

## Classification models in the monitoring systems of the population life quality

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**Abstract.** The paper is devoted to the assessment of living standards of population. Countries with emerging markets are characterized by significant transformations of the public sector in the context of European integration processes, which requires the adaptation of models for assessing the living standards of the population, allowing to analyze the effectiveness of public administration and ongoing reforms. The complex of models for assessing the living standards of the population as an assessment of the effectiveness of public administration is also interesting for countries with developed markets. The advantages and disadvantages of existing methods of predictive analytics for the study of standards of living are shown. It should be noted that the universal method of analysis and assessment of living standards contains the set of intangible components. Therefore, it is advisable to make a proposal on the need to improve a complex of models for assessing and analyzing living standards. The data set is built using of such key indicators that objectively reflect the real situation in EU and Ukraine. The proposed complex of models for assessing the living rating of the country has been provided by combination of multivariate exploratory analysis methods and predictive analysis methods (cluster and discriminant methods, the method of canonical correlations). The adaptation of models for assessing the quality of life of the population involves solving the problem of assessing the informativeness of indicators, the formation of a system of diagnostic indicators, the construction of an integral assessment and its scaling. The clustering and classification methods can be effectively used to solve these problems, which is shown in the paper. The provided complex of models can be used to make optimal decisions in developing of social and economic development strategy, transforming the public sector of government, smoothing the asymmetry of territorial development.

**Keywords:** System, Standards of Living, Index of Living Standards, Model, Estimation, Predictive Analytic, Modeling.

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## 1 Introduction

In the context of the implemented processes of globalization and European integration of Ukraine, the assessment of the living standards of the population acquires special significance. It is classified as a key concept in defining the policy of socio-economic development of the country. Overcoming Ukraine's lag behind the European Union dictates the need for consistent implementation of the principles of a social market economy, characterized by developed market relations, high economic development, political democracy, guaranteed access to education and health care, and a well-developed social protection system.

The current economic situation in Ukraine confirms that the measures the government takes to improve the lives of its citizens (increase of minimum wage, living wage, etc.) are insufficient. To ensure a significant increase in the efficiency of all sectors of the economy, the reform of all spheres of public life in accordance with European standards should be completed. The standard of living of the population of Ukraine during the market reforms and by the influence of external and internal destabilizing factors has decreased, and it does not meet international standards. The most important direction of socio-economic transformations should be the achievement of sustainable positive dynamics of welfare of the population on the basis of increasing effective demand, in particular, increasing the wages of the working population.

The relevance of this work lies in the need to substantiate and improve models for assessing and analyzing the living standards of the population of Ukraine in terms of mathematical modelling and methods of predictive analytics. The need for this is due to the development of crisis phenomena and the decline of socio-economic development of Ukraine in the context of European integration processes, the existence of significant drawbacks in approaches to assessing the level of social development and analysis of living standards. This need to improve the existing tools and statistical processing of information to determine the living standards of the population of Ukraine is realized through the creation of a set of economic and mathematical models that can position the country on international indices of living standards and predict living standards for the future.

## 2 Literature Review

The conducted analysis of modern scientific literature has shown that many approaches to determining the living standards of the population exist in world practice. A part of scientific works [5, 7, 11 – 13, 15 – 19, 22, 26, 28] is devoted to the analysis of the standard of living, identification of the factors influencing it in individual countries. For example, in the paper [15], the influence of the shadow labor market in Ukraine living standards through a mathematical model of balance based on modeling of a small group using the graph theory is investigated. In the paper [16] the author explores the interregional  $\beta$ - and  $\sigma$ -convergence of the living standards of the population in Ukraine. In the article [11] the relationship between sustainability and quality of life was evaluated. The indicators were presented as an example used in the quality of urban life study for

the Istanbul Metropolitan Area. Author [22] proposes the model is built to identify the factors that influence income inequality in Vietnam based on the application of the Generalized Method of Moments (GMM).

A large of modern research [2, 4, 9, 23, 25, 27, 33] is devoted to the development of models by multivariate exploratory technics and regression analysis. In the paper [23] authors found a positive effect of GDP growth and average gross earnings at employment growth in the EU based on panel data and cluster analysis. In the paper [25] authors describe a model to integrate data between two surveys (Eurostat EU-SILC and Lifestyles survey) through a statistical matching method (hot deck distance) and cluster analysis. In [9] the authors investigate the influence of the information and communication technologies development on the social and political activities of modern society based on the application of correlation-regression analysis and cluster analysis. In [3], the authors, based on the use of correlation analysis, studied the correlation of the rate of economic growth (according to the forecast of the IMF) and the indicators of quality of life, calculated by Numbeo, and the index of economy digitization, calculated by the IMD. And based on the analytic hierarchy process (AHP), they investigated the impact of social development on economic growth. Authors of the research [33] propose a model of the impact of technology on the standard of living based on fuzzy linear regression. The Human Development Index (HDI) was chosen as a dependent variable as an indicator of the health and well-being of the population. The explanatory variables are the Network Readiness Index (NRI), which measures the impact of information and communication technologies on society and the development of the nation, and the Global Innovation Index (GII), which measures the driving forces of economic growth. The study was conducted for four groups of countries with different levels of GDP per capita.

