“Assessment of key parameters for clustering EU countries by socio-economic development components”

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ASSESSMENT OF KEY PARAMETERS FOR CLUSTERING EU COUNTRIES BY SOCIO-ECONOMIC DEVELOPMENT COMPONENTS

Abstract

Socio-economic development in the EU countries is a complex process encompassing both social and economic progress. It involves enhancements in living standards, quality of life, and overall well-being, alongside economic growth and structural changes. Thus, the paper aims to identify and assess the key parameters for clustering EU countries by the components of their socio-economic development. The study utilized fifteen indicators from the Social Progress Index and the Human Development Index, reflecting different components of countries' social development. Using the k-means method, the EU population is divided into three clusters (13, 5, and 9 countries, respectively) based on their similarity in social development. Then, using the decision tree method, the above indicators were assessed, including the following: "Nutrition and Medical Care," "Health," "Environmental Quality," "Rights and Voice," "Freedom and Choice," and "Advanced Education." These indicators are used as the key parameters for clustering countries by components of socio-economic development; therefore, their change largely determines the positions of countries as a whole and, accordingly, their convergence at the EU level. The study found significant differences between EU countries in their socio-economic aspects, particularly between the "old" and "new" members. The results obtained can be used to justify the priorities of EU socio-economic policy to ensure overall progress.

Keywords EU, member states, socio-economic development, components, indicators, clustering, classification analysis, key clustering parameters, assessment, supranational policy, convergence

JEL Classification C38, O15, O52

INTRODUCTION

Human capital is traditionally viewed as a crucial and specific economic resource, the foundation of economic activity, entrepreneurship, and a source of knowledge and innovation. The emphasis is primarily placed on highly skilled workers, who in the modern economy create the main specific advantages for both businesses and the country. This leads to increased global competition for human capital and an increase in the volume of resources directed toward improving its quality. In addition, in recent years, human capital has begun to be studied in a broader sense. Social development is increasingly viewed as a whole, encompassing its various components and manifestations. In addition to ensuring economic efficiency and competitiveness, social progress is crucial to achieving sustainability as a new management paradigm, which creates new requirements for its quality and provision.

Given the strategic objectives of the transition to sustainable development, the EU gives priority to ensuring the socio-economic development of its member states. This took the form of a targeted suprana-

tional policy to promote socio-economic development at all levels, involving the governments of all member states and lower-level entities in this process. This policy covers all major components of social progress, including employment, income, health, quality of education, reduction of inequality, etc., aligning with the Sustainable Development Goals (SDGs). At the same time, the EU needs to ensure the overall positive dynamics of socio-economic development in member countries, to overcome critical gaps in their individual components, which is especially relevant for countries that have become new members of this association. Given the multifaceted nature of socio-economic development, addressing the problems mentioned above facing the EU requires examining the primary differences and identifying key parameters for clustering member states in the social development area. This will allow us to identify the root cause of existing gaps and, by eliminating them, achieve a higher level of socio-economic convergence among member countries.

1. LITERATURE REVIEW

This article is a continuation of the previous study of Bilozubenko et al. (2025). It used the same methodology of clustering.

Ensuring human and social progress is critical to the modern economy. Given the synergy of the SDGs, it should be noted that social development is one of the main factors in increasing sustainability, environmental efficiency, and the transition to a sustainability model (Tahir et al., 2024). The SDGs related to social development are among the most important, as it is the change in the quality of human capital that allows us to increase the level of well-being (life) and improve the state of the environment (Payab et al., 2023). The experience of the G20 countries confirms this; therefore, considering the importance and role of human capital is crucial for improving the efficiency of public administration (Qing et al., 2024). Human capital development is closely linked to and a prerequisite for ensuring economic sustainability, which is consistent with the Sustainable Development Goals (in particular 1, 3, 4, 5, 8, 10, 13, and 16) and has become a priority issue on the global political agenda (Bekele et al., 2024).

Ensuring high-quality social (human) development for individual countries has become a priority task in terms of intensifying innovation, increasing productivity, and global competitiveness in the context of achieving the SDGs. Human resources, if managed effectively, are seen as essential to the competitiveness and sustainability of a company, manufacturing sector, industry, or the economy as a whole (Alzghoul, 2025; Masárová & Ivanová, 2023; Feng et al., 2024; Floyd et al., 2024). In modern economic conditions, given the increasing competition and stricter environmental requirements, the human factor is becoming the most important resource for all national economies striving to improve competitiveness and innovation. This creates competition for highly qualified personnel (talent). Based on this, the competitiveness of talents and competitiveness through talent are considered (Șerban & Andanut, 2014), which involves comparing countries, in particular, from the point of view of social development. Countries are trying to respond to the challenges by paying more attention to nurturing, attracting, and retaining talent (Lin et al., 2024). Talent is a factor that drives and influences the trajectory of innovation and determines the likelihood of its success, which requires increased attention to finding, developing, employing, and managing talent (Liu, 2024). Industry research shows that talent quality, among other things, is important for the progress and effectiveness of green innovation, therefore requiring the aggregation and development of highly skilled human capital (Liu et al., 2024). Talent has become a key resource for national progress, and talent competitiveness is a key indicator on which the performance of the innovation ecosystem depends (Huang et al., 2023). The importance of human capital quality for global competitiveness is universal for all countries, but is especially important for those that are lagging behind and need to modernize (Mulliqi et al., 2018).

