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# RESEARCH OF THE PLACE OF UKRAINE IN IMPLEMENTATION OF THE GOALS OF THE SUSTAINABLE DEVELOPMENT MODEL

*Об'єктом дослідження є система процесів визначення рівня розвитку країни в контексті моделі сталого розвитку. Одним з найбільш проблемних місць є помилково побудовані чи неправильно інтерпретовані композитні показники, які можуть стати причиною спрощених аналітичних чи політичних висновків.*

*Проведено дослідження щодо використання композитних показників як інструментів ідентифікації тенденцій розвитку країн Європейського Союзу, що дало можливість визначити переваги і недоліки їх застосування. А також встановити спільні та відмінні риси з показниками, зазначеними у Стратегії сталого розвитку країни до 2030 року. Здійснено побудову ієрархічної системи композитних показників з подальшою їх перевіркою на повноту і розмірність, відповідно до вимог вибраних теоретико-методологічних методик аналізу.*

*В ході дослідження визначено взаємозв'язану послідовність кроків щодо визначення інтегрального показника для кожної з досліджуваних країн з метою їх рейтингового оцінювання на основі системи отриманих композитних показників та їх вагомості. На основі отриманих індивідуальних значень центровано-нормованих головних компонент для кожної з досліджуваних країн та визначених змістовних інтерпретацій головних компонент, проведено попарний порівняльний аналіз в межах досліджуваної множини країн. А також здійснено кластерний аналіз, який дав змогу визначити групи країн, близькі за значенням інтегрального показника. Проведено ранжування досліджуваних країн на основі розрахунку індивідуальних інтегральних показників розвитку, обчисленого як сума її інтегральних показників по двох підмножинах – індикаторів-стимуляторів і індикаторів-дестимуляторів.*

*Дослідження 33 країн дало змогу визначити місце України в напрямку реалізації окремих цілей її розвитку на основі системи композитних показників. А також оцінити відносну віддаленість України як від держав, які є близькими за своїм соціально-економічним розвитком, так і від високорозвинутих європейських країн.*

**Ключові слова:** *модель сталого розвитку, композитні індикатори, кластерний аналіз, тенденції розвитку країни, індикатори-стимулятори, індикатори-дестимулятори.*

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## 1. Introduction

In 2015, the United Nations (UN) identified new Sustainable Development Goals for the global community. Despite this, the concept of sustainable development plays an increasingly important role in the context of identifying key areas of government policy at both the national and global levels.

This Concept brings together various but interrelated areas of human development, ranging from environmental protection, the impact on it of sustainable economic growth rates, to key trends in social integration.

Today, the introduction of the doctrine of progressive balanced socio-economic development into the practice of public administration is extremely relevant. This doctrine should have clearly identified strategic goals and the potential for their implementation, and harmoniously connect them with global trends of world development.

Therefore, the study of building effective models of strategic development of both individual national states and the entire world community in the context of specific strategic goals is relevant. For a particular country, such models can be used as a tool for developing strategic development plans.

## 2. The object of research and its technological audit

*The object of research* is a system of processes for determining the level of a country's development in the context of a sustainable development model.

193 countries of the world in 2015 approved the Global Sustainable Development Goals (SDG) until 2030. It was assigned 17 goals and 169 development objectives that all countries of the world today adhere to, setting their own development indicators. Each country adapts them to its priorities and tries to achieve it based on its own capabilities and available resources.

September 15, 2017 The Government of Ukraine presented the National Report «The Sustainable Development Goals of Ukraine», which defines the basic indicators for achieving the SDG. With the assistance of the UN system, an adaptation of the SDG was carried out in Ukraine. Taking into account all the impact factors using information, statistical and analytical materials, a national system of the SDG has been developed (86 development objectives and 172 indicators for monitoring their performance).

An analysis of the information base available in Ukraine for monitoring global indicators of the SDG achievement shows that, at present, the state statistical bodies collect information on 96 indicators.

At the same time, information is collected and developed: for 52 indicators – in full compliance with existing international standards, and for 44 indicators – in incomplete compliance (partial) with existing international standards.

It should be noted that 35 global indicators are not quantifiable and, as a rule, can be calculated by international organizations. The remaining indicators remain uncertain (if they are available, additional consultations with state authorities are needed) or require methodological explanations from the Interdepartmental Expert Group.

Problems that may make it difficult to conduct high-quality monitoring of the SDG:

1) at the global level:
- lack of methodology for determining a number of indicators;
- a number of indicators require the organization and introduction of special surveys;
- existing methodology is scattered among international organizations;

2) at the national level:
- lack of methodology and method for calculating a number of indicators;
- lack of a methodology for analyzing the compliance of national indicators with international standards;
- absence of a normative act defining the CEA (central executive authorities), which is responsible for developing a procedure for conducting monitoring at both the international and national levels, as well as the CEA responsible for providing information;
- insufficiency of the Ukrainian information base, which makes it necessary to introduce special surveys.

So, one of the most problematic places for research is the composite indicators that are mistakenly constructed or misinterpreted, which can lead to simplified analytical or political conclusions.

## 3. The aim and objectives of research

*The aim of research* is identification of the place of Ukraine in comparison with other European countries on the basis of key indicators (I-indicator) of the implementation of the Sustainable Development Strategy, identified as priorities for Ukraine.

To achieve this aim it is necessary to perform the following objectives:

1. To identify a variety of key indicators from a full set of indicators using descriptive statistics methods.
2. To determine the system of composite indicators (SCI-indicator) and on their basis to carry out a pair-wise comparison of countries in the directions of realization of individual goals of their development based on a system of composite indicators.
3. To form groups of countries that are close in terms of the values of the integral indicator and assess the relative remoteness of Ukraine both from countries that are close in their socio-economic development and in highly developed European countries.
4. To determine the integral assessment of countries (GCI-indicator) in the system of indicators of sustainable development.

