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## MANAGEMENT OF STRUCTURAL CHANGES IN THE SYSTEM OF ECONOMIC FORMATION OF SUSTAINABLE DEVELOPMENT

**Purpose.** To create an algorithm of the system of preparation and decision-making of management of structural changes in the system of formation of economy of sustainable development and mathematical formalization for its block of an efficiency estimation of a choice of strategic administrative decision set and to propose a systematic approach to the analysis of trends in structural changes towards the introduction of a sustainable economy.

**Methodology.** The set of general and special methods of cognition was used for scientific research. The method of comparison and scientific analysis was used to develop the algorithm of the system of preparation and decision-making of structural change management in the system of formation of the economy of sustainable development. The method of mathematical formalization was used to develop a mathematical model for selecting the most effective solutions using the specified algorithm. The method of economic modeling is used for the analysis of the indicative approach to decision-making of a systemic nature and the choice of the integral value of the resulting index. The method of comparative analysis, quantitative and qualitative comparison is used for analyzing the existing trends in economic indicators and identifying, when using them, trends in structural changes for the implementation of a sustainable economy.

**Findings.** An algorithm for the system of preparation and decision-making for managing structural changes for the formation of an economy of sustainable development and a mathematical algorithm for the implementation of the block for assessing the effectiveness of choosing a set of strategic management decisions of the specified algorithm have been developed. The analysis of trends in structural changes for the implementation of the concept of a sustainable economy using a systematic approach has been conducted. A significant unevenness of the structure of financial resources aimed at the implementation of the Development Strategy in 2021–2023 in the regions of Ukraine has been revealed.

**Originality.** For the first time, an algorithm and a mathematical model for evaluating the effectiveness of management decisions for the management of structural changes in the system of sustainable development economy have been proposed. The use of the forecast of dynamic change in indicators and factors of influence on them for development of effective management strategy is improved. For the first time, it has been proposed to use not indicators of achieving a particular goal, but an integral indicator of a complex systemic achievement of a result to determine the achievement of a certain level of sustainable development of a country.

**Practical value.** The developed algorithm and mathematical approach can be used for scientific research and practical tasks of finding effective management decisions. Since a comprehensive systemic analysis of indicators for all sustainable development goals requires significant computing resources, for operational analysis it is proposed to use indicators that are not included in the main group of indicators determined by the adopted methods. For a practical example of an operational indicative approach, the analysis and forecast of the dynamics of changes in the population's income were used including the available average monthly income, the structure of the population's income, the structure of expenses and savings, and others applying the time series method and taking into account non-random influences.

**Keywords:** *regulation, sustainable development, goals, strategy, management, national economy*

**Introduction.** According to the concept of sustainable development, the management of structural changes nowadays should not be limited only to certain areas of environmental and economic problems of society. With strategic radical changes in the very structure of the economy, especially manufacturing industries, it is the effective management of

these changes that must ensure the success of the sustainable economy.

17 specific sustainable development goals (SDG) have been identified not only by the scientific community but also at the regulatory level and by international organizations. State statistical bodies regularly assess the progress of the achievement of the SDG in Ukraine according to the methodology of the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). The complexity of the

analysis of the achievement of the SDG in Ukraine is emphasized by the fact that not only in many scientific papers, but also in official sources, this analysis is presented not in the formalized numerical form, but in the qualitative one. The analysis of the level of effectiveness of management decisions to achieve the SDG presents even greater complexity and, accordingly, causes the proposal of different economic and mathematical approaches. This is partly due to the fact that the results of systematic strategic forecasting of the consequences of a set of management decisions to achieve the SDG in their entirety are not publicly available.

