Managing the Process of Restructuring the National Railway Systems Using Fuzzy Logic

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***Abstract* – Carrying out the restructuring of the national railway systems inside and outside of EU is conducted by different level of dynamics which causes different levels of national railway reforms. The different level of restructuring has influence on the railway market establishment and its liberalisation. The EU institutions' tendency is to synchronise the process of restructuring of the national railway systems. The initial point of synchronisation is the estimation of the level of restructuring of the national railway systems. This paper presents a model of estimation of the level of restructuring of the national railway system using fuzzy logic.**

***Keywords* – estimate, restructuring, railway system, fuzzy logic**

I. INTRODUCTION

The reform level of a particular subject is often the matter of discussion and mutual misunderstandings. The evaluation is given according to the experience, intuition and subjective attitudes of particular institutions and experts. The institutions are: the Government, Ministries, Agencies, Companies, the EU organs, Financial Institutions (international: World Bank-WB, European Bank for Reconstruction and Development-EBRD, International Monetary Fund-IMF , European Investment Bank-EIB, or domestic banks) and experts that work on their own behalf and represent a particular organisation (market surveying, regulative compatibilities and the EU reforms and etc.). However, uncertainty, regarding the input data necessary for the certain decision making, is also present. This implies that all the parameters of evaluation are characterised by uncertainty, subjectivity, inaccuracy and ambiguity. There is a similar problem with the railway reform evaluation. The theory of fuzzy sets (scattered – inarticulate sets), is a very suitable tool for the treatment of uncertainty, subjectivity, ambiguity and inaccuracy [14].

The establishment of the railway reform levels was conducted several times in the past during the process of the national railway system reconstruction. The railway reforms represent a continuous process. The certain railway systems are at the beginning of the reforms, some of them have advanced and some have applied a large number of measures in the process of reform implementation.

The evaluation was mostly necessary for the approval of financial funds for the reforms and railway recovery but also to determine the level of the railway harmonisation with the European ones. The manner, in which the railway reform evaluation was conducted, is not always scientifically founded, except in the few cases which are to be analysed in this paper. The reformation level evaluation was mostly conducted by a heuristic evaluation method and it was based on the individual opinions, reasoning and intuitions and without any mathematical method application. The similar report was the one on major economic aspects of the EU railway reforms [10], mutual influence within the railway systems in the research of the South East Europe Transport Observatory organisation on the reforms of railways [12]. The significant evaluation of railway reforms in Europe with the reference to the infrastructural approach was given in the European Conference of Ministers of Transport report (ECMT) [5].

The WB described the railway system reforms as low, medium and high [1]. The IBM Business Consulting Services conducted the research for the evaluation of market liberalisation level in 27 European countries [7]. The Benchmarking method for the evaluation of legal and practical obstacles of the approach to the railway market was included in the research. Rank order of the countries regarding the railway transport market liberalisation was conducted by LIB Index (Fig. 1). The LIB index presents information on the relative degree of market opening in the European rail transport markets.

Fig. 1. Railway reform evaluation using LIB index

One of the latest approaches to the railway reform evaluation, applying the SWOT analysis, is presented in this paper [13].

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 [8].

According to this analysis, it can be determined which countries have the highest level of market liberalisation and the most extensive application of the EU Directives (Fig. 2).

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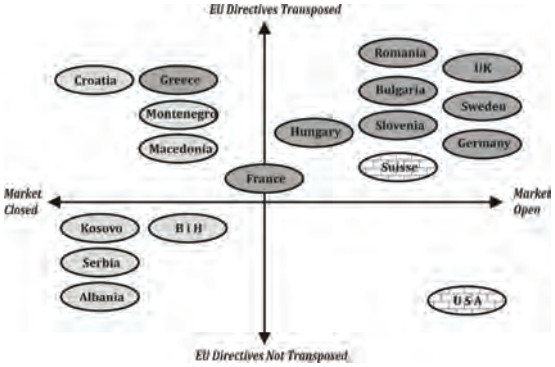

Fig. 2. Railway reform evaluation using SWOT analysis

The SWOT analysis is a widely applied method of analysis. The application of this analysis for the evaluation of railway system reformation also implies the use of intuition and subjective evaluation. However, the SWOT and A'WOT analysis are not only used as a direct research method. The results on SWOT analysis are too often only a superficial and imprecise listing or an incomplete qualitative examination of internal and external factors [3].

