Analysis of Standard of Living Models based on Multiple Criteria Decision Analysis

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Abstract—The aim of this article is to design our own ranking and analysis of standard of living in selected countries (17 Eurozone countries) and to compare calculated ranks of countries with ranking acquired in selected indexes. After the selection of appropriate approaches and indexes of standard of living (Czech Economic Journal E15 Index and Prosperity Index), the modeling of ranking is provided. Modeling of countries ranking is designed by means of multiple criteria decision analysis with using analytic hierarchy process. In conclusion, the obtained results are based on the comparison of different approaches to modeling of standard of living rankings.

Keywords—Analytical hierarchy process, E15 index, Legatum prosperity index, MCDA, standard of living ranking.

I. INTRODUCTION

THE economists, sociologists and politicians presently compound the fact that prosperity and success of economies is not possible to measure with only one indicator – with Gross Domestic Product (GDP) growth. However, without the GDP growth, it is impossible to achieve nation's progress. But better results in economic indicators should be reflected in more accessible health care, higher standard of education, cleaner environment and ability to help persons who are at risk of poverty and social exclusion. GDP growth is not a sole possibility of measuring standard of living and prosperity. We should place equal importance to evaluating the effort the countries put into reaching personal wealth, and impacts of growth on the quality of personal life. Successful nation's effort balanced growth, in which it is not supported only by reaching higher level of incomes, but where the space for personal and social development exists. They also pay attention to relationship between economic growth and quality of environment.

It is not simple to find out the consensus in how these aspects of personal and social life should be evaluated, how to measure the standard of living (SL) and the changes that influence various fields of life besides the economical.

In principle, various composite indexes that are constructed by more or less prestigious institutions, are used for the assessment.

In the article the attention is paid to two selected measures of standard of living – E15 Index and Legatum Prosperity Index. The emphasis is on comparison of ranks and order of the 17 Eurozone member countries based on these indexes, with our modeling ranking on the 2009 data.

SL should be expressed by the system of quantitative and qualitative indicators [1], mostly aggregated into the composite indexes based on subjective SL and quality of life evaluation, as well as objective indicators characterized by socio-economical, ecological and political conditions.

Among the most frequently used indicators for expressing SL are: Index of Sustainable Economic Welfare [2], Human Development Index [3], life fulfillment indicators - Quality of Life Index [4], Better Life Index [5], Legatum Prosperity Index [6], Happiness Indicators [7], Ecological Footprint [8], etc.

The indicators are based on the very similar components (ecological, economic, and social), which are developed for estimating sustainable development of a country, region and an enterprise e.g. Sustainable Society Index [9].

The quality of life and SL measurement is provided by number of researches and institutions, namely e.g. United Nations [3], with its Human Development Index created in 1990, OECD [5], with quite new Better Life Index, Legatum Institute and its Prosperity index [6], Mercer Human Resource Consulting with Mercer's quality of Living Survey Liveability [10], [11] and the Economist Intelligence Unit's Global Liveability Report [12], by economics journals [13] and individual countries as indicator Gross National Happiness [7], which is presented by Bhutan state.

The objectives of the paper are:
- Selecting the appropriate approaches and indexes for the SL assessment, that are composed of various indicators and measures
- Designing the models for SL ranking evaluation in Eurozone countries, using a multiple criteria decision analysis (MCDA) method
- Comparing our own modeling ranking of SL in Eurozone countries with real results obtained in two selected approaches generated by E15 Czech journal

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II. STANDARDS OF LIVING MODELS AND INDICATORS

Among the indexes mentioned above, two indexes for 2009 have been chosen – one produced by Czech economic journal E15 and a very comprehensive Prosperity Index provided by Legatum Institute since 2007 year.

We have chosen this explicit year because of comparability of both indexes (E15 index is not produces every year) and for obtaining the relevant data for individual countries from open sources [14]. For completeness' sake it is necessary to mention that in spite of Estonia joining Eurozone as late as 2011, it was included in our analyses (we are aware of this inaccuracy, but the overall results of modeling are not changed).

A. E15 Standard of living index

Czech economic journal E15 calculated index of standard of living on the sample of all 27 European Union member countries in 2009 year. The authors ranked the countries according to the following economic indicators: GDPs per capita (in purchasing power parity (PPP) in USD), average salary in country (in PPP in EUR), rate of unemployment (in percentage), level of taxation as a percentage of GDP (so called tax quota), the length of working week (number of working hours per week under condition of the full time job). Among socio-demographic indicators are these indicators - life expectancy (in years), the level of expenditures on food (as a portion of total household expenditures, in percentages), people at risk of poverty or social exclusion (as a percentage of total population, so called poverty rate), index of corruption expressed by Corruption perception index (adopted from research provided each year by international organization Transparency International [15] and number of female managers (in percentages). Number of women in managerial positions expresses the approach of society to both genders in given country.

Values of individual economic **x** and socio-demographic **y** indicators and their ranks for selected 17 Eurozone countries are illustrated in Table I and Table II. Vectors **x** and **y** are defined by the following way:

$$\mathbf{x} = \{x_1, x_2, x_3, x_4, x_5\} \text{ and } \mathbf{y} = \{y_1, y_2, y_3, y_4, y_5\}, \qquad (1)$$

where x_1 is GDP per capita, x_2 is Rate of unemployment, x_3 is Average salary, x_4 is Tax quota, x_5 is Number of working hours, y_1 is Life expectancy, y_2 is Index of corruption, y_3 is People at risk of poverty, y_4 is Expenditures on food and y_5 is Number of female managers.

Based on the economic indicators (GDP per capita and unemployment rate), the highest ranked were Luxembourg, Netherlands and Austria. The top of the table based on GDP per capita was Luxembourg (79 400 USD), the second highest level was reached by Ireland (46 600 USD) while simultaneously having had disproportionately high rate of unemployment. The lowest GDP per capita rating was reached by Slovakia (20 200 USD), which also had the highest rate of

unemployment in the beginning of the year 2009. Values of unemployment rates in European countries have worsen since 2009 due to the economic crisis, but their ranking remains unchanged.

