LPD} are shown in Figure 2 (b).

Fuzzy logic

Fuzzy logic is the base of fuzzy system. It enables making decisions based on incomplete information, and models based on fuzzy logic consist the so-called "IF-THEN" rules. "IF-THEN" rules are interconnected with "ELSE" or "AND".

When we assume that $x = [x_1, x_2, \dots, x_n]$ is a vector of features describing any object or state and $y = [y_1, y_2, \dots, y_m]$ is the vector of output values of a system, the rules are represented in the form:

R^r: IF x_1 is A^r_1 AND x_2 is A^r_2 AND...AND x_n is A^r_n THEN y_1 is B^r_1, y_2 is B^r_2, ..., y_m is B^r_m

where:

$x \in X = X_1 \times X_2 \times \dots \times X^n, y \in Y = Y_1 \times Y_2 \times \dots \times Y_m$

and

$A^r = A^r_1 \times A^r_2 \times \dots \times A^r_n \subseteq X, Br = B^r_1 \times B^r_2 \times \dots \times B^r_m \subseteq Y$

are the fuzzy sets (Nowicki, 2009).

Fuzzy logic is defined using algorithms for approximate reasoning. The special significance of fuzzy logic is in the possibility of its application for modeling complex systems in which is very difficult to determine the correlation of certain variables that exist in the model. Possible and logical rules are with weight 1, less possible 0.5.

Approximate reasoning algorithm for countries (region) size evaluation, developed in this paper consists the following rules:

I **The number of inhabitants is Small (SI):**

1. If (Area of the country is SA) and (Population density is ANY) then (The level of the size of the countries is SMALL) – weight: (1)
2. If (Area of the country is MA or LA) and (Population density is SPD) then (The level of the size of the countries is MEDIUM) – weight: (1)
3. If (Area of the country is MA) and (Population density is MPD) then (The level of the size of the countries is MEDIUM) – weight: (0.5)

II **The number of inhabitants is Medium (MI):**

1. If (Area of the country is SA) and (Population density is MPD or LPD) then (The level of the size of the countries is MEDIUM) – weight: (1)
2. If (Area of the country is MA) and (Population density is SPD) then (The level of the size of the countries is MEDIUM) – weight: (0.5)
3. If (Area of the country is MA) and (Population density is MPD) then (The level of the size of the countries is MEDIUM) – weight: (1)
4. If (Area of the country is MA) and (Population density is LPD) then (The level of the size of the countries is LARGE) – weight: (0.5)
5. If (Area of the country is LA) and (Population density is SPD) then (The level of the size of the countries is LARGE) – weight: (1)
6. If (Area of the country is LA) and (Population density is MPD) then (The level of the size of the countries is LARGE) – weight: (0.5)

III **The number of inhabitants is Large (LI):**

1. If (Area of the country is SA) and (Population density is LPD) then (The level of the size of the countries is MEDIUM) – weight: (1)
2. If (Area of the country is MA) and (Population density is MPD) then (The level of the size of the countries is MEDIUM) – weight: (0.5)
3. If (Area of the country is MA) and (Population density is LPD) then (The level of the size of the countries is LARGE) – weight: (1)
4. If (Area of the country is LA) and (Population density is SPD) then (The level of the size of the countries is LARGE) – weight: (0.5)
5. If (Area of the country is LA) and (Population density is MPD or LPD) then (The level of the size of the countries is LARGE) – weight: (1)

The incoming variables in fuzzy systems represent the so called linguistic variables. The outcome is given in a continual phase. An adequate level of belonging is determined for all possible outcome sums of variables. After being observed, the levels of belonging of particular outcome sums of variables are to be made by defuzzification.

Defuzzification is the process of producing a quantifiable result in fuzzy logic, given fuzzy sets and corresponding membership degrees. It is typically needed in fuzzy control systems. These will have a number of rules that transform a number of variables into a fuzzy result, that is, the result is described in terms of membership in fuzzy sets. A useful defuzzification technique must first combine the results from the rules. The most typical fuzzy set membership function has the graph of a triangle. If this triangle were to be cut in a straight horizontal line somewhere between the top and the bottom, and the top portion were to be removed, the remaining portion forms a trapezoid. Typically, the first step of defuzzification is chopping off parts of the triangle to form trapezoids (or other shapes if the initial shapes were not triangles. In the most common technique, the trapezoids from all input functions are then superimposed one upon the other, forming a single geometric shape. Then, the centroid of this shape, called the fuzzy centroid, is calculated. The x coordinate of the centroid is the defuzzified value (Qiao, et al. 2009).