The relevance of social development issues is increasing due to the growing demand for qualified human capital, which is only increasing in connection with modern economic transformations and technological changes (Polyakov et al., 2020; Hernik et al., 2025; Huaping & Binhua, 2022;

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Fahmi et al., 2025). In particular, talent agglomeration is important for intensifying innovation (Wang et al., 2023). It has been empirically confirmed that skilled human capital contributes to the growth of business activity and is important at all levels, for cities, regions, and countries as a whole (Hernández et al., 2023). Objectively, social development is characterized by significant spatial differences and is associated with increased competition for qualified human capital (Dey et al., 2024). In the global race for talent, the countries that are leading are those that pay more attention to the ability to ensure social development, its quality, growth parameters, and implementation. In terms of attracting talent, country factors are often more important than factors such as the place of work (Lepori et al., 2015).

Thus, the growing importance of human capital and the intensification of competition for this resource make the issue of ensuring sustainable social development, necessary for intensifying innovation, increasing economic productivity, efficiency, global competitiveness, and, most importantly, achieving sustainability, relevant for all countries. At the same time, in modern conditions, social development must be ensured in the context of international progress, particularly at the level of world regions and within the framework of integration associations such as the EU. This, among other things, presupposes a comparison of countries, a study of the differences and gaps between them, which is of fundamental importance from the point of view of competition. Paying increased attention to social development and solving social problems, the EU implements a comprehensive supranational policy in this area. Therefore, measuring social development parameters and tracking their changes is a separate methodological problem of statistical monitoring in the EU, in particular, related to determining the influence of social factors on economic growth, innovation, sustainability, etc.; characterization and assessment of the quality of human resources; measuring differences between countries, etc. (Brodny & Tutak, 2024).

An important step toward a more rational measurement of human progress, determined primarily by social goals, was the introduction of international indices (ratings), in particular the Human Development Index (HDI) and the Global Social Progress Index (SPI), which are among the most authoritative. Such information and statistical products have certain objective limitations. However, in general, they remain one of the most important sources of operational information for international comparisons, assessment of the positions and progress of countries as a whole, etc. (Hickel, 2020). This is essential to ensure the implementation of the SDGs. HDI and SPI include a specific set of indicators and assessments that reflect various components of countries' social development and can be used as separate parameters for relevant international comparisons and other studies (Abubakar et al., 2024; Singh et al., 2025; Pala, 2024; Beltrán-Esteve et al., 2023). This is necessary to address a wide range of state (supranational) social policy tasks related to achieving the SDGs, increasing well-being, improving education systems, talent management, etc. (Ma et al., 2025; Marlapudi & Lenka, 2023; Zhuravka et al., 2023).

The conducted research review proves the high attention paid to ensuring social development and management of its components in the world as a whole and especially in the EU. In this context, there are objective difficulties in measuring social progress, assessing changes in its components, and conducting appropriate analysis across different groups of countries, which is required by state and international policy. An analysis of research and expert practice confirms the need to improve the methodology of multidimensional international comparisons in the field of social development as a multifactorial phenomenon. Given the focus of EU policy on ensuring overall progress and convergence of member states in the social sphere, the study of their similarities and differences, covering various components of social development, becomes a particularly important issue.

The purpose of the study is to identify and assess the key parameters of clustering the EU countries by the components of their socio-economic development.

2. METHODS

Socio-economic development covers the reproduction and use of human capital, well-being, quality of life and human activity, empowerment, social justice, etc., which are assessed by appropriate in-

dicators. Their increase is crucial for achieving balanced social development and economic progress, as well as achieving sustainability, which is important for future generations. The indicators included in the Social Progress Index (SPI) (Social Progress Imperative, 2025) and the Human Development Index (HDI) (UNDP, 2024) were selected as assessments of sustainable social development components. The SPI summarizes 58 socio-economic and environmental indicators that describe different aspects of social development and divides them into three dimensions (Basic Needs; Foundations of Well-being; Opportunity), each of which includes four aggregate parameters (Table 1).

To demonstrate the approach, this study will include twelve aggregated parameters taken from the SPI-2024, calculated in scores without taking into account the rank of countries (Social Progress Imperative, 2025).

The Human Development Index (HDI) used by the United Nations Development Programme is a composite index that sums up four indicators reflecting key aspects of human development, three of which are used for the analysis: life expectancy at birth (years), expected years of schooling (years), and mean years of schooling (years) (UNDP, 2024). GNI per capita (PPP USD) is not included in the analysis as it introduces significant differences across countries and makes it difficult to focus on social parameters.