Table I Economic indicators E15

Overall country rank	Economic indicator				
	x_1	x_2	x_3	x_4	x_5
Luxembourg	79 400 (1)	4.2 (6)	27 395 (1)	36.40 (12)	40.0 (11)
Netherlands	39 000 (4)	2.9 (2(	15 814 (12)	40.40 (19)	38.9 (1)
Ireland	46 600 (2)	6.0 (16)	22 207 (2)	34.00 (8)	39.2 (4)
France	32 600 (12)	7.4 (21)	18 873 (6)	46.10 (24)	39.1 (3)
Austria	39 300 (3)	4.1 (4)	18 960 (5)	43.40 (22)	42.4 (27)
Belgium	36 200 (7)	5.7 (14)	17 143 (9)	46.80 (15)	39.0 (2)
Finland	36 000 (8)	6.1 (18)	16 882 (10)	43.60 (23)	39.2 (5)
Germany	34 100 (10)	7.4 (20)	18 055 (7)	40.60 (20)	40.3 (13)
Slovenia	28 000 (15)	4.3 (7)	8 851 (17)	39.30 (18)	41.4 (24)
Italy	30 900 (13)	6.5 (19)	16 617 (11)	42.60 (21)	39.3 (6)
Cyprus	27 100 (16)	3.5 (3)	12 344 (14)	36.60 (23)	39.9 (9)
Spain	33 600 (11)	9.9 (26)	13 431 (13)	37.30 (15)	40.9 (17)
Estonia	21 800 (19)	4.1 (5)	5 611 (20)	31.10 (5)	41.0 (19)
Malta	23 400 (18)	5.8 (15)	8 308 (18)	35.20 (10)	40.4 (14)
Greece	30 600 (14)	7.8 (25)	12 203 (15)	33.50 (6)	40.7 (16)
Slovakia	20 200 (22)	10.5 (27)	4 889 (24)	29.50 (2)	40.9 (18)
Portugal	21 800 (19)	7.5 (23)	9 674 (16)	33,80 (7)	41.2 (20)

Comment: The number in the bracket () represents country's position in particular indicator for selected 17 Eurozone countries

The level of the average salary expressed in purchasing power parity is highest in Luxembourg (27 395 EUR), in Ireland (22 207 EUR) and Austria (18 960 EUR), the lowest average salary is in Slovakia (4 889 EUR). The share of taxes on the GDP (tax quota) is relatively low in Slovakia, Estonia, Greece, Portugal and Ireland, on the other end of the scale, it is high in France, Finland, Cyprus.

Concerning the number of working hours, the employees in Europe work much less than in other developed countries. Working hours in most countries of the European Union is limited by law to 40 hours a week, in some countries it is considerably less (France 35 hours, Belgium 38 hours).The Dutch and the Belgians spend the least time at work, while the most being spend by Slovenians.

It is generally accepted that people in most economically prosperous countries live the longest. The data provided in the Table II show us that the highest life expectancy is in France (80.87 years), followed by the South European countries of

Italy (80.07 years), Spain (79.92 years) and Greece (79.52 years). On the other hand, the lowest life expectancy is in Estonia (72.56 years), Slovakia (75.17 years) and in Slovenia (76.73 years) which are countries from Central Europe and Eastern Europe that joined the EU in the year 2004.The lower life expectancy in these countries, having been ruled by communist regimes in the past, reflects a lower standard of living and lower standard of health care compared with other Eurozone countries. Inhabitants of South European countries have the highest life expectancy; ironically, these countries recorded the worst impact of economic crises.

Table II Socio-demographic indicators E15

Overall country rank	Socio-demographic indicator				
	y_1	y_2	y_3	y_4	y_5
Luxembourg	79.18 (9)	8.3 (5)	14 (11)	10.0 (3)	26.3 (20)
Netherlands	79.25 (8)	8.9 (4)	10 (1)	11.5 (6)	25.6 (22)
Ireland	78.07 (16)	7.7 (8)	18 (17)	7.0 (1)	30.2 (15)
France	80.87 (1)	7.1 (11)	13 (7)	15.0 (11)	37.1 (4)
Austria	79.36 (6)	8.1 (6)	13 (7)	11.0 (4)	27.0 (18)
Belgium	79.07 (11)	7.3 (10)	15 (14)	14.0 (10)	32.9 (8)
Finland	78.82 (13)	9.0 (3)	13 (7)	13.0 (9)	29.7 (17)
Germany	79.10 (10)	7.9 (7)	13 (7)	12.0 (7)	26.4 (19)
Slovenia	76.73 (18)	6.7 (12)	12 (3)	16.0 (15)	32.8 (9)
Italy	80.07 (3)	4.8 (21)	20 (21)	15.5 (13)	31.9 (12)
Cyprus	78.15 (14)	6.4 (15)	16 (15)	16.5 (16)	13.6 (27)
Spain	79.92 (4)	6.5 (14)	20 (21)	15.0 (12)	32.3 (11)
Estonia	72.56 (25)	6.6 (13)	18 (17)	18.5 (21)	37.5 (3)
Malta	79.30 (7)	5.8 (17)	14 (11)	17.0 (18)	14.5 (26)
Greece	79.52 (5)	4.7 (22)	21 (26)	16.0 (14)	25.8 (21)
Slovakia	75.17 (21)	5.0 (20)	12 (3)	19.0 (23)	31.2 (13)
Portugal	78.04 (17)	4.6 (23)	19 (20)	19.0 (23)	32.5 (10)

Comment: The number in the bracket () represents country's position in particular indicator for selected 17 Eurozone countries

For a person to be considered 'poor' by EU standards, that person has to have a net income (after deducting taxes and adding all social benefits and allowances) lower than 60% of median. At risk-of-poverty threshold depends especially on the value of median in each country, the absolute at risk-of-poverty threshold being set the highest in rich countries. For example, in Luxembourg a person with annual income less than 17 808 EUR is considered poor, whilst in Czech Republic a person with annual income of 2 878 EUR is at risk of poverty. It is reflected in the indicator of number of people bellow the risk-of-poverty threshold.