**Literature review.** The issue of managing structural changes in the system of sustainable development of the economy is in the field of attention of the scientific community. In particular, Klarin [1] and Zhang [2] analyzed in detail the genesis of the concept of sustainable development, identified the reasons for its success at the regional level and failure at the global level. Mikhno, et al. [3] proposed the concept of investment and innovation model as a condition for sustainable development, which is based on the analytical study by Ustymenko, et al. [4] of EU investment policy as a basis for sustainable development and the possibility of its implementation in Ukraine. Nitsenko, et al. [5] believe that sustainable development is derived from the effective management of structural transformation of the economic system. The article by Marmul, et al. [6] states that structural modernization is provided by the formation of a system of interaction between regions and government agencies and is accompanied by qualitative and quantitative transformational changes in the socio-economic system. Sievidova, et al. [7], Nitsenko, et al. [8], Li [9] and others were engaged in algorithmization of structural change management. Thus, Sievidova, et al. [7] proposed a comprehensive use of optimization numerical methods that provide a smooth approach to Nash equilibrium. Nitsenko, et al. [8] used a dynamic innovation control system that uses a vector recurrence factor with the influence of control parameters and risks. Li [9] used the concept of infinitely divided Nash equilibrium, which is supplemented by a duopoly model of Bertrand's price competition. Clark, et al. [10] proposed a synoptic approach to development management for adaptive systems. These theses are developed in the work by Preiser, et al. [11] where the organizational principles of development of methods and approaches to management of structural changes are offered. Loorbach, et al. [12] points to the peculiarities of the dynamics in the transition to a sustainable economy, which is especially important for Ukraine. In Markard, et al. [13], this is described in a formalized way, which is useful when applying an algorithmic approach. Sachs, et al. [14] proposes the phased implementation of management actions for structural changes. Geels [15] proposed a multidimensional model of structural changes, taking into account the methods of social constructivism, evolutionary economics and neo-institutional theory. Oberlack [16] introduced a polycentric management approach in related resource systems for structural change management. But this approach is not sufficiently studied for implementation in practical control algorithms. The introduction of a database of changes in management modes in the article by Biggs et al. [17] is interesting for the analysis of efficiency [17]. Bengtsson [18] studied the transformation of socio-economic systems to achieve sustainable development goals and their exceeding efficiency. The Avelino article [19] presents the developed POWER-IN-Transition (POINT) structure, which minimizes the "unintended consequences" for the authorities during the phased transition to sustainability.

**Unsolved aspects of the problem.** The analysis of scientific research indicates the need to implement an algorithmic approach designed for the management of changes, this approach should be based on the use of a mathematical approach. This mathematical approach should provide an objective choice of the most effective management actions, taking into account the systemic nature of the impact of each of them

individually and as a whole. The data on which the results of the formalized analysis are based also need to be analyzed. A systematic approach, the need for which will be mentioned in many scientific papers, should also be used at the stage of taking into account the comprehensive nature of changes, rather than selective assessment of the level of achievement of individual goals.

**Purpose.** The purpose of the article is to create an algorithm of the system of preparation and decision-making of management of structural changes in the system of formation of economy of sustainable development and mathematical formalization for its block of an efficiency estimation of a choice of strategic administrative decision set and to propose a systematic approach to the analysis of trends in structural changes towards the introduction of a sustainable economy.

**Methods.** The set of general and special methods of cognition was used for scientific research. The method of comparison and scientific analysis was used to develop the algorithm of the system of preparation and decision-making of structural change management in the system of formation of the economy of sustainable development. The method of mathematical formalization was used to develop a mathematical model for selecting the most effective solutions using the specified algorithm. The method of economic modeling is used for the analysis of the indicative approach to decision-making of a systemic nature and the choice of the integral value of the resulting index. The method of comparative analysis, quantitative and qualitative comparison is used for analyzing the existing trends in economic indicators and identifying, when using them, trends in structural changes for the implementation of a sustainable economy.