Alhambra-Borrás, T., Doñate-Martínez, A. [1] studies of The Living Standards Capabilities for Elders scale (LSCAPE), its application for assessing living standards capabilities among older adults based on the use of self-reported measures of quality of life and income. Other researchers [20] conduct a comparative assessment of the concepts of “comfort” and “well-being” on the example of the EU countries and Ukraine. In this work, the authors paid the main attention to identifying the main economic and non-economic factors affecting the external migration of the population (the result of the discomfort of living in their country). In the paper [26] authors are focusing on determining the degree of influence of macroeconomic indicators characterizing certain areas of life (health, education, living conditions, safety, income, etc.) in living standards.

Thus, the methods described above do not allow creating a unified assessment system.

But, achieving a high standard of living, similar to the level in European countries is possible for Ukraine, subject to the study and adaptation of European social standards in their practice.

In international practice, the index of social (human) development was proposed by the UN Research Institute for Social Development. It indicate the level of the country's achievements in the most important socio-economic spheres and accumulates the following indicators: life expectancy; literacy and learning coverage; GDP per capita at

currency parities, the ratio of prices to the "consumer basket", consisting of several hundred goods and services. In 2010, the method of calculating the HDI was significantly adjusted: the indicators of education and income were modified, the procedure for their aggregation changed [14]. They allow a more balanced assessment of the country's progress than GDP per capita.

The standard of living is also determined by gross national product (GNP), using indicators of purchasing power parity (PPS) per capita. There is also The Social Progress Index, a combined measure of the international research project "The Social Progress Imperative", which measures the achievements of countries around the world in terms of social well-being and social progress. Developed in 2013 under the direction of Michael E. Porter [31] the index does not include indicators of economic development of the world (such as GDP and GNI). The index evaluates achievements in the social sphere separately from economic indicators, which allows a deeper study of the relationship between economic and social development.

The Global Innovation Index is a global study and the accompanying ranking of the world's countries in terms of the level of innovation development [10]. It consists of 82 different variables that characterize in detail the innovative development of the world at different levels of economic development. The authors of the methodology believe that the success of the economy is associated with both the availability of innovation potential and conditions for its implementation.

The World Happiness Report is an international research project by The Earth Institute, which measures the happiness of the world's population as part of the UN Sustainable Development Solutions Network in order to show the achievements of countries and individual regions in terms of their ability to provide their residents with a happy life [8].

Among the attempts to comprehensively assess and analyze the level and quality of life of the population the index of physical quality of life developed by D. Morris can be named [6]. It is based on life expectancy after the age of 1, infant mortality and literacy. For each indicator, countries are ranked on a 100-point scale, where 1 is the worst result and 100 is the best. The results of the research showed a slight correlation between the value of the quality life index and GDP per capita. That is, some countries with high GDPs had low estimates of the Morris index.

Quite common is the calculation of a generalized indicator in the form of a weighted average of partial indicators of living standards (groups of indicators). The weights are expert estimates, and the sum of the weights is 1. An example of such an indicator is the conjugation indicator. Its components are the degree of supply of consumer goods, the level of crime, the degree of dissatisfaction of the population with a set of unresolved social and political, and economic environmental problems.

Another way to reduce partial living standards to a single scale is to rank countries for each indicator. However, this method also has disadvantages: firstly, it is assumed that the comparison of objects on all indicators is in relation to a sample; secondly, that all indicators appear to be equivalent. Generalizations of the most famous techniques, their advantages and disadvantages are presented in table 1.

**Table 1.** International methods of assessing living standards

Name	Indicators	Main advantage	Main disadvantage
1	2	3	4
System of National Accounts (SNA) [21]	Domestic national product, gross domestic product, net national income, personal and personal available income	Gives the opportunity to measure the personal income of society members, to link together the formation of income and expenditure, to identify trends in regional economic development	The method takes into account only the economic aspects of life, which determine the standard of living, which is only one of the criteria of quality of life
Physical Quality of Life Index (PQLI) and its modification (PSLI) developed by the American Council on Foreign Development [6]	Life expectancy after the age of one year, infant mortality, adult literacy	The quality of life indices obtained using this technique are simple, accessible, but focused on a low degree of satisfaction of natural needs	Social indicators are not taken into account. The question of what meaning is attached to the concept of "physical quality of life" remains open.
Human Potential Development Index (HDI) and its modification which considers the gender factor (IRGF) developed by UN experts [14]	Life expectancy, education, living standards index	The method makes it possible to conduct a comparative analysis of socio-economic development by country and region, allows tracking the dynamics, comparing achievements. The technique is simple and accessible	Subjective indicators of quality of life are not taken into account, the social aspect is represented only by the level of education, there are no such sections as the degree of development of science, social tension, the state of the environment, etc.
Triangular welfare index of the nation [29]	The level of development of the economic sphere, social environment, information infrastructure	By means of this technique both the level of development of the specified spheres of vital activity of a society and their balance are estimated.	The need to collect a large set of indicators, as well as the fact that the political and spiritual spheres are not taken into account