The expenditures on food represent one of the biggest items in most households. The indicator of the amount of average salary spent on food expresses the amount of salary households spend on their hobbies and interests. In "old" European countries the expenditures on food are lower than in Central and Eastern European countries. Despite the fact that prices of basic food are lower in these countries than in Western European countries, the level of salaries is more than three times lower. The highest value of this indicator is reached by Slovakia and Portugal (19%), and Estonia (18,5%). The lowest amount of average salary spent on food is in Ireland (7%) and Luxembourg (10%).

The indicator of female managers illustrates how successful is the policy of equal opportunities. Regardless of the European effort, serious differences still exist between women and men in participation on the labor market, employment, salaries and professional career. Indicator is highest in Estonia (37.5%), in France (37.1%), the lowest number of women at managerial positions is in Cyprus (13.6%) and Malta (14.5%).

The level of corruption belongs among the qualitative indicators that influence the overall satisfaction and quality of life. The index of perception of corruption is traditionally low in Scandinavian countries (in Eurozone countries in Finland), Netherlands and Luxembourg. The index is highest in Portugal, Greece and Italy (see Table II).

The overall standard of living index was created as an average mean of country's individual place in each particular indicator.

B. Legatum prosperity index

Legatum prosperity index (LPI) was created for the first time in the year 2007. In 2009 LPI ranked 104 nations (unfortunately in this year some Eurozone countries were missing – as Cyprus, Luxembourg and Malta. These countries were included into the ranking in 2012 year). LPI is based on nine blocks of prosperity [6], [16]:

- Economic Fundamentals – a growing, sound economy that provides opportunities for wealth creation
- Entrepreneurship and Innovation – an environment friendly to new enterprises and the commercialization of new ideas
- Democratic Institutions – transparent and accountable governing institutions that promote economic growth
- Education – an accessible, high-quality educational system that fosters human development
- Health – the physical wellbeing of the population,
- Safety and Security – a safe environment, in which people can pursue opportunity
- Governance – an honest and effective government that preserves order and encourages productive citizenship
- Personal Freedom – the degree, to which individuals can choose the course of their lives
- Social Capital – trustworthiness in relationships and strong communities

Each building block corresponds to a sub-index e.g. it is

evaluated separately so that country's scores and rankings are available for each block. A country's position in the overall LPI is produced by equally weighting and averaging its nine sub-index scores. The scores are then ranked to produce the overall ranking. Four of the sub-indexes in the LPI are created by correlating variables with per capita GDP, and five are created by correlating variables with subjective wellbeing, or happiness. Together, they give a comprehensive view of how well a nation is doing.

A vector $\mathbf{z}$ of LPI indicators is defined by the following way:

$$\mathbf{z} = \{z_1, z_2, \cdots, z_9\}, \tag{2}$$

where z_1 is Economic fundamentals, z_2 is Entrepreneurship and innovation, z_3 is Democratic institutions, z_4 is Education, z_5 is Health, z_6 is Safety and security, z_7 is Governance, z_8 is Personal freedom and z_9 is Social capital (Table III) [16].

Table III Indicators of LPI in 2009 (Part 1)

Overall country rank	Value and country score in sub-index measures				
	z_1	z_2	z_3	z_4	z_5
Finland	0.81802 (10)	0.85899 (9)	0.92568 (9)	0.96091 (3)	0.97556 (7)
Netherlands	0.88810 (3)	0.90434 (5)	0.89339 (19)	0.85927 (14)	0.98361 (8)
Ireland	0.86506 (5)	0.84504 (12)	0.91805 (13)	0.83639 (18)	0.99962 (2)
Belgium	0.87300 (4)	0.75165 (20)	0.96491 (3)	0.87465 (11)	0.98361 (5)
Germany	0.74027 (23)	0.87590 (8)	0.88466 (21)	0.82649 (19)	0.98144 (6)
Austria	0.79659 (12)	0.75815 (19)	0.92411 (10)	0.86447 (13)	1.00000 (1)
France	0.77567 (17)	0.82570 (14)	0.90350 (14)	0.84725 (15)	0.93701 (14)
Spain	0.79725 (11)	0.70356 (25)	0.90101 (15)	0.87093 (12)	0.93044 (17)
Slovenia	0.66564 (31)	0.58133 (36)	0.89638 (16)	0.88216 (8)	0.88391 (24)
Italy	0.71011 (25)	0.70095 (26)	0.87718 (23)	0.84105 (17)	0.95817 (11)
Portugal	0.67982 (28)	0.63746 (31)	0.87876 (22)	0.77546 (29)	0.91390 (20)
Greece	0.58569 (42)	0.53547 (43)	0.72717 (40)	0.91458 (5)	0.93713 (13)
Estonia	0.66939 (30)	0.73279 (24)	0.79861 (34)	0.74110 (35)	0.77988 (35)
Slovakia	0.63975 (35)	0.63773 (30)	0.89412 (18)	0.72532 (36)	0.77430 (36)

Comment 1: The number in the bracket () represents country's position in particular indicator for selected 17 Eurozone countries.
Comment 2: The values are not available for Cyprus, Luxembourg and Malta.

Eurozone countries generally placed no lower than 30st place, only some of them being placed in a worse position (grey cells in Table III). Those were mainly sub-indexes connected with subjective wellbeing and happiness. South European countries and East European countries achieved worse scores in Economic fundamentals and Entrepreneurship and Innovation (E&I) sub-index [16]-[18].