Table 2 presents a combined list of SPI and HDI parameters as indicators of social development components in EU countries. Based on the list, a set of empirical data was formed for the study.

Table 2. List of parameters characterizing the social development of countries (excluding units of measurement of HDI indicators)

Source: Social Progress Index (Social Progress Imperative, 2025), Human Development Index (UNDP, 2024).

Variable	Indicator
Social Progress Index indicators	
x_1	Nutrition and Medical Care
x_2	Water and Sanitation
x_3	Housing
x_4	Safety
x_5	Basic Education
x_6	Information and Communications
x_7	Health
x_8	Environmental Quality
x_9	Rights and Voice
x_{10}	Freedom and Choice
x_{11}	Inclusive society
x_{12}	Advanced Education
Human Development Index indicators	
x_{13}	Life expectancy at birth
x_{14}	Expected years of schooling
x_{15}	Mean years of schooling

When assessing the formed set of indicators, one should consider their heterogeneity and specificity, which is necessary for evaluating various components of social development. There are no indicators

Table 1. General structure of SPI parameters by measures

1. Basic Needs	2. Foundations of Well-being	3. Opportunity
Nutrition and Medical Care (Child mortality; Child stunting; Diet low in fruits and vegetables; Infectious diseases; Maternal mortality; Undernourishment)	**Basic Education** (Equal access to quality education; Gender parity in secondary attainment; Population with no schooling; Primary school enrollment; Secondary school attainment)	**Rights and Voice** (Equal protection index; Equality before the law and individual liberty index; Freedom of peaceful assembly; Political rights)
Water and Sanitation (Basic sanitation service; Basic water service; Satisfaction with water quality; Unsafe water, sanitation, and hygiene)	**Information and Communications** (Access to online governance; Internet users; Mobile telephone subscriptions; World Press Freedom Index)	**Freedom and Choice** (Early marriage; Freedom over life choices; Perception of corruption; Satisfied demand for contraception; Vulnerable employment; Young people not in education, employment)
Housing (Access to electricity; Dissatisfaction with housing; Affordability; Household air pollution; Usage of clean fuels and technology for cooking)	**Health** (Access to essential health services; Equal access to quality healthcare; Life expectancy at 60; Mortality 15–50; Satisfaction with availability of quality healthcare)	**Inclusive society** (Acceptance of gays and lesbians; Count on help; Discrimination and violence against minorities; Equal access index)
Safety (Feeling safe walking alone; Interpersonal violence; Intimate partner violence; Money stolen; Transportation-related injuries)	**Environmental Quality** (Lead exposure; Outdoor air pollution; Particulate matter pollution; Recycling; Species protection)	**Advanced Education** (Academic freedom; Citable documents; Expected years of tertiary schooling; Quality weighted universities; Women with advanced education)

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in the set that are completely duplicated or mutually exclusive. The three HDI parameters used do not contradict but complement the SPI parameters, expanding the possibilities of analysis. Differences in units of measurement are not important in this study. The interrelations and mutual influence of the indicators are not considered; the equal importance of all indicators and the contribution of each of them to social development are assumed. In terms of changes, all assessments and indicators included in SPI and HDI have the same focus on maximization and do not have possible saturation or minimum need. In general, we can say that the obtained set of indicators satisfies the conditions of consistency, sufficient completeness, and diversity in describing the complex phenomenon of social development, allowing us to cover its various aspects.

The determination of key parameters for clustering EU countries according to social development components takes place in two stages.

The first stage is to divide EU countries into clusters based on parameters that assess social development components. The indicators presented in Table 2 form the feature space for clustering, i.e., for dividing countries into relatively homogeneous groups based on the similarity of social development parameters. The possibilities of clustering countries according to a given data set are preliminarily visually assessed using a special web tool for 2D and 3D visualization, available on the scientific portal ScienceHunter. After this, it is advisable to determine the optimal number of clusters using the dendrogram and special calculation indicators (Sum of Squared Errors Index (SSEI), Davies-Bouldin Index, Trace Index, Calinski-Harabasz Index, Dunn Index, and PBM index). Given the nature of the data, it is proposed to cluster countries using the generally accepted *k*-means method (metric – Euclidean distance), which is widely used in socio-economic research and is effective when objects in a given dataset form fairly compact clusters that are well separated from each other. The calculation procedure for the *k*-means method is well known and does not require explanation. Tools for the corresponding calculations are also presented on the ScienceHunter portal.

The second stage is to identify, using classification analysis, those information groups of features (IGF) by which the resulting EU country clusters differ to the greatest extent. For classification, the data set is mathematically processed using the logical-combinatorial decision tree method, since it allows obtaining relatively small combinations of indicators with the maximum, if possible, absolute, separating (discriminating) power or information content, i.e., IGF. This will allow us to identify the most significant differences between clusters and, accordingly, to determine the greatest differences between countries in the entire general population. As a result of analytical processing, one or more combinations of indicators can be obtained. The informativeness of these IGFs will be compared with the information content of the entire data set (sample), depending on which one or more combinations may be selected as more suitable for analysis. Based on the essence of the classification analysis task, the indicators included in the IGF and most strongly separating clusters can be considered as key parameters for clustering EU countries by social development components.