Analysis of foreign methods of assessing living standards in relation to the structure and indicators of living standards, found that this issue remains controversial. The following conclusions can be drawn:

foreign scientists are actively working in the development of methods for assessing the level and quality of life; the world community pays more and more attention to the living standards of the population every year;

achieving and maintaining its high quality is the goal of all developed countries;

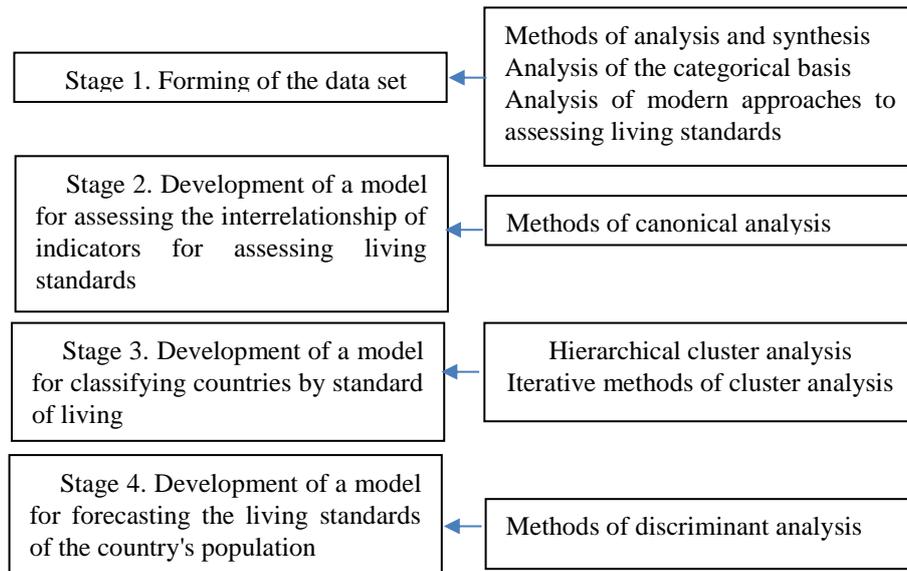
existing methods differ significantly in the number and composition of indicators (the number of indicators varies from three to several dozen, and the composition includes indicators of economic, social and physiological components of quality of life);

most of the considered methods evaluate only objective indicators of quality of life and do not take into account subjective ones; all the considered methods allow to estimate only separate components of quality of life of the population and cannot claim universality. There is no universal method of analysis and assessment of living standards.

In our opinion, it is necessary to improve the assessment models, which include such assessment indicators that will more objectively reflect the living standards of the population.

### 3 Problem Formulation, Methods

The purpose of the study is to develop a set of models for assessing and analyzing the living standards of the population of Ukraine based on the use of tools of economic and mathematical modelling: canonical correlation analysis, cluster and discriminant analysis. This allows to assess Ukraine's position in the European space and to forecast the living standards of the population in the future. For a qualitative analysis of the living standards of the population of Ukraine and its assessment in the European space, as well as to solve these problems, the following conceptual scheme of modelling the living standards of the population is proposed (Fig. 1).



**Fig. 1.** Conceptual scheme of modelling the living standards of the population

Let's consider in more detail the main stages of the constructed model, the methods applied at the corresponding stage and the selected indicators on the basis of which calculation was carried out. The first stage of the study is to form arrays of source data.

The main method for information processing is the method of synthesis and analysis of information, based on the analysis of the categorical basis and analysis of modern approaches to assessing living standards.

The array of initial data was formed from such international indices as the ranking of countries in the world by happiness, the global index of innovation, the index of social progress, the index of human development, the global charity index, the index of global competitiveness. All the above indices define the standard of living as a complex set of characteristics, which includes indicators: a person's ability to work and live in normal conditions, to have a decent level of education, to receive high quality health care, to have access to cultural values, to live in a safe society.