Four Eurozone countries are in the top 10 in sub-index

Economic fundamentals: Netherlands, Belgium, Ireland and Finland. Spain surprisingly lies in 11th position, whilst Germany is in 23rd position. Countries breaking into the top 30 are Slovenia, Slovakia and Greece (grey cells). Economic Fundamentals sub-index correlates most closely with the Entrepreneurship and Innovation (E&I) sub-index, suggesting that the two are mutually reinforcing catalysts for national prosperity.

Table III Indicators of LPI in 2009 (Part 2)

Overall country rank	Value and country score in sub-index measures			
	z_6	z_7	z_8	z_9
Finland	0.96293 (2)	0.96558 (2)	0.95832 (7)	0.87297 (6)
Netherlands	0.83895 (15)	0.91151 (8)	0.94005 (10)	0.82586 (8)
Ireland	0.92825 (5)	0.89074 (12)	0.81280 (25)	0.77969 (12)
Belgium	0.83263 (16)	0.82767 (15)	0.94531 (9)	0.54288 (26)
Germany	0.76676 (21)	0.81695 (17)	0.87661 (17)	0.67924 (19)
Austria	0.88328 (10)	0.87186 (14)	0.72463 (36)	0.59392 (23)
France	0.74929 (23)	0.78959 (18)	0.89212 (15)	0.41547 (48)
Spain	0.71269 (28)	0.74344 (21)	0.92562 (13)	0.29396 (71)
Slovenia	0.89025 (8)	0.69884 (24)	0.72972 (33)	0.42357 (44)
Italy	0.69794 (31)	0.60738 (35)	0.70241 (40)	0.46351 (37)
Portugal	0.83081 (17)	0.69061 (25)	0.78386 (26)	0.32602 (64)
Greece	0.68181 (32)	0.65249 (30)	0.55553 (65)	0.40291 (51)
Estonia	0.67933 (33)	0.75377 (19)	0.69484 (43)	0.09961 (94)
Slovakia	0.67803 (34)	0.61736 (33)	0.50619 (69)	0.30264 (69)

Comment 1: The number in the bracket () represents country's position in particular indicator for selected 17 Eurozone countries.
Comment 2: The values are not available for Cyprus, Luxembourg and Malta.

A key part of a country's capacity for entrepreneurship is its ability to commercialize new ideas and create markets for innovative products. The E&I sub-index therefore assesses the nations in the Prosperity Index by variables such as business start-ups, technological capacity, royalties on inventions, and other key measures of entrepreneurial activity. Netherlands and Finland are European countries owing to environments favorable to new enterprises. Germany takes 8th position, despite being eclipsed from the top 10 in the Economic Fundamentals sub-index. The lowest spots are occupied by South European countries (Portugal and Greece) and Slovenia.

The Democratic institutions sub-index is one of two sub-indexes that take account of how governance affects prosperity. The Democratic Institutions sub-index relates governance measures to economic performance. The Governance sub-index relates governance measures to life satisfaction. Measures of democratic governance indicate

whether or not a nation is fostering institutions that are conducive to the expansion of political and economic liberty, both of which are important to success over time. Belgium, Finland and Austria dominate the top tier rankings in this sub-index. Estonia and Greece rank in the 34th and 40th places, respectively.

Nations with poor governance and low levels of innovation and entrepreneurship also generally perform poorly on education. Greece's and Slovenia's performance in education is significantly better than their performance in Economic Fundamentals, Entrepreneurship and Innovation, and Democratic Institutions. As might be expected, Finland reaches the top on education.

Empirical evidence shows that health affects other aspects of prosperity. The Health sub-index is most highly correlated with overall life satisfaction and also has a strong relationship with the Education, Entrepreneurship and Innovation, and Economic Fundamentals sub-indexes, demonstrating that a healthy population is also one that is educated and part of a strong, flourishing economy. The top leader in Health is Austria, followed by Ireland and Belgium. Below the first 30 countries are Estonia and Slovakia.

Safety and security sub-index combines objective measures of security with subjective survey responses to questions about personal safety. The top in this sub-index reaches Finland and Netherlands. On the bottom of the sub-index are Italy, Greece, Estonia and Slovakia.

Governance sub-index combines three objective governance variables with a variety of subjective responses to survey questions. The result is a good picture of how the rule of law, the effectiveness of governments, corruption, political participation, and other key factors contribute to the wellbeing of a country's citizens. Nations that perform well in the Democratic Institutions sub-index do not necessarily score well in the Governance sub-index, and vice versa. For instance, Netherlands scores eighth on the former and 19th on the latter, Slovenia 24th of the former and 36th of the latter, Estonia scores 19th of the former and 34th of the latter, while Belgium scores 15th on the former and third on the latter, Slovakia scores 33rd on the former and 18th on the latter.

Countries that rank higher in the Personal freedom sub-index are ones in which citizens are able to choose the course of their lives, practice their religion, move about, and express their thoughts in the media with both limited interference and protection from the government. Of these top countries, 3 also rank in the top 10 in the overall LPI, demonstrating that high levels of personal freedom are important for prosperity.

The diversity in ranking of Eurozone countries in Social capital sub-index demonstrated that social capital is a social good that is valued and can be created in a variety of societies, regardless of a country's stage of development. Two countries out of the top 10 countries in this sub-index also rank the top for the overall Index. This shows that social capital is a strong driver for prosperity.

The world's most prosperous countries are successful because they have strong and broad foundations and are generally doing well across all nine areas of prosperity with very little variation between each area.

III.   MULTIPLE CRITERIA DECISION ANALYSIS

A ranking evaluation of objects of interest by "various indices" is possible on the basis of MCDA.