The basis for the classification analysis is a training sample formed by an array of empirical data constructed according to the list given in Table 2, with the division of EU countries into classes (clusters) as a result of clustering. The separating ability (information content) of the entire sample, each of the indicators included in it, and their combinations is assessed directly based on the training sample data using the formula:

$$V\left(x_{i1},\ldots,x_{ij}\right)=\frac{1}{k}\sum_{\Delta\in\Gamma}\max_{Y}\left(\frac{m_{\Delta Y}}{m_{Y}}\right), \qquad (1)$$

where k is the number of classes (clusters); m_Y is the number of objects belonging to class (cluster) Y; $\Delta = t_{i1}, t_{i2}, ..., t_{ij}$ $(0 \le t_{ij} \le k_{ij} - 1)$ $(j = 1, ..., \Gamma)$ means the arbitrary set of parameter values $x_{i1}, ..., x_{ij}$ $(1 \le \Gamma \le n)$; $m_{\Delta Y}$ denotes the number of sampling sets of the m class, for which the relation $x_{ij} = t_{ij}$ $(j = 1, ..., \Gamma)$ is performed; t_{ij} are the values of parameters x_{ij} in the set of Δ; Γ means variety of all sets of parameter values $x_{i1}, ..., x_{ij}$. With complete separation (distinction) of classes, this estimate acquires a limit value equal to 1. If, as a result of the calculations, several IGFs with the highest separating power are identified, then within the framework of this study, a single list of parameters included in these IGFs will be compiled, considering their possible duplication.

3. RESULTS

First, based on the list of indicators given in Table 2, a feature space and a dataset for clustering EU countries were constructed. According to the 3D visualization, dendrogram, and special indices described earlier, it was determined that, based on the available dataset, it would be optimal to divide the EU countries into three clusters. This is the amount specified for mathematical data processing on the special tools of the ScienceHunter portal, which resulted in the distribution into three groups of 13, 5, and 9 countries (Table 3).

Table 3. EU country clusters by socio-economic development indicators obtained as a result of mathematical data processing

Clusters	Countries included in the cluster
I (13 countries)	Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Ireland, Luxembourg, the Netherlands, Slovenia, Sweden
II (5 countries)	Greece, Italy, Malta, Portugal, Spain
III (9 countries)	Bulgaria, Croatia, Cyprus, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia

Primary data and clusters of EU countries by social development indicators, as well as calculated auxiliary analytical indicators for each cluster and the entire population, are presented in Table A1 (Appendix A). The countries within each cluster are similar to each other, considering the entire array of indicators. Thus, clustering determined the general structure of the distribution of EU countries by social development indicators, reflecting their similarities and differences. Cluster I includes thirteen of the most economically successful countries, mainly from Western and Northern Europe, excluding the Czech Republic, Slovenia, and Estonia. It is characteristic that most of the countries in the cluster are "old" EU members (EU-15). The cluster includes mainly countries with the most powerful economies in the EU, as well as several relatively small countries that also demonstrate a high level of social development. Cluster II included five countries of Southern Europe, which, except for Malta, are considered "old" members. These countries have similar subregional proportions of economic structure and institutional specificity, which ultimately determined their similarity in social progress. Cluster III includes nine countries from Eastern and Southern Europe that are "new" EU members (enlargements of 2004, 2007, and 2013) and have historical similarities in economic dynamics and social development parameters.

The calculation of the arithmetic mean (Table A1, Appendix A) showed that cluster I is ahead of other clusters in most indicators (13 out of 15), and therefore can be considered as uniting the leading countries. This is also confirmed by the majority of the indicators' maximum values. At the same time, the cluster includes about half of the EU countries, which form a social development "locomotive" of the entire association. Cluster II, in turn, also surpasses cluster III in most indicators (11 out of 15), that is, the "old" members of Southern Europe demonstrate a higher level of social development than the "new" members from Eastern and Southern Europe. In terms of maximum values of indicators, cluster II is ahead of cluster III only in five indicators out of fifteen. Cluster III's lag is also evidenced by the fact that it accounts for ten absolute minimum values in the sample.

The calculation of the coefficient of variation showed that the sample is generally quite homogeneous: the highest values of this coefficient for each of the indicators are much less than the conditional threshold of 33%. The maximum value of the variation coefficient for x_7 is 11%, for x_{11} and x_{12} it is 12%, for x_{11} it is 10%. Naturally, individual clusters are even more homogeneous. In cluster I, the value of the coefficient of variation for the indicators does not exceed 10%; in cluster II, the coefficient is 10% only for one indicator, and in cluster III, it is 11% only for one indicator. The analysis of the leadership of individual countries in clusters shows the same picture. In cluster I, only Denmark leads in five out of fifteen indicators, Finland in three, Germany, Luxembourg, and Sweden in two, and Belgium in one. In cluster II, the situation is similar: Italy and Malta are leaders in four indicators out of fifteen, Greece in three, Portugal and Spain in two.

