Model for Quality of Life Evaluation of Countries European Union with using Rule-based Systems

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Abstract: This paper deals with the quality of life (QL) evaluation of countries European Union (EU) and progress of this evaluation in years 2007, 2011 and 2015. QL evaluation is based on official Eurostat methodology for QL evaluation - QL indicators for the EU, the data presented here come from several sources from within the European Statistical System (ESS). The set of indicators is organised along the areas: Material living conditions, Productive or main activity, Health, Education, Economic and physical safety, Governance and basic rights and Natural and living environment. QL is evaluated with using rule-based systems method: Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) - modification fuzzy TOPSIS fuzzy inference system (FIS) and Analytic hierarchy process (AHP). The aim of this paper is creating model for QL evaluation with using these methods, comparing results of these methods and their progression. Result of model is final recommendation to reach the grant allocation for the countries or regional development.

1 INTRODUCTION

Defining term QL brings dilemmas and each author or institution has own approach and own solving this problematic. If we occupy ourselves with defining QL term, we have to consider influence of historical, cultural and social changes, which take place in given society.

The definition aptly describes the expert discussions (Royuela et al., 2010), which state that QL: "usually refers to the degree to which a person's life is desirable versus undesirable, often with an emphasis on external components, such as environmental factors and income. In contrast to subjective well-being, which is based on subjective experience, quality of life is often expressed as more objective and describes the circumstances of a person's life rather than his or her reaction to those circumstances."

Among some common traits (Andráško, 2016) which are typical for the issue of the QL research also belongs a fragmentation of definitions, an approach to the evaluation as well as multidisciplinary and multidimensionality. The term QL refers (Rapley, 2003) to human existence, comprehension of meaning of life itself of individual being. QL can be observed through two variables – material and non-material part of human life and includes individual way of life, not only individual living conditions, but also living conditions of wider groups of society as a whole. Model of QL (Rapley, 2003) is in Figure 1.

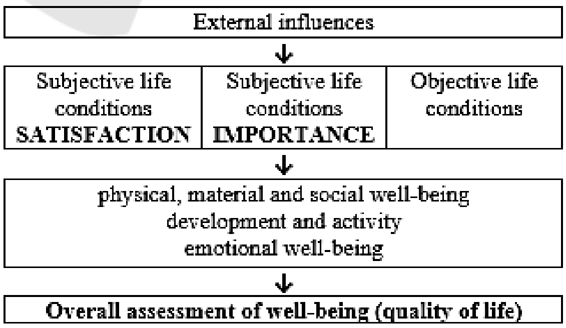

Figure 1: Model of quality of life.

QL should be looked (Curtis et al., 2002; Phillips, 2006) upon as a multidimensional variable, which contains information about psychosocial status of an individual which is influenced by, for example, age, gender, education, social status,

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economical situation or individual's values. QL can be viewed as availability of options, from which an individual can pick during filling his life.

2 QUALITY OF LIFE EVALUATION

The QL evaluation is a difficult thing and exist a lot opinions and approaches. QL is evaluated by the using of indicators. Individual indicators then form a set of indicators or the whole methodology for evaluating the QL. As examples of methodologies (approaches) of QL evaluation we can quote: Active Ageing Index (AAI, 2015); Economist Intelligence Unit Limited (EIU, 2015); Eurofound (EF, 2015); Better Life Index (OECD,2015).

The Eurostat official methodology was selected for the created model. This methodology comprised nine areas for QL evaluation and for evaluation were selected indicators in years 2007, 2011, 2015. These years have been selected due to the availability of data and the trend of evaluation of the individual countries. In this paper and in this model will be evaluated countries, that have become members of the EU in 2004 - Czech Republic, Estonia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Slovenia and Slovakia with compared to the EU-wide average.

The created model will then be applicable to other states or other selections. Unfortunately, only 27 pointers from seven areas were available for evaluation, so this model will work with this number. In the case of availability of data for multiple indicators, the model could be expanded (more indicators and areas). List of indicators is described by Eurostat (2017): area of indicators (area): indicators (unit) - sign.