The traditional MCDA process P, is determined by the set of decision alternatives A and the set of criteria C according to which the desirability of an alternative is to be evaluated where:

$$A = \{a_1, a_2, \ldots, a_n\} \text{ and } C = \{c_1, c_2, \ldots, c_m\}. \qquad (3)$$

It can be expressed in a real matrix $\mathbf{R}$. Process P can be expressed by the following way [16]:

$$P = \{A, C, \mathbf{R}(n \times m)\}, \qquad (4)$$

where a matrix element r_{ij} of $\mathbf{R}$ indicates the performance rating of the i-th alternative a_i with respect to the j-th criterion c_j.

The MCDA problem can be solved by means of analytic hierarchy process (AHP). The AHP method points to an effective decision under difficult situation. It is the method of analyzing difficult unstructured situation that separates the hierarchical problem into several different groups of simpler elements (also called levels, clusters, stratums) thus creating so called hierarchy structure. Hierarchy is a particular type of system, which is based on the assumption that the entities, which we have identified, can be grouped into disjointed sets, with the entities of one group influencing the entities of only one other group and being influenced by the entities of only one other group [19]-[21]. The AHP [14], [22], [23] is possible to apply to the easiest type (3-level) of hierarchy structure of MCDA. We aim to find their weights of influence: the vector $\mathbf{w}$ represents "importance" of criteria and the matrix $\mathbf{V}$ expresses "importance" of alternatives for each criterion by the following way:

$$\begin{aligned} \mathbf{w} &= [w_1, w_2, \ldots, w_m], \\ \mathbf{V} &= [v_{11}, v_{12}, \ldots, v_{1n}; v_{21}, v_{21}, \ldots, v_{2n}; \ldots; v_{m1}, v_{m2}, \ldots, v_{mn}]. \end{aligned} \qquad (5)$$

Basic problems of the method are [20], [22], [23] subjective evaluation of the pair wise comparison of the criteria and determine an output vector, it means evaluation $\mathbf{E}$ alternatives.

Subjective evaluation of the pair wise comparison of the criteria, assigns a numerical value to individual components. It expresses relative importance of the individual criteria by weights w_j and v_{ij}, where $i = 1, 2, \ldots, m$ and $j = 1, 2, \ldots, n$. It determines the output vector of alternative a_i with the highest priority on the basis of the multiplication i-row of the matrix $\mathbf{V}$ and the transposed vector $\mathbf{w}$. It means:

$$\mathbf{E} = [e_1, e_2, \ldots, e_j] = [v_{1j}, v_{2j}, \ldots, v_{mj}] \cdot [w_1, w_2, \ldots, w_m]^T . \quad (6)$$

IV. PROBLEM SOLUTION

For creating a rank of order based on the real data MCDA method was used, whereas to individual indicators weights of importance were assigned [24].

A set of alternatives $A = \{a_1, a_2, \ldots, a_{17}\}$ represents seventeenth Euro zone countries and was defined by the following way: a_1 is Austria, a_2 is Belgium, a_3 is Cyprus, a_4 is Estonia, a_5 is Finland, a_6 is France, a_7 is Germany, a_8 is Greece, a_9 is Ireland, a_{10} is Italy, a_{11} is Luxembourg, a_{12} is Malta, a_{13} is Netherlands, a_{14} is Portugal, a_{15} is Slovakia, a_{16} is Slovenia and a_{17} is Spain.

On account of analysis of above-cited approaches to assessment SL and quality of life, appropriate indicators what characterize economical, and socio-demographical aspects in Eurozone countries for modeling analysis were assorted. Elements of the set of criteria $C = \{c_1, c_2, \ldots, c_6\}$ are in the Table IV.

Table IV Data dictionary of criteria set (Part 1)

Name	Type	Range	Unit
HICPs	Range	[83.29; 132.93]	%
Unemployment	Range	[2.47; 21.45]	%
GDP	Range	[1 225; 20 475]	EUR per inhabitant
Life expectancy	Range	[70.5; 81.7]	age
Public health care expenditures	Range	[4.8; 12]	%
People at risk of poverty or social exclusion	Range	[14.9; 33.5]	%

Table IV Data dictionary of criteria set (Part 2)

Name	Description	Attribute
HICPs	Rate of inflation (year average from monthly growth rates)	c_1
Unemployment	Rate of unemployment	c_2
GDP	Level of Gross Dmestic Product	c_3
Life expectancy	Life expectancy at birth at certain age	c_4
Public health care expenditures	Percentage of GDP	c_5
People at risk of poverty or social exclusion	Percentage of total population	c_6

The most common, the simplest and the most frequently used indicator for the performance of the economy, is the GDP. It is an indicator of the output of a country or a region.

Harmonized indices of consumer prices (HICPs) gives comparable measures of inflation for the countries and country groups they represent. There are economic indicators that measure the change over time of the prices of consumer goods and services acquired by households. There are a set of consumer price indices calculated according to a harmonized approach and a single set of definitions. HICPs are produced and published using a common index reference period (2005 = 100). In the article growth rates with respect to the previous month (M/M-1) are used.

The unemployment rate represents unemployed persons as a percentage of the labor force based on International Labor Office definition. The labor force is the total number of people employed and unemployed. Unemployed persons comprise persons aged 15 to 74 who: a) are without work during the reference week; b) are available to start work within the next two weeks; c) have been actively seeking work in the past four weeks or had already found a job to start within the next three months. Data are presented in seasonally adjusted form.

Life expectancy at certain ages represents the mean number of years still to be lived by a person who has reached a certain exact age, if subjected throughout the rest of his or her life to the current mortality conditions (age-specific probabilities of dying).

Public health care expenditure (in percentage of GDP). Data provide information on expenditure in the functionally defined area of health distinct by provider category (e.g. hospitals, general practitioners), function category (e.g. services of curative care, rehabilitative care, clinical laboratory, patient transport, prescribed medicines) and financing agent (e.g. social security, private insurance company, household).