## 4. Research of existing solutions of the problem

One of the first attempts to use composite indicators (SCI) as tools for policy analysis and public communication is proposed in [1]. More than 160 indicators are considered that would make it possible to compare the development of countries with each other. At the same time, it is pointed out that they could be used in the study of complex systems such as separate public areas of activity, economic systems, technological development, etc.

Composite indicators as tools for identifying development trends of individual countries, as well as for comparative analysis of effective management are presented in [2]. The advantages and disadvantages of using composite indicators, if they are mistakenly constructed or misinterpreted, may lead to simplified analytical or political conclusions. It is the possibilities of using such indicators in the context of evaluating the effectiveness of policies (economic, social, etc.) are presented in [3].

A very important aspect in the definition of a composite indicator has the existence of a corresponding basic formalized model of their formation. The need to form an integral set of composite indicators for evaluating multidimensional complex systems is indicated in [4].

In the matter of using composite indicators, there are two opposing approaches: the first, defending the effectiveness of their use, draws an analogy of their construction with the construction of mathematical or computational models. And the success of their application, to a decisive extent, depends on the perfection of the applied model, according to which such indicators are built. To a lesser extent, depend on the generally accepted scientific rules of their construction [5].

The second approach advocates the view that it is necessary to determine the most complete set of indicators exclusively without their further integration into composite indicators. This line of scientific thought is identified as «anti-aggregation». And it is most fully represented in [6].

The widespread use of composite indicators is observed in the countries of the European Union (EU). In particular, the methodology adopted by the governing bodies of the European Union is used to rank the development level of the member countries of the community, based on the calculation of the integral indicator, which is based on a system of input indicators. A clearly formalized hierarchical model for calculating composite indicators for development goals, and already on their basis an integral indicator is calculated for each of the countries. The basis of the calculation of composite indicators is the concept of knowledge bases. Quite fully, this technique is presented in [7].

Within the UN, there are expert groups that deal with a range of tasks related to the implementation of the Sustainable Development Concept. The system of indicators and methodologies for calculating composite indicators are developed, on the basis of which the annual ranking of the member countries of the organization is carried out. The analytical report on the results of the development of countries in 2017 is rather fully presented in [8].

In Ukraine, in the framework of the Country Development Strategy until 2030, a system of indicators is developed [9]. The method of their calculation is developed under the auspices of the Ministry of Economic Development and Trade and is presented in [10]. However, this system of indicators defined in the framework of the State Development Strategy is weakly consistent with the system of indicators defined within the UN framework. At the same time in Ukraine there is a significant interest of the scientific community on the implementation of programs and projects to achieve the Sustainable Development Goals at the national level. Conceptual approaches to the implementation of such a country's development strategy are most fully represented in [11].

Thus, the results of literary analysis allow to conclude that the methods of current assessment of the implementation of sustainable development goals in terms of their priority for Ukraine are not fully investigated. There is a discrepancy between the system of indicators, which determine the implementation of the Sustainable Development Goals in Ukraine and in other countries, particularly European ones, which makes it difficult to use foreign methods.

## 5. Methods of research

Economic statistical methods and models are used as a theoretical basis of research:

– methods of descriptive statistics – calculation of key statistics of the system of input indicators, for a preliminary analysis of the set of input indicators for compliance with their normal distribution;
– methods of correlation analysis and related methods of analysis of the correlation matrix, which found their use both at the stage of preliminary filtration of the system of input development indicators, and in most of the methods used in the study;
– methods of factor analysis, in particular the method of principal components, as a tool for constructing composite indicators. As well as methods for assessing the statistical significance of a system of factors that act as composite indicators of the methodology for presenting eigenvalues of the countries studied through a certain system of principal components;
– methods of cluster analysis, in particular, the *k*-means method, for the complete identification of the relative position of Ukraine in comparison with the neighboring European countries, based on the eigenvalues of the centered-normalized main components;
– methods of calculating the integral indicator of development for each of the countries studied on the basis of a preliminary division of the entire set of input indicators into two subsets – indicator-stimulators and indicator-disincentives.

The professional statistical data processing system Statistica for Windows is used as a tool for implementing most of the above methods and techniques.

## 6. Research results

The study is conducted on the basis of data provided by the UN and other international organizations in the context of a system of indicators defined by these organizations for monitoring the implementation of the strategy for achieving the Sustainable Development Goals [10]. According to [11–13], the monitoring system of the implementation of the Sustainable Development Strategy is defined as a hierarchical system of indicators. It can be formally presented in the form of an interconnected system of goals, objectives and a corresponding set of indicators (Fig. 1).

The logic of the proposed approach to solving the main tasks within a certain research objective is based on a reasonably selected set of indicators to form a statistically significant set of factors that explain a certain level of variance of the initial set of indicators. In the future, on the basis of certain factors, identify the relative of Ukraine relative to neighboring European countries in the direction of the implementation of the Sustainable Development Strategy. At the same time, first quantify the closeness of the relationship between indicators and factors, followed by justification of the ranking estimates of the influence of each of the factors on the integral indicator of evaluation of each of the countries studied in the direction of its exit to the trajectory of sustainable development. Such logic is well illustrated by Fig. 2, which presents a hierarchical three-level model of indicators, which demonstrates the relationship of input data ($I_k$-indicators) with knowledge in the form of a set of composite $\{SCI_k\}$, $(k=1.17)$ followed by the definition of the Global Composite Indicator – GCI.