- Material living conditions (area A): indicator Mean and median income (unit Euro) - K1, At-risk-of-poverty rate (% of total population) - K2, S80/S20 income quintile share ratio (quotient) - K3, Actual individual consumption per capita (Nominal expenditure per inhabitant in Euro) - K4, Severely materially deprived people (% of total population) - K5, (In)ability to make ends meet (% of total population) - K6, Share of total population living in a dwelling with a leaking roof, damp walls, floors or foundation, or rot in window frames of floor (% of total population) - K7, Overcrowding rate (% of total population) - K8, Share of people living in under-occupied dwellings (% of total population) - K9,
- Productive or main activity (area B): Unemployment rate (%) - K10, People living in households with very low work intensity (% of total population aged less than 60) - K11, Average number of usual weekly hours of work in main job by economic activity (hour) - K12, Population in employment working during unsocial hours - nights (%) - K13, Temporary contracts (%) - K14,
- Health (area C): Self-perceived health, good and very good (%) - K15, Self-reported unmet needs for medical examination, too expensive or too far to travel or waiting list (%) - K16,
- Education (area D): Education attainment, tertiary education (% of total population) - K17, Early leavers from education and training (% of the population aged 18-24 with at most lower secondary education and not in further education or training) - K18, Individuals' level of Internet skills (% of Individuals who completed at least 2 of the 6 internet-related activities) - K19, People that participated in education or training in the four preceding weeks (%) - K20,
- Economic and physical safety (area E): Population unable to face unexpected financial expenses (% of total population) - K21, Population in arrears, debt (% of total population) - K22, Crime, violence or vandalism in the area (% of total population) - K23,
- Governance and basic rights (area F): Gender employment gap (difference between the employment rates of men/ women aged 20-64) - K24, Gender pay gap in Industry, construction and services, except public administration, defense, compulsory social security (average gross hourly earnings of male/female paid employees as a % of average gross hourly earnings of male paid employees) - K25,
- Natural and living environment (area G): Pollution, grime or other environmental problems (% of total population) - K26, Noise from neighbours or from the street (% of total population) - K27.

3 MODEL FOR EVALUATION

As described in the previous section, 27 indicators from seven areas of the Eurostat official methodology from 2007, 2011 and 2015 were selected for the QL evaluation.

3.1 Describe of Model

For QL evaluation has proven to be a beneficial use of system engineering methods (for example Šanda and Mandys, 2017; Šanda and Křupka, 2016; Křupka et al., 2010; Kačmárová et al., 2013) among which, among other things, are the methods of multi-criteria decision making, rule-based systems and fuzzy logic.

The combination of these methods was been used to solve problems and creating model. In model were used TOPSIS method (respectively its fuzzy modification) and FIS for solving problem and QL evaluation. Subsequently, the AHP method was used to compare the ranking results between the methods. The model then worked with defined fuzzy sets (FSs) too. The general scheme of the model is in Figure 2.

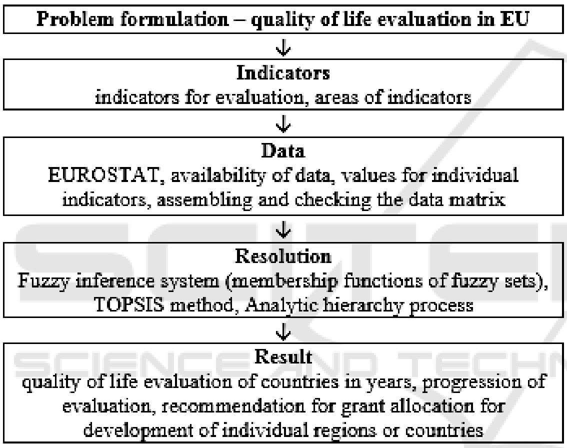

Figure 2: Model for quality of life evaluation.

In the previous text were described the issue of QL assessment, data source and selected indicators. The following will be described methods, which have been used to solve the problem - "core" of the model.

3.2 Fuzzy Sets

Fuzzy logic was also used for the solution - fuzzy sets were defined for QL evaluation. Based on previous work in this field QL were defined 4 fuzzy sets for area evaluation and 5 FS for total QL evaluation - described below. In this article the intervals of FS were specified and there were used FS of trapezoidal shape of MF in the form [a b c d] Mathworks (2017), where parameters 'a' and 'd' locate the 'feet' of the trapezoid and the parameters 'b' and 'c' locate the 'shoulders'.

Defined FS and their linguistic variables for areas evaluation: very bad [0 0 0.4 0.45], bad [0.4 0.45 0.6 0.65], good [0.6 0.65 0.8 0.85], very good [0.8 0.85 1 1.2]. A graphical image of the defined FS is in the Figure 3.