People at risk of poverty or social exclusion (percentage of total population). This indicator corresponds with the sum of persons who are: at risk of poverty or severely materially deprived or living in households with very low work intensity. Persons are only counted once even if they are present in several sub-indicators. At risk-of-poverty are persons with an equalized disposable income below the risk-of-poverty threshold, which is set at 60% of the national median equalized disposable income (after social transfers). Material deprivation covers indicators relating to economic strain and durables. People living in households with very low work intensity are those aged 0-59 living in households where the adults (aged 18-59) work less than 20% of their total work potential during the past year.

Real data set from Eurostat has been used in the process of ranking modeling from year 2009.

In our modeling analysis, selected economic and socio-demographic indicators have been used (see Table IV). Three models MR_1, MR_2 and MR_3 have been proposed and analyzed. Specific set of criteria has been modified on the basis of Eurostat real data set and E15 index and LPI for each model.

A. Ranking modeling and comparison with E15 ranking

On the basis of [11], [13], [14] criteria c_2, c_3, c_4 and c_6 were used in a modeling of MR_1 ranking.

Based on Saaty matrix $\mathbf{S}_{MR1}(4\times4)$ for the sub model MR_1 is defined standardized weight vector of criteria $\mathbf{w}_{MR1}$ in the following way:

$$\mathbf{w}_{MR1} = [0.3241\,0.5078\,0.1025\,0.0656], \quad (7)$$

where maximal eigenvalue λ_{max} is 4.0605, consistency index CI is 0.0202 and consistency ratio CR is 0.0224 for $\mathbf{S}_{MR1}$.

Based on Saaty matrix $\mathbf{S}_{C2}(17 \times 17)$ for the sub model MR_1 is defined standardized weight vector of criteria $\mathbf{v}_{1,C2}$ in the following way:

$$\mathbf{v}_{1,C2} = [0.1217\,0.0494\,0.1119\,0.0144\,0.0348$$
$$0.0304\,0.0494\,0.0304\,0.0197\,0.0494\,0.1153 \quad (8)$$
$$0.0742\,0.1672\,0.0226\,0.0197\,0.0807\,0.0089],$$

where λ_{max} is 17.6614, CI is 0.0413 and CR is 0.0257 for $\mathbf{S}_{C2}$.

The value of random consistency index RI of $\mathbf{S}_{C2}$ is in [25]. The vector $\mathbf{v}_{1,C2}$ represents an evaluation of all alternatives for the criterion c_2 and it is the first row in the matrix $\mathbf{V}$.

Saaty matrixes $\mathbf{S}_{C3}(17 \times 17)$, $\mathbf{S}_{C4}(17 \times 17)$ and $\mathbf{S}_{C6}(17 \times 17)$ were defined in the same way and CRs are < 0.1. Vectors $\mathbf{v}_{2,C3}$, $\mathbf{v}_{3,C4}$ and $\mathbf{v}_{4,C6}$ were computed as $\mathbf{v}_{1,C2}$. Finally, based on (4) the evaluation of alternatives was computed as vector $\mathbf{e}_{MR1}$ that it is represented "weights" or "score" of alternatives in the MR_1 model by the following way:

$$\mathbf{e}_{MR1} = [0.0985\,0.0687\,0.0608\,0.0123\,0.0684$$
$$0.0482\,0.0452\,0.0268\,0.0662\,0.0439\,0.1890 \quad (9)$$
$$0.0380\,0.1257\,0.0173\,0.0166\,0.0438\,0.0305].$$

Because in our article we compare only standard of living of Eurozone countries, in Table V are listed only these countries in ranking created by E15.

The Table V illustrates that the highest E15 standard of living is in Luxembourg. The same score was also achieved by Netherlands, but Luxembourg achieved better places within the individual indicators. Slovakia and Portugal ranked on the opposite end of scale.

The same states are on the first two positions in modeling ranking as well as in E15 standard of living index – Luxembourg and Netherlands. The ranking of other countries is different, however, in comparable indexes. The lowest score in our index was reached by Estonia; whilst in E15 index it reached better score (Estonia took higher place in individual indicators – mainly low tax quota, low rate of unemployment and high number of women in managerial positions).

B. Ranking modeling and comparison with Legatum Prosperity Index

On the basis of [6], [11], [14], [19] criteria c_1, c_2, c_3, c_5 and c_6 were used in a modeling of MR_2 ranking.

Based on matrix $\mathbf{S}_{MR2}(5 \times 5)$ for the sub model MR_2 is defined standardized weight vector of criteria $\mathbf{w}_{MR2}$ in the following way:

$$\mathbf{w}_{MR2} = [0.0288\,0.2992\,0.4460\,0.1496\,0.0764], \quad (10)$$

where λ_{max} is 5.2924, CI is 0.0731 and CR is 0.0653 for $\mathbf{S}_{MR2}$.

Based on matrix $\mathbf{S}_{C1}(17 \times 17)$ for the sub model MR_2 is defined standardized weight vector of criteria $\mathbf{v}_{11,C1}$ in the following way:

$$\mathbf{v}_{11,C1} = [0.0177\,0.0329\,0.0394\,0.2606\,0.0329$$
$$0.0144\,0.0177\,0.1080\,0.0177\,0.0329\,0.0597 \quad (11)$$
$$0.0666\,0.0107\,0.0177\,0.0967\,0.1080\,0.0666],$$

where λ_{max} is 18.1327, CI is 0.0708 and CR is 0.0440 for $\mathbf{S}_{C1}$.