Second, based on the clustering results, a training sample is formed, where each cluster of countries can be represented as a separate class. Considering the task of classifying clusters, i.e., finding the main differences, the obtained training sample was subjected to mathematical processing to assess its ability to completely separate (distinguish) classes according to equation (1). The corresponding assess-

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ment was 1, which proves the possibility of absolute separation of all classes. That is, the available training sample is informative and suitable for cluster classification to find the main differences between them. Knowing the assessment of the separating power (informativeness) of the entire training sample, the separating power of each indicator included in it was evaluated, and the results are presented in Table 4.

Table 4. Assessing the separating power of individual indicators within the existing training sample

Variable	Indicator name	Separating power
Social Progress Index indicators		
x_1	Nutrition and Medical Care	0.62
x_2	Water and Sanitation	0.61
x_3	Housing	0.42
x_4	Safety	0.49
x_5	Basic Education	0.56
x_6	Information and Communications	0.59
x_7	Health	0.59
x_8	Environmental Quality	0.55
x_9	Rights and Voice	0.58
x_{10}	Freedom and Choice	0.59
x_{11}	Inclusive society	0.61
x_{12}	Advanced Education	0.59
Human Development Index indicators		
x_{13}	Life expectancy at birth	0.63
x_{14}	Expected years of schooling	0.61
x_{15}	Mean years of schooling	0.58

As Table 4 shows, the separating power of individual indicators ranges from 0.42 to 0.63; that is, there is no single indicator that would completely or at a high level separate all clusters from the rest. This necessitates the search for specific combinations of indicators (i.e., IGFs) that have a higher total separating capacity than individual indicators and are close to the entire training sample's separating power, i.e., to the complete separation of classes. The two-characteristic IGFs identified during mathematical processing did not show a significantly higher separating power than individual indicators. When testing combinations of three features, several IGFs with a high and absolute level of separating power were obtained, namely:

1. combination "x_1, x_7, x_9" (separating power – 1);
2. combination "x_1, x_8, x_{10}" (separating power – 0.96);
3. combination "x_1, x_{10}, x_{12}" (separating power – 0.96).

Given that two of the obtained IGFs have a separating power level close to absolute, and one completely distinguishes between classes, further search for combinations of four or more indicators was not performed.

Thus, based on the results of the classification analysis, combinations of indicators were identified that completely or almost completely distinguish the previously obtained clusters of EU countries. Given that within each cluster, the countries have the greatest similarity in the structure of social development indicators, the resulting combinations (IGFs) include key parameters of country clustering in this area. This means that the indicators obtained within certain combinations determine, to the greatest extent, the positions of countries in the aggregate and, accordingly, the gaps (divergence) between countries included in different clusters. Therefore, an increase or decrease in the indicators for these IGFs will lead to the most significant change in the positions of countries and their belonging to one cluster or another. Given the above, the indicators included in the selected combinations of IGFs within the available dataset should be considered key parameters for clustering EU countries in the area of social development. Each indicator reflects a certain component of such development, so the identified parameters in the period under study can be considered as the most significant factors that determine the gaps between EU countries in the field of social development. Therefore, from the point of view of countries that are significantly behind the leaders or the EU average and are seeking to improve their positions as quickly as possible, the key parameters obtained should be considered as priorities for improvement.

It is advisable to combine the main parameters of clustering EU countries by social development components, obtained in the form of the IGF, into a single list, namely (all parameters are taken from the SPI; therefore, they are presented in detail in Table 1):

x_1: "*Nutrition and Medical Care*" is the only indicator from the "Basic Needs" column that was included in the IGF, which demonstrates that significant differences in basic needs persist between EU countries. The extremely high significance of this parameter is due to the fact that it evaluates infant and maternal mortality, malnutrition, and infectious diseases, etc., and is confirmed by its inclusion in all selected combinations.

x_7: *"Health"* – The inclusion of this indicator from the "Foundations of Well-being" column in the IGF proves that the health sector, which is of particular importance for improving demography, the quality of the workforce, and raising the standard of living of the population, is a problematic area for the EU. The indicator assesses various aspects of healthcare (access to basic health services, life expectancy, mortality rate, satisfaction with health care, etc.) and demonstrates the existence of a significant gap in healthcare between economically prosperous and less prosperous EU countries.

x_8: *"Environmental Quality"* is also from the "Foundations of Well-being" column and is one of the most important from the point of view of ensuring social development and sustainability. Given its content (air pollution, particulate matter pollution, waste management, etc.), its inclusion in the IGF confirms that significant differences remain between EU countries in the area of environmental protection. This indicates objective differences between countries, which hinder the implementation of the European Green Deal goals.