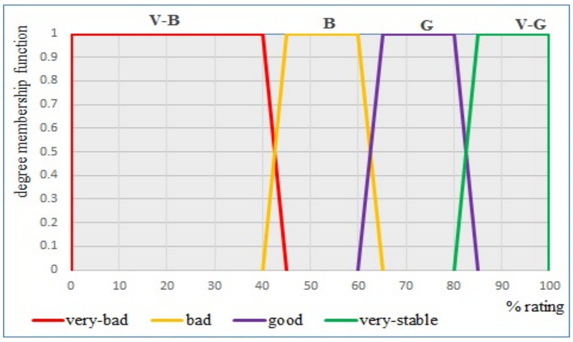

Figure 3: Fuzzy sets for areas evaluation.

Defined FS and their linguistic variables for total evaluation: very bad [0 0 0.4 0.45], bad [0.4 0.45 0.6 0.65], good [0.6 0.65 0.75 0.8], very good [0.75 0.8 0.9 0.95] and perfect [0.9 0.95 1 1]. A graphical image of the defined FS is in the Figure 4.

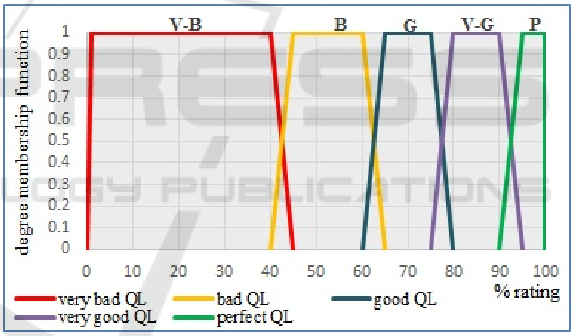

Figure 4: Fuzzy sets for total evaluation.

3.3 Using Methods in Model

The model worked with methods TOPSIS and its fuzzy modification, FIS and AHP.

TOPSIS method is according to Senouci et al. (2016), Chen and Hwang (1992) one of the multi-criterial decision algorithm, which is based on the option selection. It is assumed that the maximization character of all criteria (if all criteria are not maximization, it is necessary to transform them). TOPSIS ranks the subjects according to the score, when the highest is the best resolution.

The basic rule is that, the preferred alternative should have the shortest distance from the ideal resolution and the longest distance from the negative – the worst resolution. In the created model was used the extension of TOPSIS - fuzzy TOPSIS,

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where defined fuzzy sets were used. Weights of indicators were solved with share (1/27).

General structure of FIS is used for the resolution according to Zadeh (2015); Hu et al. (2017); Yang et al. (2017); Bělohlávek et al. (2002) and Kang et al. (2017). Before its own QL evaluation with FIS usage, it is necessary to resolve: normalized matrix, define the rules and fuzzy sets for the QL evaluation, Mamdani type of FIS was used. Based on experimental FIS settings (Šanda and Křupka, 2017), it was the optimal solving trapezoidal shape of membership function (MF) and method Centre of Gravity used in defuzzification. The number of rules depends on the number of criteria in the individual area (for area B is 5) and the number of defined FSs (for areas 4), for area B it is 45, a total 1024 rules.

Examples of rules of area B:

- Rule$_{54}$: If (K10 is very-bad) and (K11 is very-bad) and (K12 is bad) and (K13 is very-good) and (K14 is bad) then (QL-area-B is bad)
- Rule$_{907}$: If (K10 is very-good) and (K11 is good) and (K12 is very-bad) and (K13 is good) and (K14 is good) then (QL-area-B is good).

Inputs to FIS-area are indicators (chapter 2), output is QL evaluation of area; inputs to FIS-TOTAL are outputs form FIS of areas, output is total QL evaluation - see in Figures 5 and 6.

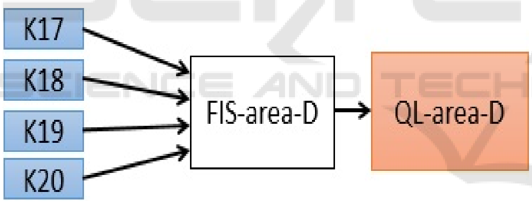

Figure 5: Hierarchy structure of FIS for QL-area-D.

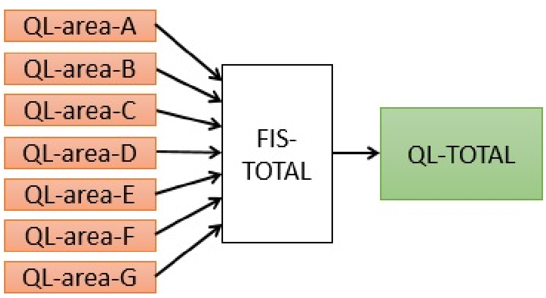

Figure 6: Hierarchy structure of FIS QL-total evaluation.