**Fig. 1.** Sustainable Development Goals 2030 [9]

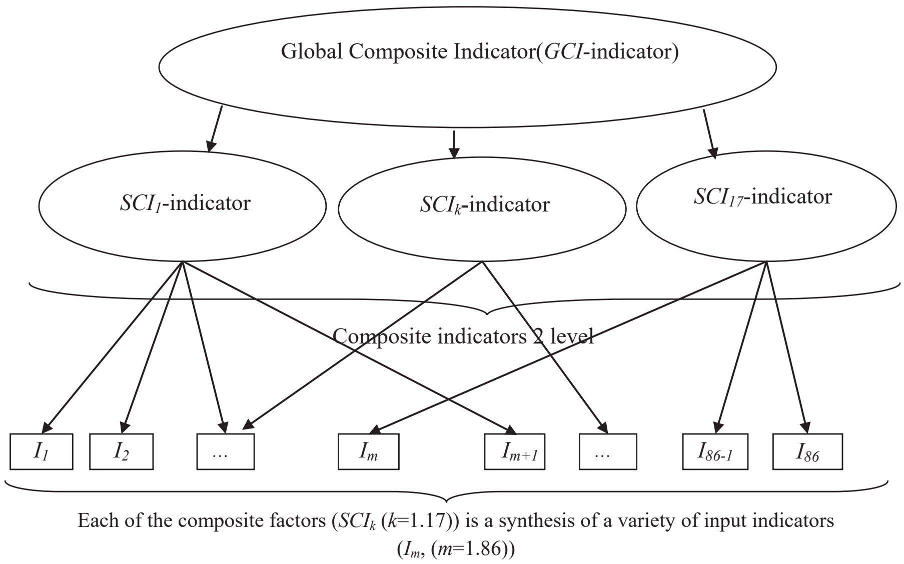


**Fig. 2.** A hierarchical three-level model of indicators that demonstrates the relationship of input data ($I_k$-indicators) with knowledge in the form of a set of composite $\{SCI_k\}$, ($k=1.17$) followed by the definition of the Global Composite Indicator – GCI

The use of composite indicators makes it possible to evaluate the effectiveness of managing the country, compares it with other countries, and is an effective tool for analyzing state-building policies, which is especially promising for Ukraine. In fact, composite indicators should be considered as a means of initiating, discussing and stimulating public interest [8, 12, 14]. In the study of the construction of a system of analytical composite indicators, methodological recommendations were used to conduct such studies, rather fully described in [7, 12].

According to these recommendations, the study performed is an interrelated sequence of steps that can be identified as follows:

1) reasonable choice of the theoretical basis of the study;

2) selection of input data arrays, on the basis of which a hierarchical system of composite indicators is constructed and then checked for completeness and dimensionality in accordance with the requirements of selected theoretical and methodological analysis methods;

3) bringing the input data in a normalized form, to make them comparable to each other;

4) implementation of the relevant aggregation procedures within certain theoretical approaches;

5) mandatory assessment of the uncertainty and sensitivity of the calculated composite indicators;

6) meaningful interpretation of the obtained composite indicators based on the study of the closeness of their connection with the input indicators;

7) conducting cluster analysis on a set of composite indicators with the subsequent visual presentation of the results of clustering;

8) determining the integral indicator for each of the countries studied with a view to rating them based on the system of composite indicators obtained, their significance, displaying the characteristics of the respective clusters.

As the countries studied, except Ukraine, 32 countries are selected. In this sample, all the former republics of the USSR, today independent states, countries of the former socialist camp, developed European states – Germany, France, Sweden, as well as countries geographically close to us – Turkey, Greece, and the like. The sources of initial information were data [8, 9, 15]. Detailed elaboration of data from these sources of information at the initial stage of the study allowed identifying 32 input indicators, each of which necessarily belongs to one of the 17 Sustainable Development Goals of the country.

For the theoretical basis of research, methods of factor analysis were chosen, in particular, the method of principal components. Their use as a theoretical basis for the study is due to the fact that:

- first, it allowed to significantly reduce the dimension of the problem, without losing the informative description of the objects under study;
- secondly, to realize the possibilities of visualization of input data through the use of specialized software tools, namely, Statistica for Windows.

According to the research results of the correlation matrix of the full set of input indicators, they were prefiltered. The key criteria for the selection of filters were the meaningful value of the corresponding indicator and its priority in the system of target indicators of Ukraine's strategic development.

Such filters reflected the expert assessment of the set of indicators under study using appropriate methods for the coordination of expert judgments. From the initial set of indicators (their number was 86), 32 indicators were selected according to the results of expert evaluation. Since the input system of indicators differs significantly in units of measurement, then for their further processing classical methods of normalization were applied [16]. At the initial stage of research, methods of correlation analysis were applied for the normalized system of indicators. Its partial results in the form of a correlation matrix are presented in Fig. 3.

According to the results of this analysis:

- preliminary filtering of the array of the investigated input information is conducted;
- before carrying out a factor analysis, it is advisable to make sure that the studied set of normally distributed and at a certain level of significance ($\alpha=0.05$) the correlation matrix of the system of investigated

indicators is not diagonal. This led to the conclusion that the studied matrix of paired correlation coefficients of the system of input indicators is statistically significant [16]. When analyzing the correlation matrix of the selected system of indicators ($R$) for its diagonality, $\chi^2$ statistics were used:

$$\chi^2 = -\left(n - \frac{1}{6}(2m + 11)\right)\ln\left|\hat{R}\right|, \quad (1)$$

where $n$ – the sample size (number of countries); $m$ – the number of selected indicators; $\left|\hat{R}\right|$ – the determinant of the correlation matrix, which is defined as the product of estimates of the eigenvalues of the correlation matrix $\left|\hat{R}\right| = \gamma_1 \cdot \gamma_2 \cdot \ldots \cdot \gamma_m$.

Only after this, methods of factor analysis, in particular the methodology of principal components (PCA analysis), were implemented. Its implementation was carried out by means of Statistica for Windows. According to the results of the analysis performed, the eigenvalues of the correlation matrix were obtained $\hat{R}$ – $\{\gamma_1 \cdot \gamma_2 \cdot \ldots \cdot \gamma_m\}$. The number of eigenvalues of the matrix under studywas obtained, on the basis of which the number of key factors (main components) for the set of indicators under study was determined.

