

## MODELING OF SUSTAINABLE DEVELOPMENT OF EU-28 COUNTRIES

Kovalchuk O.Ya., Fedoronko N.I., Masonkova M.M.

Ternopil National Economic University

The article is considering the question of application of modern mathematical methods in order to evaluate the level of sustainable development of countries. The analysis of indexes that traditionally applied for determination of degree of socio-economic development of separate regions is conducted. The model analysis of sustainable development of Eurozone countries was executed according to the data of official statistical sources for the members of EU for 2016. Clustering and classification of EU-28 countries was conducted according to the meaningful measurements of sustainable development.

**Keywords:** European Union, sustainability, Human Development Index, mathematical modeling, clustering, classification.

**Introduction.** Many problems the world runs today are the result of unstable development. Global climate change, holes in the ozone layer, resource depletion, space debris, biodiversity loss, malnutrition, extinction of ecosystems, global inequality and the risk of unprecedented nuclear wars are perhaps among the most well-known but not always the only examples.

Traditionally researches of problems of sustainable development had a tendency to concentrate on the aspects of ecological or proof development and ignore no less important spheres. In particular, it is problems of unfair development, extreme poverty and starvation, resource wars, mostly because of oil. However, in the near future water can become the subject of conflicts also, as her deficit becomes all more extreme [4, p. 5].

Today stability needs to be examined as a new paradigm, where the future is balance of three components (economy, society and ecology), and the aim is development and improvement of quality of life.

In different years the row of scientists from the different countries of the world studied the questions of modeling of sustainable development, in particular M. Hersh, J. Rehmeyer, W. Mellor, R. Clift, P. Boulanger, T. Brechet, M. Kissinger, W. Rees, S. Faucheux, D. Pearce, J. Proops, V. Todorov, D. Marinova, G. Malinetskiy, A. Potapov, etc.

**Selection of earlier unsolved parts of general issue.** Researches of problems of sustainable development were conducted during not alone decade. However, a previous analysis had a tendency to use «soft» approaches that does not need the use of instruments of analytical, mathematical or calculable methods. However, complication and interactiveness of receipt of decisions of many inter-related problems of sustainable development, that can be used for development of compromises and support of making decision in difficult, indefinite terms, need necessary application of mathematical and calculable methods [5, p. 352].

**Purpose.** The main purpose of this work is a model analysis of process of sustainable development of EU-28 countries by facilities of modern instruments of mathematical modelling. Application of more formal, mathematically reasonable approach for determination of progress, related to providing of sustainable development, will give an opportunity to get the deeper understanding of process and work out a reliable, scientifically

reasonable base for politicians and officials that make decisions.

**Main Part.** Sustainable development is a general model of society, that envisages the observance of balance between satisfaction of modern necessities of humanity and defence of interests of future generations, in particular safe and healthy environment of existence. It is the guided development, basis of that is systems approach and modern information technologies, that give possibility to design the different possible variants of development quickly and qualitatively, with high probability to predict their results and accept optimal decisions.

A question of choice of optimal variant of development is important for every country, as development of economy is related to natural limitations. However, there are countries for that a survival is an only strategic aim. Such countries provoke threats and calls to international safety. The closeness of the nearby states creates ecological risks. Swift globalization assists formation and intensifying of economic and social dangers. Therefore an achievement of sustainable development of regions is an extraordinarily important problem. Direction of sustainable economic development was chosen by the row of the developed states, among them there are the USA, Japan, European Union countries [1, p. 48].

Sustainable development is a main objective for the European Union. It aims to improve quality of life for present and future generations. Progress for EU is economic development in combination with the safe of environment and social justice. For the estimation of level of sustainable development of EU 10 primary purposes were selected and appropriate indicators were identified by Eurostat [13].

Socio-economic development envisages prosperity, introduction of innovations, development of education and science, riches, competitive and ecologically effective economy that provides the high standard of living and full, quality employment on all territory of European Union. One of indicators is rates of increase of the real GDP per capita – measure of dynamism of economy and its ability to create new workplaces (in %). The high rates of increase of GDP mean that society generates additional economic resources for satisfaction of economic necessities of present generation, in order to invest in the future, or for the solution of social and ecological problems [4, p. 61].

Social integration envisages creation socially inclusive society, including solidarity between countries and into generations; providing of safety and upgrading of life of citizens as precedent conditions for development and prosperity of individual.