**Results.** As it is noted in many scientific papers, the formation of an economy of sustainable development has a systemic nature, and the development of the system, as we know, is characterized by a holistic, integrated nature. That is, it is impossible to achieve the effectiveness of the implementation of certain changes, improving only certain areas. Therefore, change management is a complex mutually agreed process of achieving results, when each management action has an impact on the whole set of areas to achieve the SDG. And this, in turn, requires a rather complex algorithmic forecasting system; analysis of the influences of managerial actions – both for each of them individually and in their entirety; continuous monitoring of the consequences of managerial influences and their prompt adjustment in order to achieve the strategic goal.

The efficiency of this algorithmic system largely depends on the efficiency and reliability of the mathematical core, which is the basis for the development and analysis of solutions. To achieve this goal, it is proposed to use a mathematical core based on graph theory, in particular, relations on the graph. This approach is as follows – the elements  $v$  of the general continuum  $\mu$  are considered nodes of the graph  $Q$ , and denoted as  $v_i$ . We set the rule: the graph  $Q(R)$  of the relation  $R$  has an edge directed from  $v_i$  to  $v_{i+1}$  if  $(v_i R v_{i+1})$  is fulfilled. Then, to formalize the optimal set of management decisions

$$R = (v, y) | v, y, \mu, [\text{effective achievement of the CSB}].$$

Next, we analyze the transitive circuit by choosing the path on the graph  $L$

$$\hat{v}Ry \Leftrightarrow \exists L \subseteq \mu; \\ L = \{l_1 = v; l_2, l_3, \dots, l_{n-1}; l_n = y\} | [l_i R l_{i+1}] \{1, \dots, n-1\},$$

where  $\hat{R}$  is the fulfillment of the relation  $R$  for all elements of the path  $L$ . To find better alternatives we use the so-called externally stable set  $E: y\mu | E[vRy]$ .

The Neumann-Mongenstein decision testifies to the achievement of the result. To do this, from the set of indicators of the SDG we distinguish extreme in time  $\tau - (F'_t)$ , extreme

in cost  $c - (F_c^/)$  and rigid extreme in cost  $c (F_c^{**})$ , the closest to the extreme in time  $(F_\tau^*)$ , the closest to the cost extremum  $(F_c^*)$  and rigid extreme in time  $(F_\tau^{**})$  on the continuum  $\mu$  then many of the best alternatives can be found as

$$F_\tau^{**} = \{xE|y\mu[y\tau x]\}; F_\tau^* F_\tau^{**};$$

$$F_c^{**} = \{xE|y\theta; yx[yRx]\}; F_c^* F_c^{**}.$$

The presented mathematical core is used in the developed algorithm of the system of preparation and decision-making of structural change management in the system of formation of the economy of sustainable development (Fig. 1). Not only the time and cost required to achieve the SDG, but also other characteristics selected by experts can be taken as indicative characteristics of the effectiveness of decisions. Management of structural changes in the system of economic development of sustainable development cannot begin immediately with the stages of “Strategic Planning” and “Formation of strategic management decisions and verification of the results of their integrated impact” (Fig. 1). At the stage of “Determining the goal, selection and evaluation of development indicators” a decision should be made to form a vector value of the integrated indicator  $\bar{f}$ , which would combine the individual values of indicators  $f_i$  and its weight  $a_i$ .

$$\bar{f} = \sum_1^n a_i \bar{f}_i.$$

The analysis should begin with the study on the dynamics and forecast for each of the indicators of each SDG and should be accompanied by monitoring of these indicators and their strategic control. This analysis should end with a formalized calculation of the integrated impact of each management decision and the overall achievement of the SDG. At the stage of “Goal setting, selection and evaluation of development indicators” it is necessary to consider not only official indicators but also other indicative factors.