Fig. 4 shows the final result of the factor load table, obtained as a result of a sequence of actions using orthogonal rotation (Quartimax raw). This made it possible to adequately interpret each of the fourteen main components through a variety of input indicators.

| | Correlations (Stal_rozv_26_10_18(Standart))<br>Marked correlations are significant at p < ,05000<br>N=32 (Casewise deletion of missing data) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Induk1 | Induk2 | Induk3 | Induk4 | Induk5 | Induk6 | Induk7 | Induk8 | Induk9 | Induk10 | Induk11 | Induk12 | Induk13 | Induk14 | In |
| Induk1 | 1,00 | -0,23 | -0,26 | -0,07 | 0,20 | -0,28 | -0,33 | -0,11 | -0,41 | -0,08 | -0,17 | 0,25 | 0,26 | -0,18 | |
| Induk2 | -0,23 | 1,00 | 0,28 | 0,06 | 0,00 | 0,34 | 0,29 | -0,27 | 0,23 | 0,40 | 0,03 | -0,34 | -0,07 | -0,30 | |
| Induk3 | -0,26 | 0,28 | 1,00 | 0,18 | -0,21 | 0,37 | 0,40 | -0,12 | 0,25 | 0,61 | 0,34 | -0,42 | 0,01 | -0,14 | |
| Induk4 | -0,07 | 0,06 | 0,18 | 1,00 | -0,36 | 0,34 | 0,32 | 0,21 | 0,42 | 0,30 | 0,48 | -0,41 | 0,09 | -0,22 | |
| Induk5 | 0,20 | 0,00 | -0,21 | -0,36 | 1,00 | -0,45 | -0,57 | -0,15 | -0,63 | -0,46 | -0,63 | 0,56 | 0,12 | 0,29 | |
| Induk6 | -0,28 | 0,34 | 0,37 | 0,34 | -0,45 | 1,00 | 0,82 | 0,11 | 0,53 | 0,73 | 0,59 | -0,69 | 0,07 | -0,27 | |
| Induk7 | -0,33 | 0,29 | 0,40 | 0,32 | -0,57 | 0,82 | 1,00 | 0,34 | 0,68 | 0,70 | 0,66 | -0,74 | -0,19 | -0,37 | |
| Induk8 | -0,11 | -0,27 | -0,12 | 0,21 | -0,15 | 0,11 | 0,34 | 1,00 | 0,39 | -0,07 | 0,14 | -0,09 | -0,14 | 0,03 | |

**Fig. 3.** Fragment of assessment of the system of input indicators using correlation analysis methods

| | Factor Loadings (Varimax raw) (Stal_rozv_30_10_18(Standart)<br>Extraction: Principal components<br>(Marked loadings are >,700000) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Factor 6 | Factor 7 | Factor 8 | F |
| Poverty headcount ratio at $1.90/day (% population) | 0,25 | -0,03 | 0,20 | 0,86 | -0,05 | 0,03 | -0,17 | -0,07 | |
| Prevalence of undernourishment (% population) | 0,43 | -0,06 | -0,01 | 0,02 | 0,04 | -0,02 | -0,85 | 0,14 | |
| Cereal yield (t/ha) | -0,67 | 0,04 | -0,19 | 0,31 | 0,05 | -0,17 | -0,08 | 0,03 | |
| Maternal mortality rate (per 100,000 live births) | 0,62 | -0,05 | 0,22 | 0,08 | -0,67 | -0,11 | -0,17 | -0,14 | |
| Incidence of tuberculosis (per 100,000 population) | 0,76 | 0,11 | 0,03 | 0,07 | -0,42 | 0,21 | -0,16 | -0,15 | |
| HIV prevalence (per 1,000) | 0,13 | 0,14 | 0,04 | -0,16 | -0,04 | 0,16 | 0,12 | 0,14 | |
| diabetes, and chronic respiratory disease in populations | 0,82 | 0,04 | 0,34 | 0,05 | 0,07 | 0,26 | 0,07 | 0,01 | |
| Age-standardised death rate attributable to household air pollu | 0,85 | -0,10 | 0,05 | 0,14 | -0,20 | -0,13 | -0,30 | 0,04 | |
| Traffic deaths rate (per 100,000 population) | 0,81 | -0,01 | 0,13 | -0,21 | -0,21 | 0,07 | 0,01 | 0,14 | |
| Universal Health Coverage Tracer Index (0-100) | -0,92 | 0,16 | -0,20 | -0,09 | 0,04 | -0,06 | 0,07 | 0,12 | |
| Subjective Wellbeing (average ladder score, 0-10) | 0,02 | 0,02 | -0,05 | -0,03 | 0,01 | -0,94 | 0,04 | 0,04 | |
| Literacy rate of 15-24 year olds, both sexes (%) | -0,68 | 0,23 | 0,34 | -0,29 | -0,15 | 0,13 | -0,24 | 0,08 | |
| Female to male mean years of schooling of population age 25 | -0,12 | 0,62 | 0,05 | -0,06 | -0,17 | -0,05 | 0,15 | 0,29 | |
| Female to male labour force participation rate (%) | -0,40 | 0,76 | -0,16 | -0,13 | 0,18 | 0,03 | 0,09 | -0,15 | |
| Freshwater withdrawal as % total renewable water resources | 0,24 | -0,06 | 0,82 | 0,16 | -0,11 | 0,05 | -0,28 | -0,05 | |
| Imported groundwater depletion (m3/year/capita) | 0,01 | -0,09 | -0,05 | -0,13 | 0,01 | 0,05 | 0,16 | 0,04 | |
| Access to electricity (% population) | -0,20 | 0,00 | 0,10 | -0,01 | 0,93 | -0,04 | -0,01 | -0,08 | |
| Access to clean fuels & technology for cooking (% populatior | -0,51 | 0,07 | 0,25 | -0,18 | 0,09 | 0,23 | 0,08 | -0,09 | |
| CO2 emissions from fuel combustion / electricity output (MtC | 0,27 | 0,08 | 0,61 | -0,14 | 0,18 | 0,29 | 0,46 | 0,07 | |
| Adjusted GDP Growth (%) | 0,01 | -0,13 | 0,51 | 0,08 | 0,15 | 0,21 | 0,09 | 0,06 | |
| Adults (15 years +) with an account at a bank or other financi | -0,77 | 0,13 | -0,25 | -0,08 | 0,19 | 0,21 | 0,14 | 0,32 | |
| Unemployment rate (% total labour force) | -0,01 | -0,96 | -0,07 | -0,07 | 0,01 | -0,00 | 0,10 | 0,03 | |
| Proportion of the population using the internet (%) | -0,71 | 0,26 | -0,42 | -0,05 | 0,23 | 0,01 | 0,31 | -0,06 | |
| Quality of overall infrastructure (1= extremely underdevelope | 0,13 | 0,08 | 0,78 | 0,32 | 0,06 | 0,03 | 0,06 | 0,11 | |
| Logistics performance index: Quality of trade and transport-re | 0,10 | 0,05 | -0,05 | 0,04 | 0,02 | 0,04 | 0,05 | -0,97 | |
| The Times Higher Education Universities Ranking, Average s | -0,83 | 0,04 | -0,14 | -0,19 | 0,02 | 0,19 | -0,02 | -0,06 | |
| Research and development expenditure (% GDP) | 0,12 | 0,05 | 0,85 | -0,38 | -0,01 | -0,04 | 0,01 | 0,03 | |
| Gini Coefficient adjusted for top income (1-100) | 0,35 | -0,11 | 0,80 | 0,32 | 0,00 | -0,01 | 0,05 | -0,04 | |
| Annual mean concentration of particulate matter of less than 2 | 0,54 | -0,46 | 0,21 | 0,23 | 0,23 | 0,12 | -0,24 | -0,01 | |
| Improved water source, piped (% urban population with acces | -0,57 | -0,05 | -0,40 | 0,37 | -0,13 | 0,13 | 0,18 | 0,24 | |
| Satisfaction with public transport (%) | -0,04 | 0,21 | 0,09 | 0,37 | -0,24 | 0,28 | -0,63 | -0,18 | |
| Expl.Var | 8,21 | 2,41 | 4,30 | 1,90 | 1,96 | 1,49 | 1,97 | 1,41 | |
| Prp.Totl | 0,26 | 0,08 | 0,14 | 0,06 | 0,06 | 0,05 | 0,06 | 0,05 | |