Apart from the previously mentioned methods, the reference also comprises the application of the Computable General Equilibrium (CGE) and Dynamic General Equilibrium (DGE) method for the evaluation of regulatory measure influences on liberalisation and market balance determination [2] [6] [8] [11]. The Benchmarking analysis for the railway system establishment was used in the paper [2].

The statistic analysis does not take uncertainty into consideration. Particular elements in the analysis are usually insufficiently precise, and their values' estimation is subjective. CGE and DGE methods employ a statistical data base.

The comparative Benchmarking method is based on the concept of an innovative way of positive practice and the use of experience. The initial problem with the application of the method is in the procedure of reducing it to the simple method of comparison or innovation via copying. On the other hand, railway reforms have not reached their final phase in any country since they represent a sustained process. This led to the following questions: Can the Benchmarking method, SWOT and A'WOT analysis be used for the evaluation of reform levels if none of the railway system is completely reformed? Which reform will be used to conduct a comparison in order to evaluate the reform level? We again come to the subjective evaluations, especially in the field of weighed factor determination.

II. FUZZY MODEL

A is defined as a fuzzy output variable which represents the evaluation of a railway reform level, where uncertainty, in terms of the performance of dynamics, the number of taken reform steps, the defined transport policy that is carried out, social and political reasons of the authority's readiness to conduct the reforms, political changes etc, is present. Assuming that the reforms can be: "Low", "Medium" and "High", and that the quantity evaluation is from 0 to 10, the membership functions and are defined (Fig. 3).

The following input variables have been defined in this paper for modelling and evaluation of the railway reforms: (1) Preparation for the railway reform; (2) Railway reforms criteria fulfilment; (3) The number of Railway Undertakings (RUs).

The European Union issued the Directive 91/440/EEC in order to improve the quality of railway services and to ensure more efficient railway's participation in the transport market in the same manner [4]. The basic aim of the Directive is to simplify the European national railway adjustment in order to meet the needs of the unique market and to improve their efficiency by ensuring self-management of railway companies and improving the financial structure of the companies. 18 years have passed since the Directive was issued in 1991 and this has been a slow process so far. This indicates that the problem is serious and that there is no capacity to solve it. Furthermore, it indicates the influence of public railway companies and political reasons to keep them under control.

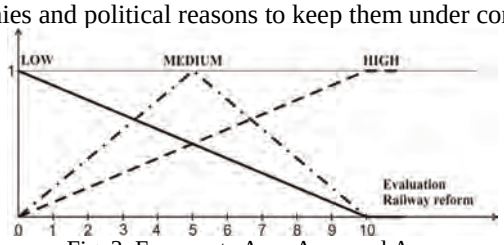

Fig. 3. Fuzzy sets A_{low}, A_{med}, and A_{high}

The restructuring of public railway companies is a process developed in three phases: (1) enforcing the law on railway (the EU Basic Regulative-Directive 91/440/EEC); (2) changing the public railway company into holding; (3) separating the infrastructural and transportation businesses into completely separate companies. Apart from the basic regulative, there is also an additional EU railway regulative in terms of the first, second and third directive sets.

Practice and review on the experience of the European countries reveal that there are two approaches in the restructuring process and they are: gradual and radical. A gradual approach implies the longer transitional period (railway law and holding). The radical approach to the restructure process means "rapid" and "sudden" transformation of the railway company regarding its organisation and its relation with the country without any previous transitional period. This means that at least two independent companies are formed: infrastructure and transport.

Different approaches to the phases of public railway company restructures in terms of duration, moment and manner of transition into the next phase imply the favourability of the theory on fuzzy sets, when it is necessary to take the following into consideration: uncertainty, subjectivity and inaccuracy of the restructure process.

The fuzzy variable B, showing the phase of the countries' readiness for the railway reforms, is defined. Assume the existence of "Unprepared" and "Prepared" countries for the railway reforms. The membership functions are defined (Fig. 4a).

The criteria number and types represent an important element according to which the level of the railway system reforms is evaluated. The following criteria for the evaluation of the railway system reforms are defined:

K_1 – "New regulative". If the first set is enforced than K_1 criterion is fulfilled. The basic regulative enforcement in the field of railway is included in the fuzzy variable "Prepared for the railway reforms".

K_2 – "Improved management structure". The criterion K_2 is considered fulfilled when the operators are converted into stock associations or they are private companies.