Usually, state statistical institutions conduct analytical surveys based on the results of monitoring 183 national indicators of the SDG, approved by the Cabinet of Ministers of Ukraine dated 21.08.2019 No. 686-r “Data collection for monitoring the implementation of sustainable development goals”, and the results of the 110 of the goals for which the performance benchmarks have been set for 2030. In the study, the analysis of the dynamics of changes in indicators for each of the SDG revealed a significant unevenness in achieving the SDG. An example is the indicator of goal 12 “Responsible consumption and production” – resource intensity of GDP (the ratio of consumed physical volumes of natural resources, waste and pollutant emissions to GDP), % to the level of 2015 (Fig. 2). This indicator includes several components: energy intensity of GDP; material intensity of GDP; carbon capacity of GDP; water capacity of GDP; waste capacity of GDP. As it can be seen from Fig. 2, the trends of each of the components are different, but in general they all have a positive trend towards strategic decline. But the pace of individual indicators (such as water capacity) indicates a slowdown from year to year. That is, despite the value of the components of this indicator, in general, the forecast data indicate some negative trends in slowing down the pace of achieving the result. And, since there is a significant time lag between making the right operational management decisions and achieving the planned result, it is worth predicting trends in indicators nowadays, analyzing results, options for a set of tactical and strategic management decisions to be made tomorrow and the consequences of these decisions. This is the task of forming a system of strategic management and a system to ensure the implementation of strategic plans.

To monitor goal No. 1 “Overcoming poverty” 5 indicators are used: “The share of the population whose average expenditures per capita are below the actual subsistence level, %”; “Proportion of persons whose daily consumption is less than \$ 5.05 according to PPP, %”; “Proportion of the poor covered by state social support, %”; “The ratio of poverty levels of households with children and households without children, times”; “The share of food costs in total household costs, %”. 11 indicators are used to monitor Goal 8 “Decent Employment and Economic Growth”. “Employment rate aged 20–64, %” is one of them. That is, the set of 183 national indica-

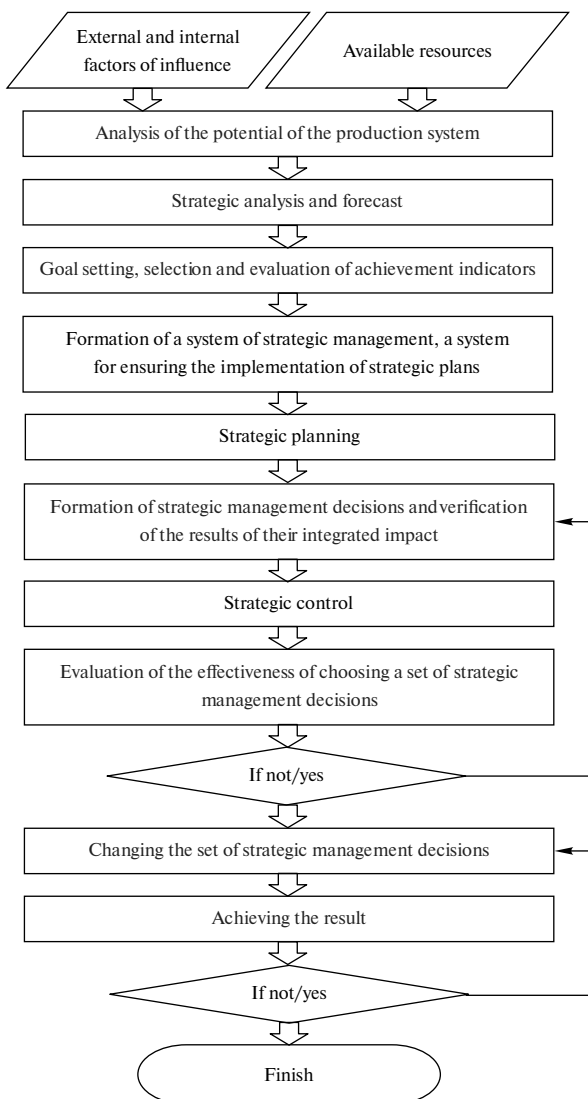


Fig. 1. Algorithm of system of preparation and decision-making of management of structural changes in the system of formation of economy of sustainable development