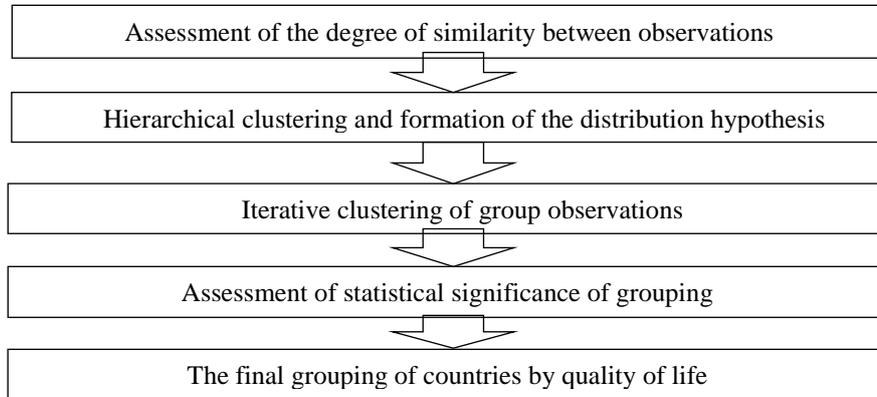
The next stage of the study reveals the process of building models of living standards analysis based on methods of predictive analytics and data science. Therefore, in the second stage, to determine the significant groups of indicators that have an impact on the quality of life, a model of assessing the relationship between sets of groups of indicators of economic development and a group of international indices of socio-moral direction. The method of canonical analysis is used for this purpose.

The concept of methods of canonical analysis is based on the nature of multiple correlation, which, according to V. Hotteling, is the maximum correlation between the chosen random result change and the linear function of the set of explanatory variables [2]. Since individual indicators do not fully characterize the group to which they belong, in the process of canonical analysis of the characteristic indicator of groups, two linear combinations of indicators of another group are established; the pair of linear combinations found by this way forms the first pair of canonical functions (roots), which describes certain properties of both groups of primary indicators. Performing a canonical correlation analysis of data, namely the construction of a scatter chart of canonical values provided the basis for further more detailed analysis of the cluster of EU member states according to international indices of living standards.

At the 3rd stage of the research, models of formation of homogeneous groups of countries are built according to the formed groups of indicators of living standards assessment. For this purpose, agglomerative and iterative methods of cluster analysis are used [4, 9, 24]. This allows to assess the quality of grouping, to form the optimal number of clusters, to determine the distribution of the country in clusters. Clustering algorithms are usually built as a specific way to search the number of clusters and to determine its optimal value in the search process and include 5 basic steps (Fig. 2).

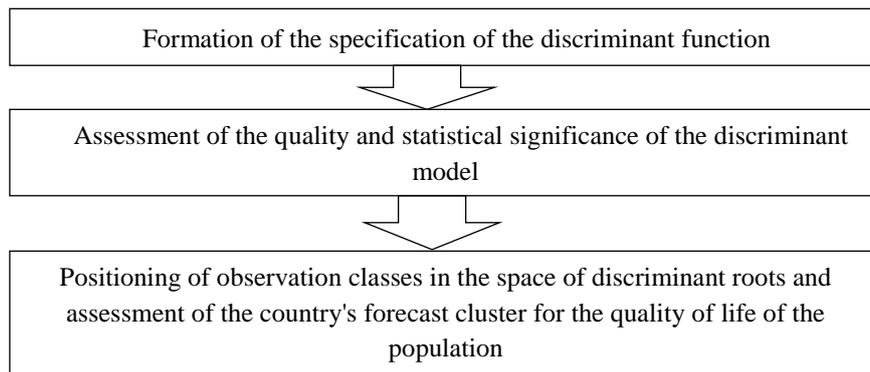
To eliminate the problem of heterogeneity of observation groups, z-transformation (standardization) of variable values was performed. Standardization reduces the values of all converted variables to a single range of values, namely the average of each is reduced to 0, and the mean deviation – to 1. Then all observations vary in the range of standard deviation from - 3 to +3.

At the 4th stage of the research a model of identification and forecasting of the living standard of the population of the European Union member states is built by methods of discriminant analysis, which allowed to determine the situation of our country and



**Fig. 2.** Algorithm for constructing cluster analysis

further way of approaching one of the groups. Schematically, the algorithm for constructing the model is presented in Fig. 3.



**Fig. 3.** Algorithm for using discriminant analysis

In the case of one variable, the  $F$ -criterion is used as the final criterion of significance of whether the variable separates the two sets or not. When using discriminant analysis for multidimensional variables, the procedure is identical to the procedure of multiple analysis of variance. At each step, all variables are viewed and the one that contributes most to the difference between the populations is located. This variable must be included in the model in the current step, and there is a transition to the next step.

Thus, the proposed set of models of assessment and analysis of living standards based on methods of predictive analysis and analysis of multidimensional objects allows to comprehensively analyze the impact of key indicators on the quality of life, to assess the country's membership in one of the clusters and to find the forecast distribution and membership of certain clusters.

## 4 Findings

In accordance with the considered concept of the study, let's consider the implementation of models. According to stage 1 of the study, living standards were analyzed, which can be divided into two sets: indices of the social and moral component (left set): Social Progress Index (SPI) [31]; World Giving Index (WGI) [32]; and the indices of the economic component (right set): Ranking of countries in the world by level of happiness (WHR, World Happiness Report) [8]; Global Innovation Index (GII) [10]; Human Development Index (HDI) [14]; Global Competitiveness Index (GCI) [30].