Table V Nations E15 ranking and MR_1 ranking

Rank E15		Rank MR_1	
Country	*Index*	*Country*	*Index*
Luxembourg	0.0892	Luxembourg	0.1890
Netherlands	0.0892	Netherlands	0.1257
Ireland	0.0792	Austria	0.0985
France	0.0705	Belgium	0.0687
Austria	0.0691	Finland	0.0684
Belgium	0.0641	Ireland	0.0662
Finland	0.0624	Cyprus	0.0608
Germany	0.0588	France	0.0482
Slovenia	0.0511	Germany	0.0452
Italy	0.0504	Italy	0.0439
Cyprus	0.0497	Slovenia	0.0438
Spain	0.0490	Malta	0.0380
Estonia	0.0480	Spain	0.0305
Malta	0.0458	Greece	0.0268
Greece	0.0430	Portugal	0.0173
Slovakia	0.0408	Slovakia	0.0166
Portugal	0.0398	Estonia	0.0123

The vector $\mathbf{v}_{11,C1}$ represents an evaluation of all alternatives for the criterion c_1 and it is the first row in the matrix $\mathbf{V}$.

Matrix $\mathbf{S}_{C5}(17 \times 17)$ was defined in the same way; $\mathbf{S}_{C2}$, $\mathbf{S}_{C3}$ and $\mathbf{S}_{C6}$ were used from MR_1 model and CRs are < 0.1. Vectors $\mathbf{v}_{12,C2}$, $\mathbf{v}_{13,C3}$, , $\mathbf{v}_{14,C5}$ and $\mathbf{v}_{15,C6}$ were computed as $\mathbf{v}_{11,C1}$. Finally, based on (6) the evaluation of alternatives was computed as vector $\mathbf{e}_{MR2}$ that it is represented "weights" or "score" of alternatives in the MR_2 model by the following way:

$$\mathbf{e}_{MR2} = [0.1052\,0.0689\,0.0475\,0.0196\,0.0636$$
$$0.0555\,0.0587\,0.0334\,0.0616\,0.0324\,0.1690 \quad (12)$$
$$0.0341\,0.1338\,0.0247\,0.0215\,0.0469\,0.0236].$$

In the analysis, Legatum Institute only shows calculated values of particular sub-indexes, the overall rank of countries is created based on them (that's the reason why the value of LPI in the Table VI is missing). We have chosen only

Eurozone countries for comparison (with the exception of three missing countries).

In this analysis, Finland ranked first overall despite not having the highest score in any of the eight sub-indexes. The other top five Eurozone countries are Netherlands, Ireland, Belgium and Germany. Slovakia ranked last, following Estonia and Greece.

Table VI Legatum ranking and MR_2 ranking

Rank Legatum		Rank MR_2	
Country	*Index*	*Country*	*Index*
Finland		Luxembourg	0.1690
Netherlands		Netherlands	0.1338
Ireland		Austria	0.1052
Belgium		Belgium	0.0689
Germany		Finland	0.0636
Austria		Ireland	0.0616
France		Germany	0.0587
Spain		France	0.0555
Slovenia	Non	Cyprus	0.0475
Italy		Slovenia	0.0469
Portugal		Malta	0.0341
Greece		Greece	0.0334
Estonia		Italy	0.0324
Slovakia		Portugal	0.0247
Cyprus *)		Spain	0.0236
Luxembourg *)		Slovakia	0.0215
Malta *)		Estonia	0.0196

where *) means that marked countries were not included in evaluation in 2009 year [16]. They were included into the ranking in 2012 year [6].

Finland ranks first overall despite not having the highest score in any of the sub-indexes. The other top 5 Eurozone countries are Netherlands, Ireland, Belgium and Germany. Slovakia ranks last, following Estonia and Greece.

In our analysis Luxembourg topped our scale (see Table VI). Netherlands and Belgium ranked at the same place as in LPI. Finland and Ireland are in lower position compared with LPI. The bottom of the table is similar, with Estonia last, one place behind Slovakia.

C. Comparison of ranking models

On the basis of [11], [14] criteria c_1, c_2, …, c_6 were used in a modeling of MR_3 ranking.

Based on matrix $\mathbf{S}_{MR3}(6\times6)$ for the sub model MR_3 is defined standardized weight vector of criteria $\mathbf{w}_{MR3}$ in the following way:

$$\mathbf{w}_{MR3} = \begin{bmatrix} 0.0240 & 0.2676 & 0.4089 & 0.0963 & 0.1397 & 0.0634 \end{bmatrix}, (13)$$

where λ_{max} is 6.3118, *CI* is 0.0624 and *CR* is 0.0503 for $\mathbf{S}_{MR3}$.

Matrixes $\mathbf{S}_{C1}$, $\mathbf{S}_{C2}$, $\mathbf{S}_{C3}$, $\mathbf{S}_{C4}$, $\mathbf{S}_{C5}$ and $\mathbf{S}_{C6}$ were used from MR_1 and MR_2 models.

On the basis of (6) the evaluation of alternatives was computed as vector $\mathbf{e}_{MR3}$ that it is represented "weights" or "score" of alternatives in the MR_3 model by the following way:

$$\mathbf{e}_{MR3} = \begin{bmatrix} 0.1000 & 0.0674 & 0.0535 & 0.0181 & 0.0617 \\ 0.0618 & 0.0583 & 0.0350 & 0.0605 & 0.0421 & 0.1585 \\ 0.0353 & 0.1256 & 0.0248 & 0.0201 & 0.0437 & 0.0337 \end{bmatrix}. \quad (14)$$

Comparison of modeling order (models of ranking MR_1, MR_2 and MR_3) created from four (MR_1 model), five (MR_2 model) and six (MR_3 model) selected indicators are included in Table VII. The rank of countries is defined on basis of the vectors $\mathbf{e}_{MR1}$, $\mathbf{e}_{MR2}$ and $\mathbf{e}_{MR3}$. It is apparent that countries on the first four places in ranks are identical. The order on the fifth place is different on the list based on six indicators (MR_3) – France got ahead Finland. It reached fifth place on the remaining lists (based on four MR_1, and five MR_2 indicators). Similarly are replaced Ireland and Germany. On the last position is identically Estonia, following Slovakia and Portugal.