Change of climate and conservation of energy has for an object strategy in relation to limitation of climate change and negative consequences of it use for society and environment. Indicators are extrass of greenhouse gases and part of renewable energy sources in the gross internal consumption of energy (in %). There are all more proofs of that the extrass of greenhouse gases are responsible for global warming that causes negative consequences for economic, social and ecological spheres at global level. The renewable energy sources have an important value for the decline of dependence of EU from the import of extractive fuel.

Strategy of effective management is an assistance to the collaboration in political sphere and co-ordination of countries of EU on local, regional, national and global levels with the aim of increase of their ante in sustainable development.

Measuring of progress is inalienable part of strategy of sustainable development of EU. Every year Eurostat determines basic economic indicators on the basis of analysis of the last international economic events for 35 countries, 28 from that are included in the zone of euro.

The value of GDP per capita or HDI are usually used for comparison of standard of living in different countries. However, these indexes not always represent the real state of affairs [5, p. 75]. Comparisons of value of GDP in general is considered to be inappropriate, as an ultimate goal of most people to be not rich, but happy and healthy. Therefore in some countries of EU the index of happiness is used for the estimation of welfare of people and state of environment. It represents the real welfare of nation. Economic freedom is one of factors of sustainable development. The index of economic freedom is annually calculated for the most world countries. The indexes of perception of prosperity are used for the estimation of quality of life. There is a row of other indexes that are traditionally use for the evaluation of sustainable development [6, p. 67].

#### Model analysis of sustainable development of EU-20 countries

For research of basic mutual dependences of traditional indicators of sustainable development the vehicle of mathematical and calculable methods is used [4, p. 346]. A model analysis is conducted according to the official data [7-13] of next most widespread indexes of sustainable development for 2016 for the EU-countries: Human Development Index (HDI), Life expectancy at birth, Expected years of schooling, Mean years of schooling, GDP per capita (\$PPP), Gini Index, Ranked of terrorism, Rank of corruption, Enabling Trade Index, Availability and quality of transport infrastructure, Availability and use of ICT, Social Progress Index, Access to Basic Knowledge, Health and Wellness, Personal Freedom and Choice, Tolerance, Global Competitiveness Index, Ranking of the world by economic freedom, The Global Peace Index records a less peaceful and more unequal world, Population, Migrants, Happy Planet Index,

Wellbeing, Happy Life Years, Footprint, Inequality of Outcomes, Happy Planet Index.

For today there is not compatible set of the universally recognized indicators and perfect methodology of determination of sustainable development. Except of that, a substantial problem is absence of reliable estimations of several indexes for some countries of EU. Therefore for realization of quality analysis it is expedient to use the different mathematical methods of analysis and compare the got results [4, p. 143].

The cross-correlation analysis of all preliminary select indexes is conducted to form an optimal set of factors that will be used in further researches. It was found, that for EU countries, as well as for other ones of the world, exactly HDI is denser in all related to the repressing amount of indexes that traditionally considered to be the measuring devices of sustainable development [2, p. 244]. However, row of factors, poorly or mildly correlate with HDI. In particular, The Global Peace Index ( $r = -0,03$ ), Gini Index ( $r = 0,08$ ), Happy Planet Index ( $r = 0,09$ ), Population ( $r = 0,33$ ), Mean years of schooling ( $r = 0,4$ ), Access to Basic Knowledge ( $r = 0,47$ ), Ranking of the world by economic freedom ( $r = 0,6$ ) Migrants ( $r = 0,56$ ) and Health and Wellness ( $r = 0,63$ ). That is why it is expedient not to use them for the construction of mathematical models of sustainable development.

Tree clustering (joining, k-means clustering) [3, p. 356] is conducted in the work for EU-28 countries for the meaningful measuring of sustainable development (Fig. 1, 2).