x_9: *"Rights and Voice"* – Quite unexpectedly for EU countries, this indicator was included in the IGF from the "Opportunities" column, which evaluates equal protection, equality before the law, and personal freedoms, freedom of peaceful assembly, etc. However, given the division into clusters (Table 3), it can be objectively stated that significant differences remain between the "old" and "new" EU member states in this area.

x_{10}: "*Freedom and Choice"* is an indicator from the "Opportunity" column that summarizes the assessment of many social problems (early marriage, freedom to choose a life path, perception of corruption, unstable employment, young people who do not study or work, etc.). Its inclusion in the IGF confirms internal social differentiation in the EU, which requires more detailed study.

x_{12}: "*Advanced Education*", an indicator from the "Opportunity" column, is critical in this study because it summarizes the assessment of academic freedom, cited scientific publications, expected years of study in higher education institutions, quality of universities, gender levels of higher education completion, etc. The inclusion of this indicator in the IGF confirms the problematic nature of higher education in the EU, as the differentiation of countries in this area is the cause of socio-economic inequality in many respects.

Overall, the results obtained indicate that a significant level of convergence has been achieved between EU countries in parameters such as "Water and Sanitation," "Housing," "Safety," "Basic Education," "Information and Communications," and "Inclusive Society." This, to some extent, confirms the effectiveness of EU social policy, especially in terms of ensuring basic needs, education policy, supporting digital transformation, and achieving social inclusion. On the other hand, the analysis shows that there are serious problems in important areas represented by the indicators of the above-listed IGFs. This is especially true for the "Opportunity" group, from which three out of four indicators were included in the selected IGFs. Apparently, this is due to the still unresolved differences between the "old" and "new" member states. The calculation of statistical indicators (Table A1, Appendix A) showed that the level of capabilities in the "new" member states and the countries of Southern Europe should be significantly increased in the context of institutional harmonization in the EU area. This requires greater intensification of social policy in these lagging member states and additional intervention by the EU.

Given the high level of separating power, the obtained IGFs and the parameters extracted from them are suitable for further analysis and management of social development in EU countries. In terms of developing national or supranational

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policies, not only are individual indicators selected as key parameters for clustering EU countries important, but also the resulting combinations of the IGFs, as this proves the relationship between certain indicators. It should also be taken into account that in the SPI methodology, all the selected indicators are complex assessments (Table 1); therefore, their increase should be carried out accordingly. For this purpose, more detailed studies can be conducted, considering data on all elements of these assessments. It is characteristic that not a single parameter from the HDI was included in the obtained IGF that does not affect the overall results of the study, and this is primarily because the SPI components calculated using the same methodology can more easily form combinations with each other in a relatively homogeneous population, such as the EU countries.

Thus, the proposed methodology forms a holistic procedure for conducting multidimensional analysis of social development and relevant international comparisons, allowing for obtaining high-quality results. These results can be easily interpreted to explain the causality of specific processes, phenomena, similarities, and differences between countries. The methodology can be used in various areas of international studies, both independently and in addition to other analytical approaches. This methodological approach is important in terms of achieving the SDGs, as it identifies priorities for accelerated development, lagging countries, and bridging gaps between countries at the regional and global levels. This is particularly important for the EU as a whole, which remains very heterogeneous in terms of social development.

4. DISCUSSION

Confirmation of the reliability of the proposed methodology for determining the key parameters of clustering countries by social development components allows us to determine the main directions of its use. Firstly, based on the developed methodology, a systematic (for example, annual) study of gaps in social development between countries (groups of countries) can be conducted, substantiating the reasons for their occurrence in dynamics. Secondly, the application of the methodology provides objective grounds for implementing the principle of selectivity, which allows us to determine priority indicators from the point of view of overcoming country differentiation and, on this basis, formulate policies in the social sphere. At the international level, this may be aimed at bridging the gap between countries; at the national level, it aims to accelerate social progress compared to other countries. Identifying key clustering indicators (as priorities for overcoming) will help specify strategic roadmaps for individual countries or groups of countries and build a system of targeted measures, for example, at the EU level. In particular, this allows investments to be directed toward improving individual components of social development, combining social programs and economic projects, and stimulating social innovation. Thirdly, the study of the parameters of country clustering (according to the components of SPI, HDI, or other indicator systems) at the global level will allow us to form an idea of the global "landscape" and the dynamics of the architecture of social development, as well as the problems of different countries. This will create the basis for improving the effectiveness of global governance by making it better adapted to the current situation. Therefore, international organizations and individual states can use the proposed methodology in the context of the transition to sustainable development, ensuring more efficient use of resources to achieve the SDGs.