The authors decided to use the center of area-COA (center of gravity-COG) defuzzification method, Mamdani fuzzy inference systems, “Min” method for operator, “And” and method “Max” for operator “Or”.

Probably the best known defuzzification operator is the COA (COG) defuzzification method. It is a basic general deffuzification method that computes the center of gravity of the area under the membership function (Van Leekwijck, Kerre, 1999). The value *x** of the output, which is resulting from the COA method, is given in the following equation:

$$x^* = \sum_{i=x_{\min}}^{x_{\max}} x_i \cdot \mu(x_i) \Big/ \sum_{i=x_{\min}}^{x_{\max}} \mu(x_i) \qquad (1)$$

Where the $\mu(x_i)$ is membership function. The formula shows that COG calculates the expected value when A is considered to be probability distribution.

Model test results

Testing the size assessment of the countries was carried out on randomly selected samples of the EU member countries and aspirants for EU membership.

The results of the assessment of the size of the countries in randomly selected sample are shown in the figure 3.

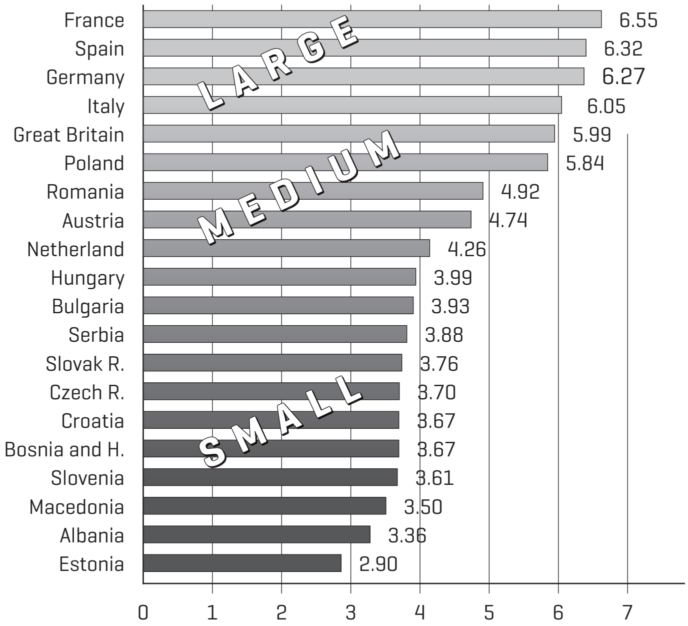

Figure 3 Assessment of the size of the countries under the chosen sample

In order to estimate the validity of the proposed model, sensitivity analysis is carried out, by changing the shape functions belonging to fuzzy sets of input and output variable and changing methods of operators for the following cases:

a. Membership functions have triangular shape and trapezoidal numbers, as defined in point 2.1 of this paper, but the method used to “prod” (Product of array elements) for the operator “AND” and the method “probor” (Probably “OR”) for the operator “OR”;
b. Gaussian curve built-in membership function (gaussmf).

The results are shown in Figure 4.

As can be seen from Figure 4, after the conducted sensitivity analysis, there are not significant changes in the evaluation of the size of the countries. In these cases, “Large” countries are: France, Spain, Germany and Great Britain. “Medium” countries are: Poland, Romania, Bulgaria and the Netherlands, “Small”: Hungary, Austria, Czech Republic, Slovak Republic, Serbia, Croatia, Slovakia, Serbia and Montenegro, Macedonia, Albania and Estonia. In the conducted sensitivity analysis, there are only very small changes in ranking order according to the results quantification.