AHP is (Dweiri, 2016) a multi-criteria decision making method. It is developed by Saaty to assist in solving complex decision problems by capturing both subjective and objective evaluation measures.

AHP uses a pair-wise comparison of the criteria importance with respect to the goal. This pair wise comparison allows finding the relative weight of the criteria with respect to the main goal. If quantitative data is available, the comparisons can be easily performed based on a defined scale or ratio and this cause the inconsistency of the judgment will be equal to zero which leads to perfect judgment. If quantitative data is not available, a qualitative judgment can be used for a pair wise comparison. This qualitative pair wise comparison follows the importance scale suggested by Saaty. The same process of pair-wise comparison is used to find the relative importance of the alternatives with respect to each of the criteria. Each child has a local (immediate) and global priority (weight) with respect to the parent. The sum of priorities for all the children of the parents must equal 1. The global priority shows the alternatives relative importance with respect to the main goal of the model. The pair-wise comparison is performed in matrix format to check the consistency of the judgment.

It breaks a complex problem into hierarchy or levels as shown in Fig. 7.

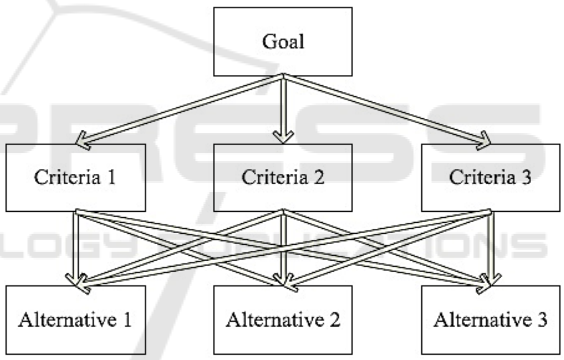

Figure 7: Example AHP structure.

3.4 Extension of Model

One of the aims of this article is the recommendation for the grant allocation or a grant for regional development (e.g. for the region with long-lasting bad results) and per cent value of the grant for the selected region. This recommendation is based on the EIU (2015), which is in the Table 1. In this article this approach is modified namely percentage (per cent amount) of from the "development" operational program (which would be specially created). It is then possible to specifically define the area for the grant allocation from the partial results of the QL evaluation of the single areas.

Table 1: Suggestion for allowance.

QL evaluation rating (%)	Suggested allowance (%)
80 - 100	0
70 - 80	5
60 - 70	10
50 - 60	15
50 or less	20

4 RESULTS

In the following tables 2 and 3 are the QL evaluation results of using fuzzy TOPSIS and FIS.

Table 2: Results of fuzzy TOPSIS method.

Country	2007	2011	2015
EU	73.86%	60.56%	75.10%
Czech Republic	61.18%	61.86%	63.15%
Estonia	53.50%	59.20%	46.42%
Cyprus	67.83%	64.99%	65.67%
Latvia	59.88%	49.77%	62.21%
Lithuania	50.81%	52.96%	52.10%
Hungary	63.32%	55.58%	71.03%
Malta	50.93%	66.28%	53.26%
Poland	70.81%	59.20%	60.49%
Slovenia	57.34%	66.50%	62.56%
Slovakia	56.20%	60.56%	55.61%

The results show that, on the basis of selected indicators, in the selected years, the Baltic States are the worst, further partial unstable values are reported in values Hungary and Poland. The Czech Republic, Cyprus, Malta, Slovenia and Slovakia show a positive trend relative to the EU average. The island states, Slovenia and the Visegrad group can then be labelled as states whose results are above the EU average after accession. On the other hand, the countries of the Baltic States have lagged behind the EU average. The result can be explained by the fact that it is the republics from Soviet Union.

Table 3: Results of FIS.

Country	2007	2011	2015
EU	52.50%	70.00%	74.61%
Czech Republic	58.34%	52.50%	76.38%
Estonia	52.50%	52.65%	70.00%
Cyprus	52.50%	70.00%	70.00%
Latvia	21.03%	52.50%	52.50%
Lithuania	52.50%	52.50%	52.50%
Hungary	52.50%	53.53%	52.50%
Malta	66.57%	70.00%	70.00%
Poland	52.50%	52.65%	52.50%
Slovenia	70.00%	76.24%	76.24%
Slovakia	52.50%	70.00%	76.24%

Differences between the fuzzy TOPSIS and FIS were as follows - 2007: average 12,92% and median 12,66%; 2011: 5,91% and 6,55%; 2015: 11,75% and 13,22%.