**Fig. 4.** A fragment of the matrix of factor loadings and the values of estimates of its eigenvalues

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According to the results of constructing the confidence intervals of the eigenvalues $\lambda_i$ of the correlation matrix $\widehat{R}$ with probability $\propto = 0.95$ calculated by formula (2), it is found that the estimates of the eigenvalues of the principal components do not overlap [17]. This makes it possible to argue about the statistical significance of the results of factor analysis. To build the confidence interval of the eigenvalues $\gamma_i$, the statistics $\sqrt{N-1}\cdot(\hat{\gamma}_i-\gamma_i)$ that are normally distributed at $N->\infty$ with the following parameters $(0.2\propto_i^2)$ are used:

$$\frac{\gamma_i}{1+\delta\sqrt{\dfrac{2}{N-1}}} \le \frac{\gamma_i}{1-\delta\sqrt{\dfrac{2}{N-1}}}, \qquad (2)$$

where $\hat{\gamma}_i$ – the point estimate of the eigenvalue $\gamma_i$; $\delta - q$ – the quantile of the standard normal distribution, $1-\alpha/2$; whereas $\alpha = 1-\propto$.

The contribution of each of the main components to the total variance of the entire set of input indicators is presented in Table 1, from which it is clear that the 14 principal components ultimately explain 93.36 % of the variance of the input data.

A feature of the main component method is that the first factors explain the largest proportion of the variance of the studied indicators. If to compare the factors with the goals of sustainable development, then they unambiguously interpret a certain goal from the 4th to the 14th factors, inclusively.

The relationship of the normalized values of the input indicators $x_i$ with the corresponding values of the main components is represented as the following dependency:

$$x_i = \sum_{j=1}^{m}\left(a_{ij}\cdot f_j\right), \qquad (3)$$

where $\{x_i\} - i = (1,\ n)$ – the set of standardized input indicators; $\{f_j\} - j = (1,\ m)$ – the set of standardized principal components; $a_{ij}$ – factor loadings.

The resulting matrix of eigenvalues of the main components for each of the countries studied is presented in Fig. 5.

**Table 1**

Main components (eigenvalues) and percentages of explaining the variance of input indicators

| No. of the main components | Eigenvalues | % of explanation of the variance of the input indicators | % of explanation of the variance of input indicators with progressive total |
|---|---|---|---|
| 1 | 7.8255013 | 25.24 % | 25.24 % |
| 2 | 3.3678313 | 10.86 % | 36.11 % |
| 3 | 2.3774946 | 7.67 % | 43.78 % |
| 4 | 1.9843274 | 6.40 % | 50.18 % |
| 5 | 1.8143343 | 5.85 % | 56.03 % |
| 6 | 1.7966142 | 5.80 % | 61.83 % |
| 7 | 1.6802418 | 5.42 % | 67.25 % |
| 8 | 1.3091561 | 4.22 % | 71.47 % |
| 9 | 1.2935523 | 4.17 % | 75.64 % |
| 10 | 1.2804188 | 4.13 % | 79.77 % |
| 11 | 1.2776968 | 4.12 % | 83.89 % |
| 12 | 1.057993 | 3.41 % | 87.31 % |
| 13 | 0.9693691 | 3.13 % | 90.43 % |
| 14 | 0.9064276 | 2.92 % | 93.36 % |