In the literature can’t be found works that are making classification of countries by size, considering population, area and density. There are works based on the subjective attitude of experts, which are classifying countries by size, only considering the area (Paunds, De Blij, Racel etc.), and fuzzy model of OECD member countries which

Figure 4 Fuzzy model sensitivity analysis

***Table 1** Comparison of the obtained result grades with other countries size and grades*

Country size	Paunds (small and very small)	De Blij	Racel	Ozkan (only OECD[1])	Proposed fuzzy models
SMALL	Great Britain, Netherland, Austria, Czech R., Hungary, Slovak R., Croatia, Slovenia, Bulgaria, Serbia, Estonia, Bosnia and Herzegovina., Albania, Macedonia	Netherland, Austria, Czech R., Hungary, Slovak R., Croatia, Slovenia, Bulgaria, Serbia, Estonia, Bosnia and Herzegovina, Albania, Macedonia	Netherland, Austria, Czech R., Hungary, Slovak R., Croatia, Slovenia, Serbia, Estonia, Bosnia and Herzegovina, Albania, Macedonia	Netherland, Austria	Czech R., Hungary, Slovak R., Croatia, Slovenia, Bulgaria, Serbia, Estonia, Bosnia and Herzegovina, Albania, Macedonia
MEDIUM	Germany, Italy, Poland, Romania	Great Britain, Italy, Poland, Romania	Germany, France, Great Britain, Italy, Poland, Romania, Bulgaria, Spain	Great Britain, Italy,	Great Britain, Netherland, Poland, Austria, Romania,
LARGE	France, Spain	Germany, France, Spain		Germany, France, Spain	Germany, France, Spain, Italy

[1] Memberships of the Countries in 2003.

classifies countries by size according to realized relative GNP (Ozkan).

As can be seen from Table 1, the country size result grades by the fuzzy model for the "Small" countries correspond with the other grades, except for Netherlands which the model has classified it as "Medium." This is because the Netherlands has a high density and that is not analyzed in other grades. For the same reason there is less difference in the size assessment of Italy (although is on the border between "Medium" and "Large"). Other countries size result grades by the fuzzy model, although they aren't fully observed by the same criteria, they are still compatible.

Conclusion

Countries (regions) size evaluation is performed, usually by country area or population. The country ranking as "Small", "Medium" or "Large" country has a great subjectivity and ambiguity in relation to the choice of thresholds crossing in to the next rank. In addition, classifying only by one criterion is incomplete.

This paper presents a new way of modeling and evaluation the countries (regions) size based on the following criteria: area of the country (region), population and population density, using the fuzzy sets theory, which allows solving problems that contain uncertainty, subjectivity, ambiguity and uncertainty. One fuzzy output and three fuzzy input variables were defined. The model testing was conducted by countries (regions) size evaluation on randomly selected samples.

Countries size evaluation model with appropriate modifications of the rules and variable values, can be used to other similar types of size evaluation, such as in: natural resources, agricultural representation, industrial development, distribution of ore resources, economic development and others.

References

Balistreri, E. J., Rutherford, T.F., Tarr, D.G. 2009. Modeling services liberalization: The case of Kenya. *Economic Modelling* 26, 668-679.

Bělohlávek, R. 2004. Formal Concept Analysis in Geology, book: Fuzzy Logic in Geology. Elsevier Science, Chapter 7, 191-237.

Bogardi, I., Bardossy, A., Duckstein, L., Pongracz, R. 2004. Fuzzy Logic in Hydrology and Water Resources, book: Fuzzy Logic in Geology. Elsevier Science, Chapter 6, 153-190.

Boreiko, D. 2002. EMU and Accession Countries: Fuzzy Cluster Analysis of Membership. Working Papers from Oesterreichische Nationalbank, No. 71.

Brazil Commercial Banking Report Q4 2009. Business Monitor International LTD, London, 8-45.

Burrough, P.A., Frank, A. 1996. Geographic Objects with Indeterminate Boundaries. Taylor & Francis Ltd, British Library Cataloguing in Publication Data, London, Great Britain.

Chang, H.H. Huang, W.C. 2006. Application of a quantification SWOT analytical method. *Mathematical and Computer Modelling* 43, 158-169.

Demicco, R.V., Klir, G.J. 2004. Fuzzy Logic in Geology. Elsevier Science, California, USA.

Dinić, J. 1992. Economic geography. Faculty of Economics, University of Belgrade. (in Serbian).

Feraboli, O. 2006. A Dynamic General Equilibrium Analysis of Jordan's Trade Liberalisation. PhD dissertation, Chemnitz University of Technology, Faculty of Economics and Business Administration, Germany, 48-74.