Estimation of mean (median) and scattering (quartiles and scope) for variables allowed to establish the symmetry of variable distribution. The results of building a model for assessing the relationship of two sets of indicators by canonical analysis are presented in Fig. 4.

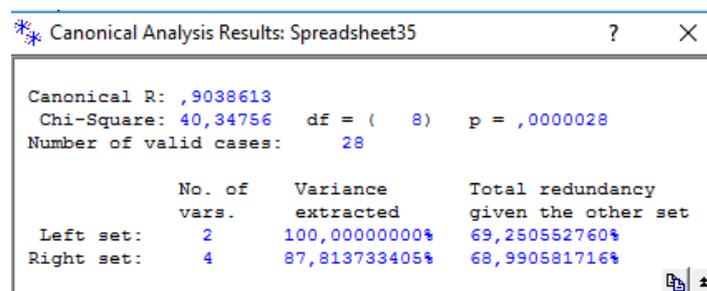


Fig. 4. The window of the results of canonical analysis

Since the number of canonical roots is equal to the number of variables in the smaller set (2), both canonical roots explain 100% of the variance (variability) from the left set and 87.81% from the right. From Fig. 4 it follows that the canonical correlation  $R = 0.9039$ , that is the correlation between the first weighted sums corresponding to the first pair of canonical variables (root 1), is strong. Its value indicates a strong relationship between the indices of the social and moral component (left set) and the indices of the economic component (right set). This means that the growth of indices of countries by social and moral components leads to an increase in the rating of the country by indicators of economic development, and vice versa - the growth of the rating of the country by indicators of economic development causes the growth of indices of countries with social and moral orientation. High value  $SPI = 40,3476$  and level of significance  $p = 0,00$ , which is much less than  $0,05$ , demonstrate the significance of  $R$ . The second row of the table shows the percentage of explained variances from the left and right sets of variables.

The value of the total redundancy of 69.25% means that the variables of the right set explain on average 69.25% of the variability of the variables of the left set. changes in the left set explain an average of 68.99% of the variability of variables in the right set. Thus, the left set is more redundant for a given right than the right for a given left set.

Indicators of redundancy additionally confirm the strong relationship between indicators of social and moral orientation and economic orientation, while indicators of economic orientation are more informative than indicators of social and moral orientation.

The canonical value of  $R$  corresponds only to the first root - the most significant correlation. The obtained results according to chi-square statistics for canonical roots showed that only the first root is statistically significant and should be investigated in more detail in Fig. 5.

Root Removed	Chi-Square Tests with Successive Roots Removed					
	Canonical R	Canonical R-sqr.	Chi-Square	df	p	Lambda Prime
0	0.903861	0.816965	40.34756	8	0.000003	0.179619
1	0.136610	0.018662	0.44271	3	0.931284	0.981338

**Fig. 5.** Checking the significance of canonical roots

All correlations between the right variables are quite high, the highest correlation is observed between GCI (Global Competitiveness Index) and GII (Global Innovation Index), the lowest - between HDI (Human Development Index) and GCI (Global Competitiveness Index). The correlation between the variables of the left set is also positive, quite high, greater than 0.5 (Fig. 6).

N=28	SPI	WGI	N=28	WHR	GII	HDI	GCI
SPI	1.0	0.69603	WHR	1.0	0.82364	0.83901	0.84403
WGI	0.69603	1.0	GII	0.82364	1.0	0.84516	0.89920
			HDI	0.83901	0.84516	1.0	0.79918
			GCI	0.84403	0.89920	0.79918	1.0

**Fig. 6.** Correlations between set variables

The analysis of the relationship between the variables of the left and right sets is of particular interest, as it explains the structure of the relationship between the international indices of the level of development of the countries under analysis. The strong correlation between social and moral indices and economic development indices is explained by the strong correlations between such indicators of economic development countries as: GII (Global Innovation Index), HDI (Human Development Index) and SPI (Social Progress Index) of a moral aspect of the development level of the countries. The WGI (World Charity Index) also has close to strong correlations with economic development indices, but these relationships are less pronounced than the relationship between SPI and economic development indices. It should be noted that the GCI (Global Competitiveness Index) has the least impact on the ranking of countries (Fig. 7).

N=28	WHR	GII	HDI	GCI
SPI	0.76163	0.83421	0.805667	0.75557
WGI	0.73346	0.779934	0.730343	0.68746

**Fig. 7.** Correlations between variables of the left and right sets

The largest factor loads (correlations) of the left and right sets have with the canonical variables that correspond to the Root 1 (Fig. 8). This fact underlines once again the strong correlation between the indicators of social and moral indices and indices taking into account the economic development of the country.