| Case | Factor Scores (Stal_rozv_30_10_18(Standart))<br>Rotation: Unrotated<br>Extraction: Principal components | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Factor 6 | Factor 7 | Factor 8 | Factor 9 | Factor 10 | Factor 11 |
| Lithuania | 0,181 | 0,440 | -0,585 | 0,627 | 0,668 | -0,445 | -1,426 | 0,699 | -0,238 | 1,239 | 0,735 |
| Tajikistan | -1,864 | -1,059 | 0,635 | -1,873 | -0,896 | 1,416 | 2,852 | 0,592 | 1,625 | 1,889 | 0,346 |
| Turkmenistan | -2,262 | 3,048 | -2,259 | 1,528 | -1,223 | -0,779 | 1,085 | -1,202 | -0,570 | 0,571 | -1,201 |
| Uzbekistan | -1,627 | 0,994 | -1,538 | -3,064 | 0,587 | -0,404 | -0,434 | 1,413 | -0,239 | -2,436 | 1,085 |
| Kyrgyz Republic | -1,507 | -0,115 | 2,783 | -0,878 | -2,622 | -0,367 | -2,123 | -0,848 | -2,099 | -0,403 | 0,190 |
| Estonia | 0,732 | 0,589 | 0,004 | 0,154 | 0,122 | -0,305 | -0,957 | 0,455 | 0,370 | 0,734 | -0,980 |
| Czech Republic | 0,811 | 0,042 | -0,555 | -0,585 | -0,378 | 0,130 | 0,438 | 0,030 | -0,381 | 0,171 | 0,450 |
| Poland | 0,473 | 0,273 | -0,675 | 0,329 | -0,244 | -0,121 | -0,283 | 0,101 | 0,021 | 0,708 | 0,967 |
| Azerbaijan | -0,471 | -0,068 | 0,537 | 0,054 | 2,756 | 1,029 | 0,842 | -2,393 | -1,286 | 0,020 | 1,837 |
| Hungary | 0,443 | 0,143 | -0,242 | -0,173 | -0,145 | 0,002 | -0,121 | 0,164 | -0,130 | 0,251 | 0,839 |
| Romania | -0,540 | -0,284 | 0,165 | -0,876 | 2,584 | 0,249 | -0,398 | -1,830 | -0,974 | -0,272 | -2,136 |
| Bulgaria | -0,182 | -0,674 | -0,167 | -0,062 | 0,996 | -0,485 | -0,609 | 0,979 | 0,556 | 0,058 | -0,949 |
| Slovakia | 0,672 | -0,101 | -0,401 | -0,104 | -0,147 | -0,142 | 0,264 | 0,213 | -0,112 | 0,067 | 0,299 |
| Ukraine | -0,329 | 0,641 | 1,864 | 1,503 | -0,094 | 1,500 | 1,113 | 0,460 | 0,870 | -2,453 | -1,625 |
| Belarus | 0,030 | 0,909 | 0,435 | 1,105 | 0,399 | 0,461 | 0,144 | 1,654 | 0,387 | -1,721 | 1,191 |
| Russia | -0,101 | 0,578 | 1,135 | 1,086 | 0,161 | 0,795 | -0,552 | 0,482 | 0,495 | -0,308 | 0,744 |
| Kazakhstan | -0,465 | 0,746 | 0,632 | 1,054 | 0,573 | 0,329 | -0,605 | 0,494 | 0,252 | 1,594 | 1,639 |
| Latvia | 0,290 | 0,352 | 0,146 | 0,240 | 0,321 | -0,015 | -0,716 | 0,621 | 0,366 | 0,672 | -0,916 |
| Sweden | 1,580 | 0,316 | 0,156 | -0,500 | -0,540 | -0,042 | 0,500 | -0,302 | -0,172 | -0,080 | -1,042 |
| Denmark | 1,388 | 0,319 | -0,157 | -0,316 | -0,384 | 0,114 | 0,534 | -0,016 | -0,463 | -0,380 | -0,311 |

**Fig. 5.** Fragment of the matrix of eigenvalues of the centered-normalized main components for each of the studied countries

Having obtained the eigenvaluesof the centered-normalized main components for each of the countries studied and determining a meaningful interpretation of the main components, it is possible to carry out a pair-wise comparative analysis within the limits of the studied set of countries. So, for example, let's identify the first main component ($f_1$) as «The level of a country's physical health» and present its graphical interpretation for a selected group of countries. Then the second main component ($f_2$) can be identified as «Labor Market Assessment». The third main component ($f_3$) is defined as «The level of popularization of access to material benefits» (Fig. 6).

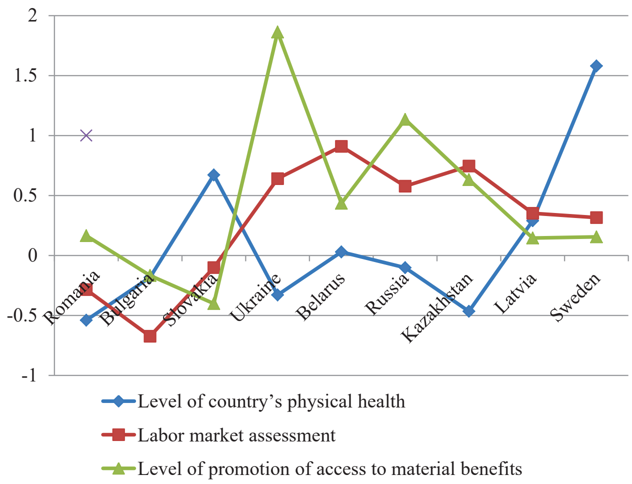


**Fig. 6.** A fragment of a graphical representation of the eigenvalues of the centered normalized principal components for each of the studied countries

In order to fully identify the relative position of Ukraine as compared with the neighboring European countries, let's conduct a cluster analysis, but already on the basis of the eigenvalues of the centered-normalized main components shown in Fig. 5. To do this, let's use one of the clustering methods – the *k*-means method. The goal of this algorithm is optimally «partition» the entire set of countries studied into *k* clusters. This procedure is based on an algorithm for moving objects from one cluster to another, minimizing the intracluster dispersion while maximizing the cluster dispersion. The results of cluster analysis by the method of *k*-means are in the assumption that the entire set of the studied countries is divided into 5 clusters. The composition of the member countries of each cluster and the individual distances to the cluster center are shown in Fig. 7. Cluster centers for each of the 10 composite indicators are defined in the titles of the figures.

An analysis of the cluster distances (Fig. 8) indicates that the first cluster, which includes Ukraine, is more distant from the third cluster, which includes the most developed countries of Europe. It does not take into account the distance to the fifth cluster, in which solely Turkmenistan enters.