K_3 – "Open access to the infrastructure". The criterion K_3 is considered fulfilled if there is a greater number of transporters in the railway system.

K_4 – "Market liberalisation". The criterion K_4 is considered fulfilled if there is at least one international operator on the railway market.

K_5 – "Commercial business of the companies on the market". The criterion K_5 is considered fulfilled when, except for the established regulation, the state provides financial means for infrastructure controllers only for the development of railway infrastructure.

K_6 – "Subventions in the public transport (PSO)". The criterion K_6 is considered fulfilled when the authorised organs provide financial means for agreed duties that are related to the transport of general interest.

K_7 – "Adjustment of the employees' number and structure". The criterion K_7 is considered fulfilled when the rationalisation of employees was made.

In literature, defining a criterion, as well as the evaluation of levels of reforms, is based on experience, intuition and subjective evaluation [1] [7] [13]. Variable C fuzzy is a variable that evaluates the fulfillment of the criterion number that is needed. Let us predict that there is: "Unsatisfactory", "Small", "Satisfactory" and "Great" fulfillment of a criterion number (implementation of criteria).

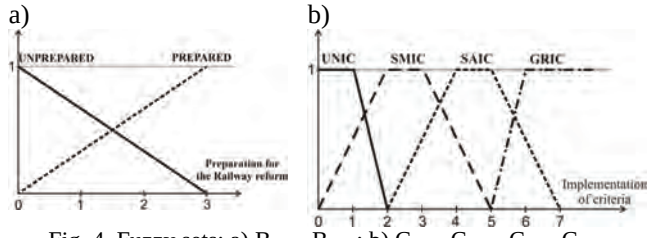

Fig. 4. Fuzzy sets: a) B_{unpr}, B_{prep}; b) C_{unic}, C_{smic}, C_{saic}, C_{gric}

The membership functions to the set C for unsatisfactory – UNIC, small – SMIC, satisfactory – SAIC and great impletion of criteria are defined (Fig. 4b).

Let us predict that there can be "Small", "Medium" and "Large" number of RUs. The fuzzy variable D that evaluates the number of RUs in a railway system is defined. The membership functions of the set D for small, medium and large number of RUs are defined (Fig. 5).

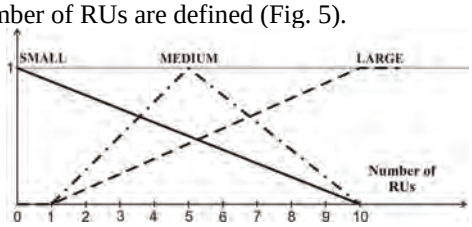

Fig. 5. Fuzzy sets D_{small}, D_{med} and D_{large}

Fuzzy logic is the base of the fuzzy system. It enables making decisions based on uncompleted information. The models based on fuzzy logic consist of the so called "IF-THEN" rules. Fuzzy logic for validation of levels of railway reforms consists of the following, equally competitive rules:

1. If (Preparation is UNPREPARED) and (Criteria is UNIC or SMIC) and (RUs is SMALL) then (Railway Reform is LOW) – weight: (1)
2. If (Preparation is UNPREPARED) and (Criteria is UNIC or SMIC) and (RUs is MEDIUM) then (Railway Reform is LOW) – weight: (0.5)
3. If (Preparation is PREPARED) and (Criteria is UNIC or SMIC) and (RUs is SMALL) then (Railway Reform is LOW) – weight: (1)
4. If (Preparation is PREPARED) and (Criteria is UNIC or SMIC) and (RUs is MEDIUM) then (Railway Reform is LOW) – weight: (0.5)
5. If (Preparation is PREPARED) and (Criteria is SAIC) and (RUs is ANY) then (Railway Reform is MEDIUM) – weight: (1)
6. If (Preparation is PREPARED) and (Criteria is GRIC) and (RUs is ANY) then (Railway Reform is HIGH) – weight: (1)

III. The Tests Results

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.

The authors decided to use the center of area (COA) method defuzzification and Mamdani fuzzy inference systems.

Probably the best known defuzzification operator is the center of gravity defuzzification (COG) method. It is basic general deffuzification method that computes the center of gravity of the area under the membership function. 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.

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 following figure.