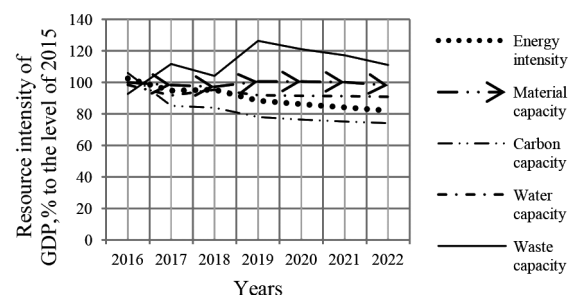


Fig. 2. Resource intensity of GDP (ratio of consumed physical volumes of natural resources, generated waste and emissions of pollutants to GDP), % to the level of 2015

tors of SDG does not provide information opportunities for analysis and forecasting of such economically and socially significant indicators as, for example, the dynamics of wages relative to average consumption per capita, the dynamics of income, growth (decrease) of real disposable income of population. And these issues should characterize the level of effectiveness of management decisions for structural changes in the formation of the economy of sustainable development. This raises the question, however, whether the results of monitoring should be limited to the indicators identified by the decision of the Cabinet of Ministers “Issues of data collection to monitor the implementation of sustainable development goals”.

For the example of analysis and forecast of the dynamics of changes in population income, in particular, the average monthly disposable income, growth (decrease) of real income, income structure, cost and savings structure the time series method is used (Figs. 2 and 3).

If, using the method of time series, the impact of so-called non-accidental noise of 2013–2014 associated with the military aggression of the Russian Federation is taken into account, then we observe a period of 2015–2019 when the average monthly disposable income of the population grew quite significantly – from 116 to 126.9 % compared to the previous year (Table 1). Then there is a period of slowing growth in average monthly disposable income. Unfortunately, the results of the forecast provided while maintaining the current level of inflation are not very optimistic. This is the first alarming marker of assessing the effectiveness of choosing a set of strategic management decisions to achieve the SDG.

The analysis of growth trends (decrease) of real disposable income of population (Fig. 3) taking into account a certain lag in 2015–2016 confirms this conclusion, as the projected change in the trend of real income growth decreased ~4.5 times – from 109 % in 2019 to 102 % in 2022. The analysis of the dynamics of changes in the structure of household

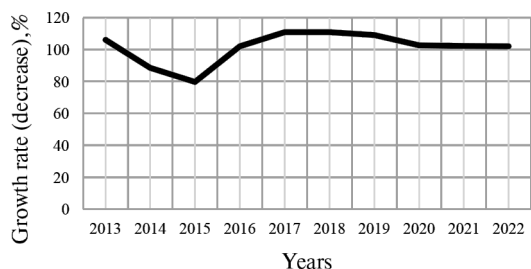


Fig. 3. Dynamics of growth (decrease) of real disposable income

Table 1

Average monthly disposable income

Years	Average monthly income	
	Billion UAH	% to the previous year
2013	1215.5	105.8
2014	1151.7	99.2
2015	1362.6	118.3
2016	1582.3	116.1
2017	2008.3	126.9
2018	2470.3	123.0
2019	2905.8	117.6
2020	3062.2	105.4
2021*	3215	105.0
2022*	3343.6	104.0

\* forecast values

income is the second worrying marker of the effectiveness of strategic management decisions (Table 2). In this table, data are provided for the second quarter of each year in accordance with the presentation of information in state statistics reports. According to the item “Wages (incomes)”, state statistics shows an increase by 3.94 % for the second quarter of 2021 compared to the second quarter of 2020. According to the item “Mixed income, property income”, there is a decrease by 3.4 %. According to the article “Social assistance”, there is a decrease by 64.2 %. According to the item “Other current transfers received”, there is a decrease by 1.1 %. That is, there is a trend of increasing the share of wages relative to other items of income, even social assistance in the structure of income. Accordingly, the forecast data are not very optimistic (Table 2).