Variable	Factor structure, left set		Factor structure, right set	
	Root 1	Root 2	Root 1	Root 2
SPI	-0.94754	-0.31963	-0.898585	0.182226
WGI	-0.88902	0.45787	-0.972681	-0.026579
			-0.928119	-0.246937
			-0.871654	-0.207150

**Fig. 8.** Factor structure of sets

Analysis of canonical roots showed the following. Canonical Root 1 explains on average about 84% of the variance from the indicators of the economic component of the level of development and about 84% of the variance from the indicators of the socio-moral component of the level of development, that is it explains 84% of the variability of the rating of countries considering socio-moral aspect. In turn, the canonical Root 2 explains, respectively, about 15% and about 3% of the variability of the economic component of the level of development and the socio-moral component of the level of development (Fig. 9).

Factor	Variance Extracted (Proportions), left set		Variance Extracted (Proportions), right set	
	Variance Extracted	Redundancy	Variance Extracted	Redundancy
Root 1	0.844095	0.689596	0.843687	0.689263
Root 2	0.155905	0.002910	0.034450	0.000643

**Fig. 9.** Table of fractions of explanatory variance

According to the values of the first canonical root, the indicators of the right set - indices of the economic aspect, explain about 69% of the variability in the indicators of the left set - the indices of the socio-moral aspect; the indicators of the left set also explain about 84% of the variability in the indicators of the right set. Thus, the indicators of both sets are almost identical in informativeness to predict each other.

Next, the coefficients of regression equations were calculated, in which the responses are canonical variables that correspond to both canonical roots, and the predicates are the indicators of the left and right sets, respectively (Fig. 10).

Variable	Canonical weights, left set		Canonical weights, right set	
	Root 1	Root 2	Root 1	Root 2
SPI	-0.637697	-1.23817	-0.246226	1.81287
WGI	-0.445160	1.31968	-0.720910	1.19173
			-0.276181	-1.46789
			0.205126	-1.63576

**Fig. 10.** Table of canonical weight coefficients of sets

Let us write the regression equations of the canonical variables of the left and right sets that correspond to the root 1:

$$\text{root 1right} = -0,25WHR - 0,72GII - 0,28HDI + 0,21GCI$$

$$\text{root 1left} = -0,64SPI - 0,45WGI$$

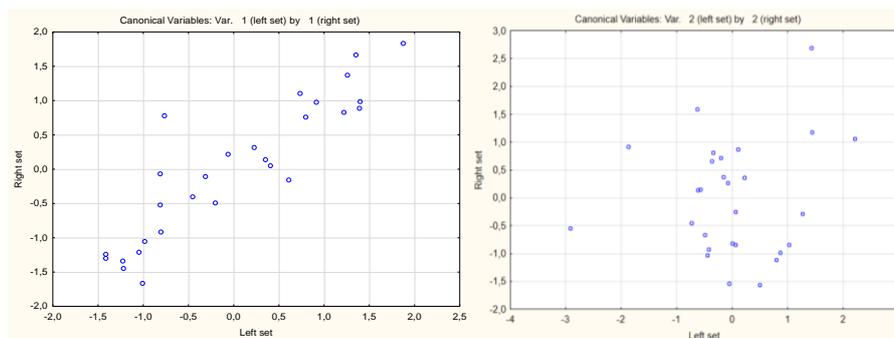
Let us write the regression equations of the canonical variables of the left and right sets that correspond to the root 2:

$$\text{root 2right} = 1,81WHR + 1,19GII - 1,46HDI - 1,64GCI$$

$$\text{root 2left} = -1,24SPI + 1,32WGI$$

In terms of the value and sign of the coefficients (canonical weights) for variables in the regression equations, for the ranking of countries by social aspect, the largest contribution to Root 1left corresponds to SPI, slightly less than WGI. For the ranking of countries by economic aspect, the largest contribution to Root 1right corresponds to the GII, the smallest – GCI. Regression equations for each root represent the weighted sum. To calculate the canonical values (values of canonical variables) for each country, it is necessary to substitute standardized (normalized) values of the country's indicators in the linear regression models corresponding to each set.

The analysis of the scattering cloud of observations in the space of canonical roots has a shape characteristic of linear dependence. The correlation between the values of the canonical variables of the left (indicators of socio-moral orientation) and the right set (economic orientation) is equal to 0.9038. The horizontal axis (abscissa) corresponds to the indicators of the indices of the socio-moral aspect, and the vertical axis (ordinate) - to the indicators of the indices of the economic aspect (Fig. 11).

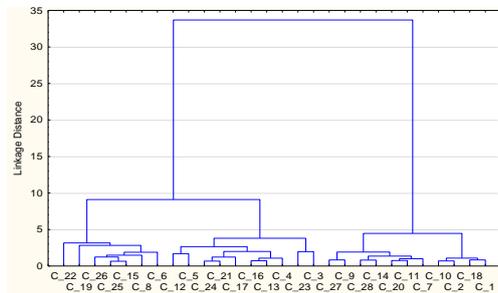


**Fig. 11.** Scattering diagram of canonical variables

The scattering diagram of the values of the canonical variables corresponding to the Root 2 has a cloud shape that is less characteristic of the linear relationship. This is due to the fact that the correlation between the values of the canonical variables of the left and right sets takes a small value equal to 0.1366.