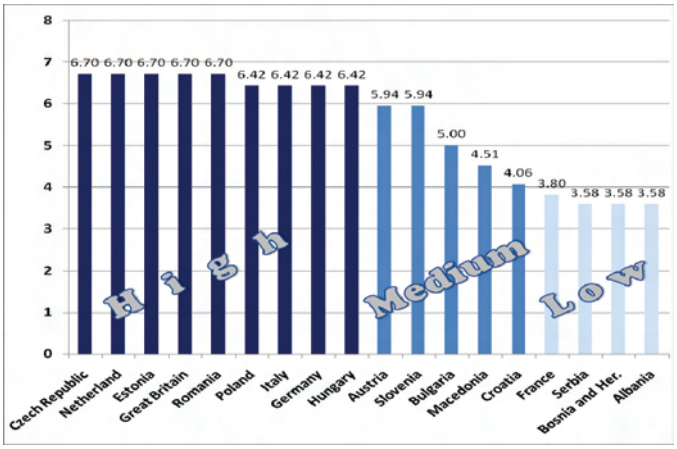

Fig. 6. Railway reforms grade of chosen countries

The results may be an indicator for the competent institutions, especially in countries with "low" reforms, to make appropriate criteria in order to acceleration of reforms. This would lead to improvement of the functioning of European railway system. Development of railway transportation may be difficult if railway system reforms are not on the same level, especially in neighbouring countries (France - German and Italy, Serbia-Macedonia etc.). If you do not establish a balance of railway reform Europe striving for liberalization of the railway market, introduction of competition, modernizing and accelerating the transport, the establishment of a single European railway system and similar, can be a problem.

IV. Conclusion

The railway reform evaluation is a very important process by which a reached level of a reform can be measured. Railway reforms becoming as similar as possible, is of a great importance for the stabilisation of the transport market. The European railway system must not be divided into non-synchronised railway national levels of reforms, because that would not contribute to making a unique European transport market.

Railway reform levels were often evaluated based on experts' beliefs or by using statistical or inadequate methods. Relevant parameters that were used in methods consisted of uncertainty, subjectivity, ambiguity and more than one meaning.

This paper shows a new way of modelling and evaluating the process of restructuring of the national railway systems by using the fuzzy logic. Railway reforms of randomly chosen countries have been evaluated by testing a model. By appropriate modification of rules and variable sums, the railway reform evaluation model can also be used in other fields of industry such as, the evaluation of the market liberalisation in general and its particular elements, then, in law system reforms evaluation, approaching EU countries, harmonisation of EU member countries, in various reform fields.

References

[1] Amos, P.: Reform, Commercialization and Private Sector Participation in Railways in Eastern Europe and Central Asia, TP-4, The World Bank Group, Washington, 2005.

[2] Balistreri, E. J., et al.: Modeling services liberalization: The case of Kenya, Economic Modelling 26, 2009.

[3] Chang, H. H., Huang, W.C.: Application of a quantification SWOT analytical method, Mathematical and Computer Modelling 43, 2006.

[4] Council of the European Union, Council Directive 91/440/EEC on the development Community's railways". Brussels: 29 July 1991.

[5] ECMT: Railway Reform & Charges the Use of Infrastructure, Paris, 2005.

[6] Feraboli, O.: A Dynamic General Equilibrium Analysis of Jordan's Trade Liberalisation, PhD dissertation, Chemnitz University of Technology, Faculty of Economics and Business Administration, Germany, 2006.

[7] IBM Business Consulting Services: 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, October 2007.

[8] Kajanus, M, et al.: The use of value focused thinking and the A'WOT hybrid method in tourism management, Tourism Management 25, 499–506, 2004.

[9] Konan, D. E., Maskus K. E.: Quantifying the impact of services liberalization in a developing country, Journal of Development Economics 81, 2006.

[10] Pietrantonio, L. D., et al.: The Economics of EU Railway Reform, Bruges European Economic Policy Briefings – BEEP briefing n°8, College of Europe, Brugge, 2004.

[11] Ruiz Estrada, M.A.: Trade Liberalization Evaluation Methodology Theoretical Framework, SciTopics pages on Economics, Econometrics and Finance, 2009

[12] SEETO: Rail and Inter-modal Working Group 5th Session, Belgrade, 2007.

[13] SEETO: 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, February 2009.

[14] Teodorović, D., Kikuchi, S.: Fuzzy Sets in Traffic and Transport Systems, Preface, Fuzzy Sets and Systems 116, 2000.