Thus, the proposed methodology expands the possibilities of international comparisons, allowing for a more detailed study of social development from the point of view of ensuring the sustainability of progress (Payab et al., 2023; Bekele et al., 2024). The methodological approach presented in the study is appropriate to substantiate decisions in the field of human resource management (Tahir et al., 2024; Marlapudi & Lenka, 2023) and public administration (Qing et al., 2024). This will allow resources to be focused on training highly qualified specialists to meet the growing demand for human capital (Huaping & Binhua, 2022) and thereby achieve high-quality economic progress (Ma et al., 2025). A separate aspect of using the methodology is conducting a competitive analysis, dividing countries (or regions, cities, companies) into groups (types), and identifying their key differences, strengths, and weaknesses (Wang et al., 2023; Hernández et al., 2023; Lepori et al.,

2015). Of course, the analysis and similar studies will complement modern methodology for assessing spatial differences in human development, including differences between countries and regions (Wang et al., 2023; Dey et al., 2024; Zhuravka et al., 2021). The developed approach will expand the possibilities for assessing the characteristics of human and social development in individual groups of countries (Brodny & Tutak, 2024), identifying their main drivers or constraints (Abubakar et al., 2024; Singh et al., 2025; Pala, 2024; Beltrán-Esteve et al., 2023). In general, the methodology is quite universal and, in particular, can be used to assess the achievement of the SDGs (Hickel, 2020).

CONCLUSION

The paper aims to identify and evaluate key parameters for clustering EU countries by the components of their socio-economic development. It uses different indicators from the Social Progress Index and the Human Development Index, reflecting the socio-economic development of EU members. According to the study results, the EU population is divided into three clusters (13, 5, and 9 countries, respectively) based on their similarity in socio-economic development, i.e.:

1. Cluster I: Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Ireland, Luxembourg, the Netherlands, Slovenia, Sweden;

2. Cluster II: Greece, Italy, Malta, Portugal, Spain;

3. Cluster III: Bulgaria, Croatia, Cyprus, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia.

The results indicate that a significant level of convergence has been achieved between EU countries in parameters such as "Water and Sanitation," "Housing," "Safety," "Basic Education," "Information and Communications," and "Inclusive Society." This, to some extent, confirms the effectiveness of EU socio-economic policy, especially in terms of ensuring basic needs, education policy, supporting digital transformation, and achieving social inclusion. On the other hand, the analysis shows that there are serious problems in important areas represented by the indicators of the above-listed IGFs.

Finally, the results obtained can be used to justify the priorities of the EU socio-economic policy to ensure overall progress.