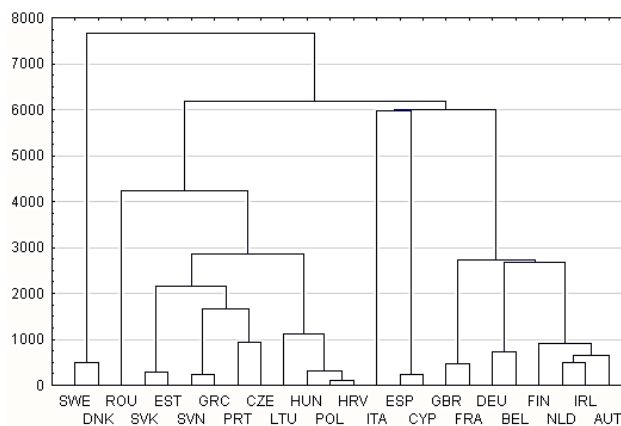


Fig. 1. Dendrogram of EU countries for the meaningful measuring of sustainable development

Source: worked out by authors after [7-13]

The research was performed with analytics platform Statistica. By means of k-means method 3 clusters of countries (Fig. 2) are distinguished. Only 3 countries entered to the first cluster – Cyprus, Italy of and of Spain. These countries are mainly characterized by the mean values of the indexes for the EU-countries that was selected for an analysis. However, the greatest mean value on the cluster of Life expectancy at birth (81,57) and the least values of Footprint (4,17) and Rank of corruption (54,33) among the EU-countries were fixed in this countries. At the same time here is minimum value among country – members of EU of Availability and use of ICT (5,31), Personal

Freedom and Choice (68,65) and Ranking of the world by economic freedom (65,73).

Variable	Cluster No. 1	Cluster No. 2	Cluster No. 3
HDI	0,87	0,84	0,90
Life expectancy at birth	81,57	77,00	80,79
Wellbeing	6,10	5,58	7,15
Happy Life Years	42,90	36,23	52,30
Footprint	4,17	4,55	5,84
Inequality of Outcomes	11,33	13,09	7,30
GDP/capita (\$PPP)	30786,67	16523,18	47984,90
Expected years of schooling	15,77	15,86	16,88
Impact of terrorism	1,87	0,71	2,92
Corruption	54,33	56,09	81,70
Enabling Trade Index	4,94	4,92	5,50
Transport infrastructure	4,91	3,81	5,26
ICT	5,31	5,34	6,23
Social Progress Index	83,04	79,48	87,75
Personal Freedom and Choice	68,65	70,59	87,12
Tolerance and Inclusion	62,58	54,98	75,64
Global Competitiveness Index	4,43	4,38	5,32
Economic freedom	65,73	66,75	72,48

Fig. 2. Centroids of the distinguished clusters

Source: worked out by authors

The second cluster is folded by countries with the most subzero for EU socio-economic indexes. In particular, AV GDP for this cluster presents 16523,18 \$PPP, that almost half as much than for the countries of the first cluster. However, in the countries of this cluster it is fixed not high Footprint (in middle 4,55) and the least among EU-countries Ranked of terrorism (0,71). It means that countries of this cluster are most safe for a residence among the EU-countries. This group was entered by such countries, as Croatia, Czech Republic, Greece, Poland, Portugal, Romania, Estonia, etc.

The third cluster was entered by such economically developed industrial countries, as Austria, Belgium, France, Sweden, United Kingdom etc. They are characterized by the high level of HDI (0,9) and other social indexes and most subzero among EU-countries level of Inequality of Outcomes (AV for a cluster 7,3). GDP (47984 \$PPP) is substantially higher comparatively with EU-countries, that entered to the first two clusters. At the same time mean values of Ranked of terrorism (2,92) and Rank of corruption (81,7), fixed in the countries of the third cluster, are considerably higher, than for other members of EU.

Thus, in distribution of countries for clusters the indexes of Inequality of Outcomes, GDP, Ranked of terrorism and Rank of corruption have most weight.

By HDI value, that is one of the most authoritative rating, by means of which the level of steady development is traditionally measured, countries are attributed to one of four groups: very high, high, medium and low.

According to The 2016 Human Development Report, that is annually published United Nations Development Program, HDI level of most EU-countries is certified as very high. Only in Bulgaria and Romania it is fixed high [11]. To check co-ordination of distribution of EU-countries according to these groups of HDI with the preliminary conducted clusterization, one of Data Mining

methods (tree classification) is used. This method is applied in the cases when predicates are qualitatively different and carry substantially different information for objects classification [4, p. 148].

Results of the conducted classification are presented as a tree structure, that branches on the left and right branches that are contained on one node knot (Fig. 3). Inequality of Outcomes appeared a basic factor in distribution of EU-countries according to HDI levels. This fact confirms the results of the preliminary conducted clusterization. Condition of countries division to the tops 2 and 3: if value of Inequality of Outcomes is more than 17,5, country refers to the group with high HDI (2 objects); in other case – to the group with very high HDI (26 objects).