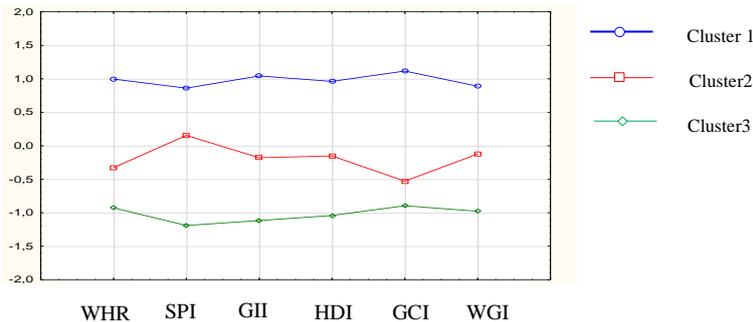
Thus, the analysis of the model of the relationship between the sets of indicators for assessing the quality of life of the population revealed the presence of strong relationships between all components of the sets. The results of the modelling, namely the construction of a scattering diagram of canonical values, gave the opportunity for further detailed analysis - the development of a model for the formation of clusters of EU member states according to international indices of living standards.

Hierarchical (tree-like) methods of cluster analysis were used to determine the current standard of living of the population of Ukraine in comparison with the EU countries. In the work to determine the number of clusters of regions of the EU countries a dendrogram of classification was constructed according to the method of Ward, depending on the values of international indices of living standards (Fig. 12).



**Fig. 12.** Dendrogram of the classification of EU countries by living standards according to the Ward method

Dendrogram analysis allows to recognize three groups (clusters) of homogeneous states in the observed data set. Based on the data of the dendrogram, the hypothesis of the existence of three clusters, which are divided into EU countries depending on the values of international indices of living standards is accepted in advance. An iterative method of clustering of k-means was used to divide the regions of the country into three clusters depending on the value of the components of the living standards of the population. The graph of average values for clusters of countries is given in Fig.13.



**Fig. 13.** Graph the means of each cluster

As can be seen from Fig. 13, clusters differ in all respects and you can see clearly defined boundaries between groups of objects. This corresponds to the initial assumption of the division of countries by living standards into three groups: countries with very high living standards; countries with a high standard of living; countries with an average standard of living. Thus, with the help of the obtained results of the classification model the countries are distributed by clusters (Table 3).

**Table 3** Distribution of countries by clusters

1st cluster	2nd cluster	3rd cluster
Austria	Czech Republic	Bulgaria
Belgium	Estonia	Croatia
Denmark	Italy	Greece
Finland	Malta	Hungary
France	Portugal	Latvia
Germany	Slovenia	Lithuania
Ireland	Spain	Poland
Luxembourg		Romania
Netherlands		Slovakia
Sweden		Cyprus
United Kingdom		

The results of analysis of variance: evaluation of the F-criterion, the values of intergroup and intragroup variances, showed the statistical significance of all selected indicators for clustering at 99 % (Fig. 14).

Variable	Analysis of variance					
	Between Group Variation	df	Within Group Variation	df	F	Significant p-value
WHR	19.50747	2	7.492533	25	32.54485	0.000000
SPI	21.08796	2	5.912037	25	44.58693	0.000000
GII	23.44965	2	3.550346	25	82.56115	0.000000
HDI	20.10858	2	6.891420	25	36.47394	0.000000
GCI	23.15670	2	3.843300	25	75.31516	0.000000
WGI	17.43817	2	9.561831	25	22.79659	0.000002

**Fig. 14.** Table of analysis of variance

Thus, the cluster No. 1 includes 11 countries with the highest ratings according to international indices of living standards compared to other countries. Therefore, it can be described as a cluster with countries with a very high level of development. Countries with a high level of development belong to the cluster № 2, namely 8 countries have average values of indicators of the level of development of regions in all studied areas. Paying attention to the fact that according to the Index of Social Progress, countries are closer to the countries of the first cluster, and according to the Index of Global Competitiveness - on the contrary, they fall to the indicators of the countries of the third

cluster. The member states of the European Union - Bulgaria, Croatia, Greece, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia were included in the cluster No. 3. These are the countries with an average level of development, which have the lowest level of population development among the countries of the European Union. Particular attention should be paid to the rather low indicators of the Social Progress Index and the Global Innovation Index, which indicate significant problems in the social and educational aspects.

We consider the next stage of modelling the living standards of the population - the implementation of the model of identification and forecasting the living standards of the population. The task is to use the International Indices for Assessing the Living Standards of the European Union (the Social Progress Index, the Global Innovation Index, the Human Development Index, the Global Happiness Report Index, the Global Competitiveness Index and the World Charitable Index) for classifying Ukraine into one of the three clusters identified by cluster analysis. The main characteristics of the model of recognizing the living standards of the population of the EU countries are shown in Fig. 15.