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APPENDIX A

Table A1. EU country clusters by social development indicators

Countries	Indicators (the numbering corresponds to Table 1)														
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}
Cluster I															
Austria	93.58	95.66	92.42	85.59	96.25	87.64	81.82	76.88	95.06	82.38	78.43	75.04	82.4	16.4	12.3
Belgium	93.65	93.03	91.78	80.41	95.47	80.43	83.80	73.39	96.54	85.06	83.53	76.45	82.3	18.9	12.5
The Czech Republic	90.43	95.87	90.05	83.46	97.82	83.31	76.45	74.31	95.86	81.82	78.50	69.98	78.1	16.3	12.9
Denmark	93.85	97.21	93.70	88.00	98.27	94.28	81.48	77.71	98.12	90.29	88.33	83.34	81.9	18.8	13.0
Estonia	90.85	94.79	92.11	84.79	98.16	93.63	70.87	79.68	94.63	83.24	67.02	72.31	79.2	15.9	13.5
Finland	91.06	98.38	94.77	86.19	96.31	94.26	77.00	79.26	96.78	88.8	93.82	82.85	82.4	19.2	12.9
France	90.54	93.04	90.61	82.46	93.41	84.78	78.91	75.16	92.29	83.55	73.44	68.42	83.2	16.0	11.7
Germany	92.14	96.31	91.35	84.46	97.48	87.34	81.25	80.67	97.53	86.65	80.98	75.54	81.0	17.3	14.3
Ireland	93.03	89.82	88.79	84.45	95.78	89.20	75.81	78.41	96.68	86.04	87.36	73.48	82.7	19.1	11.7
Luxembourg	92.61	95.41	89.11	89.59	98.62	89.42	83.38	80.31	96.29	87.85	87.44	64.26	82.6	14.2	13.0
The Netherlands	91.66	95.98	86.77	86.12	94.99	94.16	82.13	72.27	94.25	87.66	87.33	79.47	82.5	18.6	12.6
Slovenia	91.72	96.77	85.28	89.33	98.51	84.31	74.26	73.63	88.64	81.73	79.29	71.74	82.1	17.4	12.9
Sweden	91.88	98.62	90.29	85.55	94.78	89.73	81.30	79.98	96.62	89.94	90.51	79.83	83.5	19.0	12.7
Min	90.43	89.82	85.28	80.41	93.41	80.43	70.87	72.27	88.64	81.73	67.02	64.26	78.1	14.2	11.7
Max	93.85	98.62	94.77	89.59	98.62	94.28	83.8	80.67	98.12	90.29	93.82	83.34	83.5	19.2	14.3
SD[1]	1.14	2.30	2.53	2.49	1.60	4.41	3.78	2.85	2.43	2.92	7.15	5.41	1.49	1.54	0.66
Average[2]	92.08	95.45	90.54	85.42	96.60	88.65	79.11	77.05	95.33	85.77	82.77	74.82	81.84	17.47	12.77
CV[3]	1%	2%	3%	3%	2%	5%	5%	4%	3%	3%	9%	7%	2%	9%	5%
Cluster II															
Greece	96.69	89.79	88.89	80.4	90.87	75.99	70.4	69.16	87.43	67.14	72.3	72.08	80.6	20.0	11.4
Italy	94.86	93.11	91.56	81.83	92.62	83.27	78.40	74.54	92.99	70.50	81.15	68.43	84.1	16.7	10.7
Malta	93.28	91.49	87.94	86.20	93.43	82.42	84.37	62.06	90.94	78.39	87.90	53.69	83.7	15.9	12.2
Portugal	94.59	95.78	87.50	85.86	88.58	86.34	77.10	71.99	89.87	82.33	83.50	65.79	82.2	16.8	9.6
Spain	95.36	92.46	88.03	88.19	89.49	86.85	77.67	74.29	91.44	79.00	74.64	68.98	83.9	17.8	10.6
Min	93.28	89.79	87.5	80.4	88.58	75.99	70.4	62.06	87.43	67.14	72.3	53.69	80.6	15.9	9.6
Max	96.69	95.78	91.56	88.19	93.43	86.85	84.37	74.54	92.99	82.33	87.9	72.08	84.1	20	12.2
SD[1]	1.11	1.97	1.46	2.91	1.83	3.89	4.44	4.60	1.85	5.69	5.73	6.37	1.33	1.42	0.87
Average[2]	94.96	92.53	88.78	84.50	91.00	82.97	77.59	70.41	90.53	75.47	79.90	65.79	82.90	17.44	10.90
CV[3]	1%	2%	2%	3%	2%	5%	6%	7%	2%	8%	7%	10%	2%	8%	8%
Cluster III															
Bulgaria	91.66	84.92	89.73	79.22	87.91	79.81	57.41	64.40	86.09	70.76	67.81	55.23	71.5	13.9	11.4
Croatia	91.09	91.32	91.66	85.43	96.83	82.79	67.80	69.57	84.48	71.88	66.10	64.01	79.2	15.6	12.3
Cyprus	91.28	88.12	87.19	82.56	95.25	83.97	77.37	69.63	91.07	72.98	67.62	75.56	81.9	16.2	12.4
Hungary	91.49	93.65	88.19	82.47	92.36	77.42	60.87	70.87	73.85	73.55	70.7	54.26	75.0	15.1	12.2
Latvia	89.42	92.91	90.44	80.89	95.02	87.79	61.42	72.98	93.77	79.88	61.72	67.18	75.9	16.6	13.3
Lithuania	90.68	90.89	91.50	80.28	96.64	83.61	62.16	75.74	91.57	76.34	71.15	67.52	74.3	16.4	13.5
Poland	92.24	90.84	87.55	83.87	94.87	80.82	63.77	71.49	81.67	75.58	69.35	62.31	77.0	15.9	13.2
Romania	92.18	88.05	89.95	80.53	87.75	80.33	58.80	63.27	79.04	71.89	57.77	53.31	74.1	14.5	11.4
Slovakia	90.08	93.87	89.20	81.20	92.70	81.21	66.68	67.25	91.06	74.42	67.54	59.31	75.3	14.7	13.0
Min	89.42	84.92	87.19	79.22	87.75	77.42	57.41	63.27	73.85	70.76	57.77	53.31	71.5	13.9	11.4
Max	92.24	93.87	91.66	85.43	96.83	87.79	77.37	75.74	93.77	79.88	71.15	75.56	81.9	16.6	13.5
SD[1]	0.88	2.81	1.52	1.83	3.23	2.81	5.68	3.75	6.32	2.65	4.09	6.94	2.87	0.88	0.74
Average[2]	91.12	90.51	89.49	81.83	93.26	81.97	64.03	69.47	85.84	74.14	66.64	62.08	76.02	15.43	12.52
CV[3]	1%	3%	2%	2%	3%	3%	9%	5%	7%	4%	6%	11%	4%	6%	6%
For all countries															
Min	89.42	84.92	85.28	79.22	87.75	75.99	57.41	62.06	73.85	67.14	57.77	53.31	71.5	13.9	9.6
Max	96.69	98.62	94.77	89.59	98.62	94.28	84.37	80.67	98.12	90.29	93.82	83.34	84.1	20	14.3
SD[1]	1.71	3.29	2.18	2.87	3.20	4.99	8.33	5.07	5.89	6.61	9.47	8.48	3.55	1.64	1.01
Average[2]	92.29	93.26	89.87	84.05	94.45	85.37	73.80	73.29	91.28	79.99	76.86	68.90	80.10	16.79	12.34
CV[3]	2%	4%	2%	3%	3%	6%	11%	7%	6%	8%	12%	12%	4%	10%	8%

Note: [1] SD – Standard deviation; [2]Average – Arithmetic mean; [3]CV – Coefficient of variation.