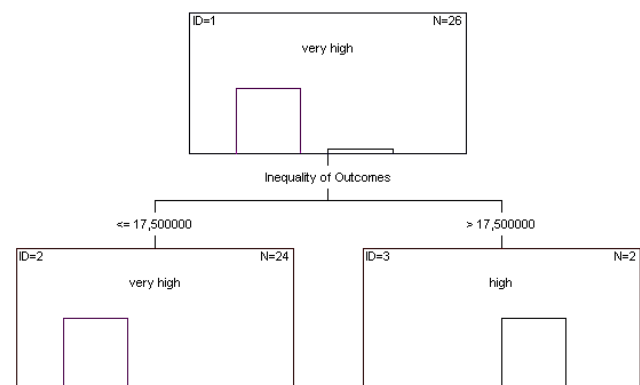


Fig. 3. Graphic presentation of tree of classification

Source: worked out by authors

The results of the conducted classification testify the absence of the wrong classified objects (Fig. 4).

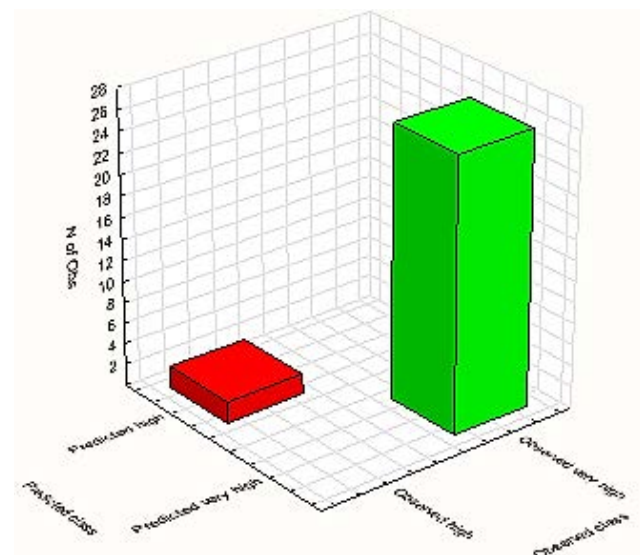


Fig. 4. 3-D diagram of classification matrix

Source: worked out by authors

**Conclusions.** The results of conducted analysis testify that not only economic factors influence on the level of sustainable development of EU-countries. Quality and safety of life, reduction of social inequality play an important value providing of balance between satisfaction of modern necessities of humanity and defence of interests of future generations, guaranteeing safe and healthy environment of existence.

In study of problems of sustainable development the basic question is development of strategies that would give possibility to accept optimal decisions on the different levels of management,

including the change of people consciousness, and also politicians and officials. The best way to understand these problems is to use modern instruments of mathematical modelling.

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**Ковальчук О.Я., Федоронько Н.И., Масьонкова М.М.**

Тернопільський національний економічний університет

## МОДЕЛЮВАННЯ СТАЛОГО РОЗВИТКУ КРАЇН ЄС-28

### Анотація

У роботі розглянуто питання застосування сучасних математичних методів для оцінювання рівня сталого розвитку країн. Проведено аналіз показників, які традиційно застосовують для визначення ступеня соціально-економічного розвитку окремих регіонів. За даними офіційних статистичних джерел для членів ЄС за 2016 рік виконано модельний аналіз сталого розвитку країн Єврозони. Проведено кластеризацію та класифікацію країн ЄС-28 за значущими вимірами сталого розвитку.

**Ключові слова:** Європейський Союз, сталий розвиток, Індекс людського розвитку, математичне моделювання, кластеризація, класифікація.

**Ковальчук О.Я., Федоронько Н.И., Масьонкова М.М.**

Тернопольский национальный экономический университет

## МОДЕЛИРОВАНИЕ УСТОЙЧИВОГО РАЗВИТИЯ СТРАН ЕС-28

### Аннотация

В работе рассмотрен вопрос применения современных математических методов для оценивания уровня устойчивого развития стран. Проведен анализ показателей, которые применяют для определения уровня социально-экономического развития отдельных регионов. По данным официальных статистических источников для членов ЕС за 2016 год выполнен модельный анализ устойчивого развития стран Еврозоны. Проведены кластеризация и классификация стран ЕС-28 за значимыми измерениями устойчивого развития.

**Ключевые слова:** Европейский Союз, устойчивое развитие, Индекс человеческого развития, математическое моделирование, кластеризация, классификация.