N=28	Discriminant Function Analysis Summary Step 4, N of vars in model: 4; Grouping: Cluster (3grps) Wilks' Lambda: 0.04509 approx. F (8,44)=20.401 p<0.0000					
	Wilks' Lambda	Partial Lambda	F-remove (2,22)	p-value	Toler.	1-Toler. (R-Sqr.)
GII	0.053644	0.840575	2.086278	0.148027	0.731639	0.268361
GCI	0.081887	0.550653	8.976275	0.001411	0.738063	0.261937
SPI	0.064797	0.695889	4.807120	0.018533	0.948881	0.051119
WGI	0.052473	0.859328	1.811704	0.188689	0.931293	0.068707

**Fig. 15.** Assessment of the adequacy of the model of discriminant analysis of EU countries by living standards

The value of Wilk's Lambda is close to zero (Wilk's Lambda = 0.045), which characterizes the excellent quality of discrimination. According to the analysis, it is seen that the GCI and SPI indices give the most significant contribution to the discriminant function, which was also noted when using the hierarchical method of clustering of  $k$ -means. The coefficients of discriminant functions for each of the indices of living standards assessment are calculated. Discriminant functions have the form:

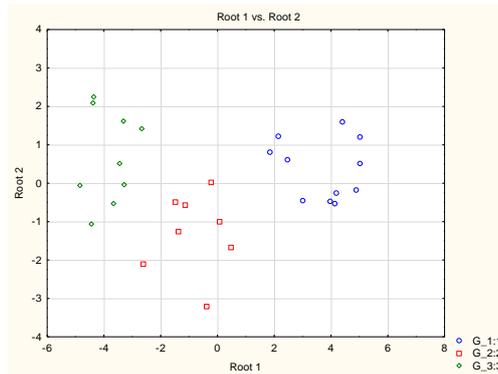
$$\text{Cluster1} = 3,44 \cdot \text{GII} + 5,70 \cdot \text{GCI} + 2,23 \cdot \text{SPI} + 2,47 \cdot \text{WGI} - 7,97;$$

$$\text{Cluster2} = 0,59 \cdot \text{GII} - 4,12 \cdot \text{GCI} + 1,2 \cdot \text{SPI} - 0,71 \cdot \text{WGI} - 2,42;$$

$$\text{Cluster3} = -4,73 \cdot \text{GII} - 3,31 \cdot \text{GCI} - 3,78 \cdot \text{SPI} - 2,39 \cdot \text{WGI} - 8,68,$$

Estimated values of classification functions for Ukraine: Cluster1 = -30,4757, Cluster2 = -0,56229, Cluster3 = 17,15047. Thus, Ukraine in terms of development of living standards of population can be attributed to cluster 3, namely the countries with average living standards, as the classification value for this function is maximum. The graph of the scattering of countries in the space of discriminant roots shows

that the objects in the three classes are grouped quite densely, and the distances between the classes are large enough (Fig. 16). This will allow us to prove with greater certainty that the recognition of countries by the three levels of life of the population has been done correctly.



**Fig. 16.** Scattering of countries in the space of discriminatory roots

The case, namely Ukraine, belongs to a group to which the distance of Mahalanobis is at least 16,458 – this is a group of countries with an average standard of living. The recognition of living standard of the population on the basis of the international indices and forecasting of its level both for the investigated period and for the future is carried out by the constructed discriminant functions. Given the results, we can once again make a statement that Ukraine in terms of living standards falls into the cluster № 3 - countries with average living standards.

## 5 Discussion and Conclusion

According to the research results it can be concluded that the analysis of modern approaches to the assessment of living standards shows that this issue remains controversial. It needs refinement and improvement due to a number of related problems, such as the lack of a universal method of analysis and assessment of the level, the difficulty of determining the optimal categorical basis, the measurement of which with objective indicators is almost impossible. Therefore, it is fair to make a proposal on the need to create a new system of analysis and assessment of living standards, which will include indicators that more objectively reflect the real situation not only in Ukraine, but it will be suitable for assessing living standards in Europe. The paper develops an adapted methodological approach to the rating of the European Union and Ukraine, which, in contrast to existing ones, is based on a combination of multidimensional analysis methods, namely the method of canonical correlations, cluster and discriminant methods, which allows to classify EU countries by living standards taking into account the differentiation of international indices of living standards for such groups of countries (with a very high level, high, average) and to refer our country to the third cluster of

countries. This allows to ensure the objectification of the evaluation results and to form a system of recommendations for further development of the country.

Prospects for further research include the possibility of developing separate strategies and trajectories of social development of the country and of a significant increase in living standards on the basis of the proposed set of models. The set of models can be expanded with additional modules for assessing the asymmetry of living standards by regions of the country and individual territories. This will build a decision-making system to equalize social asymmetry in general.

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