Table VII Comparison of three models of ranking MR_1, MR_2 and MR_3 (Part 1)

Rank MR_1	Rank MR_2	Rank MR_3
Luxembourg	Luxembourg	Luxembourg
Netherlands	Netherlands	Netherlands
Austria	Austria	Austria
Belgium	Belgium	Belgium
Finland	Finland	France
Ireland	Ireland	Finland
Cyprus	Germany	Ireland
France	France	Germany
Germany	Cyprus	Cyprus
Italy	Slovenia	Slovenia
Slovenia	Malta	Italy
Malta	Greece	Malta
Spain	Italy	Greece
Greece	Portugal	Spain
Portugal	Spain	Portugal
Slovakia	Slovakia	Slovakia
Estonia	Estonia	Estonia

The results of modeling ranks which have been created with evaluation of importance of selected criterion with using AHP are very similar. We can observe three groups of countries – countries with high scores (grey color) Luxembourg,

Netherlands, Austria, Belgium, Finland and Ireland. Countries with lower level of scores Germany, France, Cyprus, Slovenia, Italy (white color) and countries with the lowest scores Malta, Spain, Greece, Portugal, Slovakia and Estonia (grey color). It is apparent that in the group of countries with high and low level of index are much wider variances in their scores.

Table VII Comparison of three models of ranking MR_1, MR_2 and MR_3 (Part 2)

Rank MR_1	Rank MR_2	Rank MR_3
0.1890	0.1690	0.1585
0.1257	0.1338	0.1256
0.0985	0.1052	0.1000
0.0687	0.0689	0.0674
0.0684	0.0636	0.0618
0.0662	0.0616	0.0617
0.0608	0.0587	0.0605
0.0482	0.0555	0.0583
0.0452	0.0475	0.0535
0.0439	0.0469	0.0437
0.0438	0.0341	0.0421
0.0380	0.0334	0.0353
0.0305	0.0324	0.0350
0.0268	0.0247	0.0337
0.0173	0.0236	0.0248
0.0166	0.0215	0.0201
0.0123	0.0196	0.0181

Interesting is the comparison of our ranking with cluster analysis which has been created in our previous work [14]. Position of Germany and Malta is completely different. In cluster analysis three clusters have been constructed – in one case with four input attributes on the basis of [13] and in the second case with five input attributes on the basis of [6]. According to our modeling score, Germany placed among countries with middle level of standard of living, whilst in cluster analysis was in the group of countries with high level of standard of living (in both cases). Similarly Malta was not included in clusters with low SL, whilst in modeling ranking (MR_1, MR_2 and MR_3 model) is among group of countries with a low level of the standard of living.

The three-level structure of AHP algorithms for the individual sub models has been executed in MATLAB, ver. 7.1., Service Pack 3.

V. CONCLUSION

Both rankings which we used in our article (E15 index and LPI) include the economic variables and socio-demographic criteria for evaluating the quality of life and wellbeing in the construction of the index. Index E15 as well as LPI are created by averaging their indicators or sub-index scores used in standard of living measurement. Modeling ranking (MR_1, MR_2, MR_3) uses different algorithm of calculation – MCDA method, in which weighs of importance are assigned to each individual indicator.

MCDA models work with public data obtained from open sources available from Eurostat database. Because of wide extent of research, we did not consider subjective aspects of quality of life evaluation (we did not conduct our own survey). Evaluating the quality of life by using objective data is quite simpler and less accurate, based largely on available data.

Results in ranking of Eurozone countries based on MCDA models varied more in the model MR_2 in comparison to the LPI (that is based on also on subjective evaluation of respondent surveys based on Gallup World Poll [15]. This can be caused by a higher number of indicators the LPI works with, one third of those indicators rating the wellbeing. We used only five model indicators in our own analysis. MR_1 model ranking of the Eurozone countries is similar to the real ranking achieved according to the E15. From the subjective criteria, only the corruption perception index (CPI) was included in the E15 index, the emphasis in ratings having been placed on the objective criteria.

The objective of this article is to compare the three rankings – one achieved by using the E15 index, the other using the LPI index, and the last using our own method.

The results of modeling ranks which have been created with evaluation of importance of selected criterion with using AHP (Rank MR_1, Rank MR_2 and Rank MR_3) are very similar.

We can determine (on the basis of Table VII) three groups of countries with these linguistic values of SL – high, middle and low by the following way: "High SL" = {Austria, Belgium, Finland, Ireland, Luxembourg, Netherlands}, "Middle SL" = {Cyprus, France, Germany, Italy, Slovenia} and "Low SL" = {Estonia, Greece, Malta, Portugal, Slovakia, Spain}.

These linguistic values can be used for design of fuzzy classifier of SL.

Comparison of two rankings according to the E15 and LPI indexes with modeling ranking has shown that results on the first and the last places are not considerably different.

It can be observed that the method used for overall design of the countries ranking does not significantly influence the result, contrary to the selection of appropriate indicators.

Our analyses were designed only on the pattern of Eurozone countries. Generally are "old" EU member countries considered as countries with higher level of SL and quality of life [18]. Non all of them are members of Eurozone (e.g. Denmark, Sweden) and therefore were not included in our analysis. Conversely countries, which joined EU after year 2004, so called "new" member countries could be considered as countries with lower level of SL and quality of life. In our modeling only Eurozone countries (Estonia, Slovakia, Slovenia) have been included and our models confirmed their lower quality of live level.

Nevertheless, our calculations point to the fact that country's wealth has a significant effect on people's quality of life. Mainly countries with strong economies figure on the top positions of the rankings (Luxembourg, Netherlands, Austria, Finland). Countries with low level of GDP as Estonia, Slovakia and Portugal are placed on the opposite side of the rankings for the very same reason.

From the longer point of view some trends are appearing: in "new" EU member countries, notable improvements in overall prosperity can be seen [17], [26]. By contrast, many of "old" EU member countries are either just keeping pace with the European average (such as France and Spain), or are seeing substantial falls in their scores (notably Italy, which has seen the largest decrease in the whole Europe).

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