Fisher, P. 1996. Boolean an Fuzzy Regions. book: Geographic Objects with Indeterminate Boundaries, Taylor & Francis Ltd, British Library Cataloguing in Publication Data, London, Great Britain, 87-94.

Fonte, C.C., Lodwick, W.A. 2004. Areas of fuzzy geographical entities. *International Journal of Geographical Information Science* 18, 2, 127–150.

Fonte, C.C., Lodwick, W.A. 2005a. Modelling the Fuzzy Spatial Extent of Geographical Entities. Springer Berlin Heidelberg, Part 2, 121-142.

Fonte, C.C., Lodwick, W.A. 2005b. Area, Perimeter and Shape of Fuzzy Geographical Entities. Springer Berlin Heidelberg, Part 7, 315-326.

Grčić, M. 2000. Political geography. Faculty of Geography University of Belgrade. (in Serbian).

Hatzichristos, T., Potamias, J. 2004. Defuzzification operators for geographical data of nominal scale. Proc. 12th Int. Conf. on Geoinformatics – Geospatial Information Research: Bridging the Pacific and Atlantic,University of Gävle, Sweden.

Huang, C. 2004. Fuzzy Logic and Earthquake Research. book: Fuzzy Logic in Geology, Elsevier Science, Chapter 8, 239-274.

IBM Business Consulting Services 2007. Summary of the Study Rail Liberalisation Index 2007, Market Opening: Rail Markets of the Member States of the European Union, Switzerland and Norway in comparison, Brussels, 55-75.

Kajanus, M., Kangas, J., Kurttila, M. 2004. The use of value focused thinking and the A'WOT hybrid method in tourism management. *Tourism Management* 25, 499–506.

Lynn Usery, E. 1996. A Conceptual Framework and Fuzzy Set Implementation for Geographic Features. book: Geographic Objects with Indeterminate Boundaries, Taylor & Francis Ltd, British Library Cataloguing in Publication Data, London, Great Britain, 71-86.

Nowicki, R. 2009. Nonlinear modelling and classification based on the MICOG defuzzification. *Nonlinear Analysis* 71, e1033–e1047.

Patel, A.V., Mohan, B.M. 2002. Some numerical aspects of center of area defuzzification method. Fuzzy Sets and Systems 132, 401–409.

Openshaw, S. 1996, Fuzzy logic as a new scientific paradigm for doing geograph. *Environment and Planning* A 28, 761 – 768.

Ozkan, I., Erden, L., Türks, I. B. 2009. A fuzzy analysis of country-size argument for the Feldstein–Horioka puzzle. *Information Sciences* 179, 2754–2761.

Sarjakoski, T. 1996. How many Lakes, Islands and Rivers are there in Finland? A Case Study of Fuzziness in the Extent and Identity of Geographic Objects. book: Geographic Objects with Indeterminate Boundaries, Taylor & Francis Ltd, British Library Cataloguing in Publication Data, London, Great Britain, 299-312.

SEETO 2009. Exchange Of Information On Regional Legal Framework For Access To Railway Network And Draft Regulatory Manual, First Railway Reform Workshop For Task: Access To Railway Network, Belgrade, Serbia.

Stojić, G., Tanackov, I., Vesković, S., Milinković, S., Simić, D. 2009. Modelling Evaluation of Railway Reform Level Using Fuzzy Logic. Springer Berlin/Heidelberg, Volume 5788, 695-702.

Teodorović, D., Kikuchi, S. 2000. Fuzzy Sets in Traffic and Transport Systems, Preface. *Fuzzy Sets and Systems* 116, 118.

Qiao, Y., Kerenb, N., Mannan, M.S. 2009. Utilization of accident databases and fuzzy sets to estimate frequency of HazMat transport accidents. *Journal of Hazardous Materials* 167, 1-3, 374-382.

Van Leekwijck, W., Kerre, E.E. 1999. Defuzzification: criteria and classification. *Fuzzy Sets and Systems* 108, 2, 159-178.

Wenbao, L. Zongguo, X., Min, D. 2001. Modeling fuzzy geographic objects within fuzzy fields. *Geo-Spatial Information* Science 4, 4, 37-42.

Yang, Z., Wang, J., Wu, Z. 2007. SWOT Analysis and the Development Countermeasures for Ecotourism in Pengzuping Nature Reserve. *Journal of Northwest Forestry University* 22, 4, 176-179.