At the final stage, let's rank the studied countries based on the calculation of individual integral indicators of development. In this case, the following logic is implemented for calculating such integral indicators. At the initial stage, the whole set of input indicators ($G$) is divided into two subsets – stimulant indicators ($S$) and disincentive indicators ($D$) $G = S \cup D$. The assignment of an indicator to the relevant subset depends on whether its contribution to the integral indicator of sustainable development is positive or negative with an increase in its value. To reduce the dimension of the problem for each of the defined subsets, the method of principal components was applied. As a result, the sets of principal components are determined, which sufficiently explain the variance of the input data for each of the subsets (Fig. 9).

| | Members of Cluster Number 1 (Factor Scores (Stal_rozv_30_ and Distances from Respective Cluster Center Cluster contains 9 cases |
|---|---|
| | Distance |
| Estonia | 0,675864 |
| Romania | 1,083960 |
| Bulgaria | 0,729404 |
| Ukraine | 1,212546 |
| Belarus | 1,091885 |
| Russian Federation | 0,660443 |
| Latvia | 0,469432 |
| Greece | 0,703217 |
| Bosnia and Herzegovina | 1,327825 |

*a*

| | Members of Cluster Number 2 (Factor Scores (Stal_rozv_30_ and Distances from Respective Cluster Center Cluster contains 9 cases |
|---|---|
| | Distance |
| Lithuania | 0,715869 |
| Azerbaijan | 1,340941 |
| Albania | 1,376542 |
| Czech Republic | 0,349054 |
| Poland | 0,446470 |
| Hungary | 0,314927 |
| Slovakia | 0,434083 |
| Germany | 0,683810 |
| Croatia | 0,455341 |
| | |

*b*

| | Members of Cluster Number 3 (Factor Scores (Stal_rozv_30_ and Distances from Respective Cluster Center Cluster contains 6 cases |
|---|---|
| | Distance |
| Sweden | 0,379563 |
| Denmark | 0,456480 |
| Finland | 0,431864 |
| France | 0,327723 |
| Norway | 0,477074 |
| Serbia | 1,325977 |

*c*

| | Members of Cluster Number 4 (Factor Scores (Stal_rozv_30_ and Distances from Respective Cluster Center Cluster contains 7 cases |
|---|---|
| | Distance |
| Tajikistan | 1,284891 |
| Uzbekistan | 1,138077 |
| Kazakhstan | 0,901099 |
| Moldova | 0,614321 |
| Georgia | 0,890810 |
| Armenia | 0,902053 |
| Kyrgyz Republic | 1,326437 |

*d*

| | Members of Cluster Number 5 (Factor Scores (Stal_rozv_30_ and Distances from Respective Cluster Center Cluster contains 1 cases |
|---|---|
| | Distance |
| Turkmenistan | 0,00 |

*e*

**Fig. 7.** Distribution of countries by clusters based on the eigenvalues of the centered normalized principal components by the *k*-means method: *a* – countries of the 1st cluster with average values of composite indicators for the most influential first three composite indicators {0.7975; –0.2595; –0.4218}; *b* – countries of the 2nd cluster with average values of composite indicators for the most influential first three composite indicators {0.5152; 0.1240; 1.7229}; *c* – countries of the 3rd cluster with average values of composite indicators for the most influential first three composite indicators {–1.0743; 0.2327; –0.0947}; *d* – countries of the 4th cluster with average values of composite indicators for the most influential first three composite indicators {0.5517; –0.2224; –0.3574}; *e* – countries of the 5th cluster with average values of composite indicators for the most influential first three composite indicators {0.4945; 0.1778; –0.1802}

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| Cluster Number | Euclidean Distances between Clusters (Factor Scores (Stal_rozv_30_10_18(Standart)) in СталийРо Distances below diagonal Squared distances above diagonal | | | | |
|---|---|---|---|---|---|
| | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 |
| No. 1 | 0,000000 | 0,429246 | 0,510887 | 0,465529 | 2,377757 |
| No. 2 | 0,655169 | 0,000000 | 0,495285 | 0,502596 | 2,380199 |
| No. 3 | 0,714763 | 0,703765 | 0,000000 | 0,571018 | 2,490300 |
| No. 4 | 0,682297 | 0,708940 | 0,755657 | 0,000000 | 2,439704 |
| No 5 | 1 541998 | 1 542789 | 1 578068 | 1 561955 | 0 000000 |

**Fig. 8.** Euclidean distances between clusters

| Value | Eigenvalues (stimulants standard) Extraction: Principal components | | | |
|---|---|---|---|---|
| | Eigenvalue | % Total variance | Cumulative Eigenvalue | Cumulative % |
| 1 | 7,278692 | 42,81583 | 7,27869 | 42,81583 |
| 2 | 1,922242 | 11,30730 | 9,20093 | 54,12314 |
| 3 | 1,511966 | 8,89392 | 10,71290 | 63,01706 |
| 4 | 1,299636 | 7,64492 | 12,01253 | 70,66197 |
| 5 | 1,012752 | 5,95737 | 13,02529 | 76,61934 |
| 6 | 0,884366 | 5,20215 | 13,90965 | 81,82149 |
| 7 | 0,817182 | 4,80695 | 14,72683 | 86,62844 |

*a*

| Value | Eigenvalues (disincentives standard) Extraction: Principal components | | | |
|---|---|---|---|---|
| | Eigenvalue | % Total variance | Cumulative Eigenvalue | Cumulative % |
| 1 | 5,405318 | 38,60942 | 5,40532 | 38,60942 |
| 2 | 2,178299 | 15,55928 | 7,58362 | 54,16870 |
| 3 | 1,481981 | 10,58558 | 9,06560 | 64,75428 |
| 4 | 1,246002 | 8,90001 | 10,31160 | 73,65429 |
| 5 | 0,905225 | 6,46589 | 11,21683 | 80,12018 |
| 6 | 0,791072 | 5,65051 | 12,00790 | 85,77069 |
| 7 | 0,659234 | 4,70881 | 12,66713 | 90,47950 |

*b*

**Fig. 9.** The main components for the subsets: *a* – *S*; *b* – *D* and measures of the variance of the input data explained by them

In the next step, the resulting matrix of eigenvalues of the main components for each of the countries studied for each of the subsets *S* and *D* is obtained. And already by the formula (4) the integral indicators for each of the countries studied are calculated for two subsets.

$$I_i = \sum_{j=1}^{m} \alpha_j z_{ij}, \qquad (4)$$

where $m$ – the number of main components in the relevant subset of indicators; $z_{ij}$ – centered-normalized values of the $j$-th main component for the $i$-th country; $a_j$ – the weight of the $j$-th main component. Wherein $abs\left(\sum \alpha_j\right) = 1$. The absolute value of the weight of the corresponding component is corrected value of the explanatory input dispersion.