The results of these methods were then compared with the results of the AHP. The comparison showed that the biggest differences were in all the Baltic countries, partly in Hungary and Slovakia, rarely in Malta and Slovenia. In general, it can be said from the results that the larger differences were between the FIS and AHP methods. Table 4 shows an example of differences in ranking in 2011 (fT is fuzzy TOPSIS).

Table 4: Comparison ranking between methods.

Country	fT/AHP	FIS/AHP	fT/FIS
EU	1	2	3
Czech Republic	1	0	1
Estonia	1	1	2
Cyprus	2	1	1
Latvia	1	5	6
Lithuania	2	3	5
Hungary	2	7	5
Malta	0	0	0
Poland	2	4	2
Slovenia	2	2	0
Slovakia	2	3	3

5 CONCLUSIONS

On the basis of the results of the individual methods, it is possible to compile tables with recommendation for grant allocation, which should be directed to the development of states or region. Tables 5, 6 and 7 are recommendations for individual years, the "Average" column indicates the average recommendation for grant allocation.

Table 5: Recommendation for the grant allocation 2007.

Country	fTOPSIS	FIS	Average
Czech Republic	10.00%	15.00%	12.50%
Estonia	15.00%	15.00%	15.00%
Cyprus	10.00%	15.00%	12.50%
Latvia	15.00%	20.00%	17.50%
Lithuania	15.00%	15.00%	15.00%
Hungary	10.00%	15.00%	12.50%
Malta	15.00%	10.00%	12.50%
Poland	5.00%	15.00%	10.00%
Slovenia	15.00%	5.00%	10.00%
Slovakia	15.00%	15.00%	15.00%

Table 6: Recommendation for the grant allocation 2011.

Country	fTOPSIS	FIS	Average
Czech Republic	10.00%	15.00%	12.50%
Estonia	15.00%	15.00%	15.00%
Cyprus	10.00%	5.00%	7.50%
Latvia	20.00%	15.00%	17.50%
Lithuania	15.00%	15.00%	15.00%
Hungary	15.00%	15.00%	15.00%
Malta	10.00%	5.00%	7.50%
Poland	15.00%	15.00%	15.00%
Slovenia	10.00%	5.00%	7.50%
Slovakia	10.00%	5.00%	7.50%

From these two tables, it is clear that the highest recommendation is for Baltic States. Higher is recommendation partly in the Visegrad group.

On the contrary, Table 7 shows that the years are gradually improving and the trend is positive, so the overall recommendation is less range.

Table 7: Recommendation for the grant allocation 2015.

Country	fTOPSIS	FIS	Average
Czech Republic	10.00%	5.00%	7.50%
Estonia	20.00%	5.00%	12.50%
Cyprus	10.00%	5.00%	7.50%
Latvia	10.00%	15.00%	12.50%
Lithuania	15.00%	15.00%	15.00%
Hungary	5.00%	15.00%	10.00%
Malta	15.00%	5.00%	10.00%
Poland	10.00%	15.00%	12.50%
Slovenia	10.00%	5.00%	7.50%
Slovakia	15.00%	5.00%	10.00%

The total results based on Tables 5, 6 and 7 are then as follows: Latvia (recommendation for the grant allocation is 15,83%), Lithuania (15%), Estonia (14,17%), Hungary and Poland (12,5%), Czech Republic and Slovakia (10,83%), Malta (10%), Cyprus (9,17%) and Slovenia (8,33%). These results again confirm the "lagging" of the Baltic states, the good results of the island states and the attractions are also the same result Czech Republic and Slovakia (Czechoslovakia before year 1993).

If we take a closer look at the three groups - "Island states" (Cyprus and Malta), the Visegrad group (Czech Republic, Hungary, Poland and Slovakia) and the Baltic States (Estonia, Lithuania and Latvia), the recommendation for the Baltic States is 15%, Visegrad group 11.7% and "Island states" 9.6%. This grant recommendation for the Baltic States that is one of the important conclusions.

Recommendations for further work and development of the model include the use of multiple methods of system engineering, their synthesis and analysis; using more criteria; the inclusion of indicators for weights and areas; availability of data (current disadvantage).

The created model for QL evaluation can then be adjusted according to the number of available criteria, supplemented by more (available) years and applied to other states or groups of countries. The model for QL evaluation can be used, for example, for evaluating regions (NUTS2 or NUTS3) or the like. The topic for further work is also to deal in more detail with the recommendation for grant allocation, the grant source, etc.

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