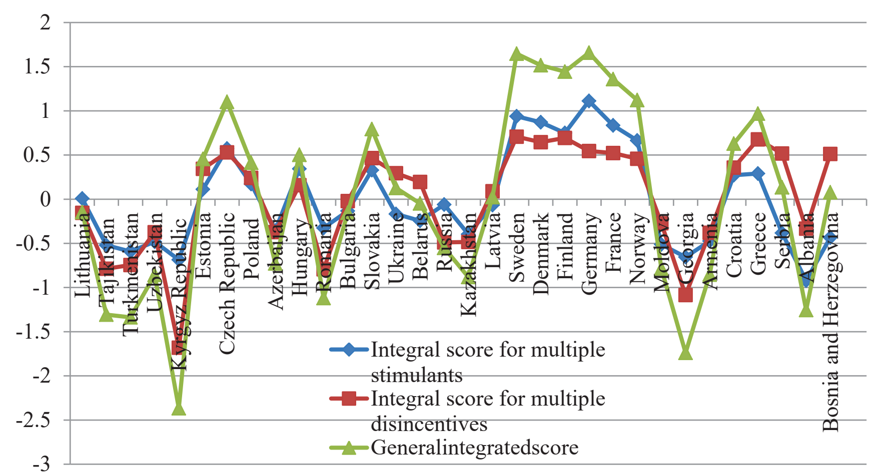


**Fig. 10.** Integral scores of countries in the system of sustainable development indicators

As a result, the integral indicator of a country's development is calculated as the sum of its integral indicators over two subsets – stimulant indicators and disincentive indicators (Fig. 10).

According to the conducted studies and certain integral assessments of countries in the system of indicators of the model of sustainable development, Ukraine ranks 18th among 33 studied countries.

As can be seen from Fig. 10 leaders with the highest values of integral scores in the system of indicators of sustainable development are Sweden, Germany, Denmark, Finland, France. Not the best results are in the following countries: Kyrgyzstan, Georgia, Turkmenistan, Tajikistan. Close to Ukraine on the values of the integral score is Serbia, Latvia, Bosnia and Herzegovina, Belarus.

## 7. SWOT analysis of research results

*Strengths.* An assessment of the level of a country's development is presented as a complex multidimensional process that needs to be properly managed. The task of building effective management systems requires the integrated integration of the system of input indicators through the definition of their metrics. The proposed method makes it possible to assess the level of development of the country and facilitates the interpretation of indicators of sustainable development for reducing the dimensions of the studied processes, as a result they can be graphically interpreted. In the future, this makes it possible to assess the level of a country in the context of its entry into the trajectory of sustainable development, as well as to compare the levels of development of countries among themselves and the dynamics of their change. Facilitates communication with civil society, which in today's environment is a powerful stimulant for increasing the efficiency of state institutions.

*Weaknesses*. The algorithm for constructing composite indicators is quite complex, which makes the process of their construction not sufficiently transparent. As a result, the weak side is the complication of a meaningful interpretation of composite indicators. Direct relationship between the maximum allowable number of input indicators and the number of studied countries.

It allows a certain degree of expert subjectivity, both in determining the level of the dispersion of input data by the system of established main components, and in determining the weights in the process of calculating the integral indicator of countries' development.

*Opportunities*. It should be noted that in the future models of controlling system implementation are proposed to be expanded with formal tools that implement work with knowledge bases based on the theory of fuzzy sets and neural network technologies.

*Threats*. One of the threats is the loss of a certain degree of initial information content, determined at the initial stage by the system of input indicators, will later lead to errors at the stage of building composite indicators.

## 8. Conclusions

1. The set of key indicators (32 indicators) are determined from the full set of indicators (their total number is 86) according to the results of expert evaluation, using the methods of descriptive statistics. The key criteria for the selection of filters were the meaningful value of the corresponding indicator and its priority in the system of target indicators of Ukraine's strategic development. Since the input system of indicators differs significantly in units of measurement, then for their further processing classical methods of normalization are applied.

2. The system of composite indicators is determined and on their basis a pairwise comparison of countries is carried out in the directions of realization of individual development goals based on the system of composite indicators.

3. A group of countries (clusters) that are close in values of the integral indicator are formed. In order to fully identify the relative position of Ukraine in comparison with the neighboring European countries, a cluster analysis is performed, based on the eigenvalues of the centered-normalized main components. For this, one of the clustering methods is used – the *k*-means method. The results of cluster analysis using the *k*-means method are based on the assumption that the entire set of the countries studied is divided into 5 clusters. As a result, Ukraine ended up in the same cluster with the following countries: Belarus, Latvia, Estonia, Greece, Russia, Bosnia and Herzegovina, Romania, Bulgaria.

4. An integrated assessment of 33 studied countries in the system of indicators of sustainable development is done. Thus, the results of the integrated assessment of Ukraine in the system of indicators of the model of sustainable development indicate that Ukraine is in 18th place among the studied countries. Close to Ukraine on the values of the integral assessment is Serbia, Latvia, Bosnia and Herzegovina, Belarus. The leaders by the highest values of integral assessments in the system of indicators of sustainable development are Sweden, Germany, Denmark, Finland, and France.

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