The analysis of the structure of costs and savings is the third negative marker (Table 3). During the period 2020–2022, there is an increase in the share of costs for the purchase of goods and services; reduction of the share of property income; an increase in the share of current taxes on income, property and other paid current transfers and a reversal of the trend in terms of savings. This data slice is largely synthetic, as it affects the results of achieving not only this goal but also other SDG. Therefore, its dynamics can also be a marker of the effectiveness of structural change management in the system of formation of a sustainable development economy. This approach to the implementation of the blocks “Formation of strategic management decisions and verification of the results of their integrated impact” and “Evaluation of the effectiveness of choosing a set of strategic management decisions” algorithm of the system of preparation and decision-making for the management of structural changes in the system of a sustainable development economy (Fig. 1) allows introducing selective operational verification of the system achievement of SDG with economical use of computing resources and time required for calculation as strategic system analysis of a set of decisions using existing methods can take much longer.

As the analysis of the forecast values of the structure of financial resources aimed at implementing the Development Strategy in 2021–2023 shows, there is a strong differentiation

Table 2

Dynamics of changes in the structure of household incomes

Income item	II quarter 2020	II quarter 2021	II' quarter 2022
Wages (profit), %	45.6	47.4	49.3
Mixed income and property income, %	15.2	14.7	14.1
Social assistance, %	2.3	1.4	1.1
Other current transfers received, %	36.9	36.5	35.5

Table 3

Dynamics of cost and savings structures, respectively, according to the results of every second quarter of 2020–2022

No.	Cost and savings item	II quarter 2020	II quarter 2021	II quarter 2022
1	Purchase of goods and services	84.7	95.4	97.8
2	Property income	1.3	1.1	0.9
3	Current taxes on income, property and other current transfers paid	10.1	11.5	12.9
4	Increase in savings	3.9	–8.0	–11.6
5	Total	100.0	100.0	100.0

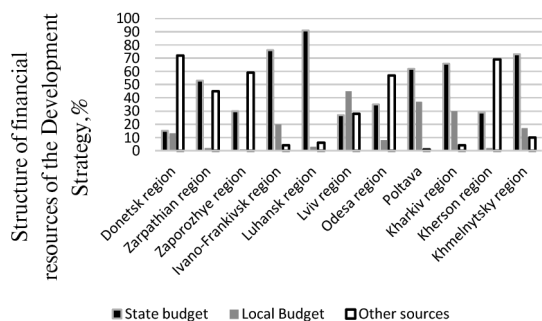


Fig. 4. Structure of financial resources aimed at implementing the Regional Development Strategy in 2021–2023

by region. Moreover, even the geographical proximity of the regions, their kinship by industry of production does not lead to similarities in the structure of their costs to achieve the SDG. For example, Donetsk and Luhansk regions are diametrically opposed in terms of cost structure. In Donetsk the predominant part (~71 %) is made up of other sources of expenditures, in Luhansk oblast the component of state expenditures predominates (~90.05 %). Zakarpattia, Ivano-Frankivsk and Lviv oblasts, and others are not at all similar in terms of cost structure. This indicates different approaches to the management of financial resources, which in turn leads to insufficient effectiveness of the Sustainable Development Strategy by region. This inequality leads to a certain deterrent effect on the country as a whole, as it is impossible to achieve a systemic result if some regions are significantly ahead in achieving the SDG and other regions fail to do that. And this necessitates the adjustment of management actions at the state level for the uniform implementation of the state development strategy for each of the regions.

**Conclusions.** The algorithm of the system of preparation and decision-making of management of structural changes in the system of formation of the economy of sustainable development is offered. Using the graph theory, a mathematical model for the block of evaluating the effectiveness of the choice of management decisions of this algorithm was developed. This allows formalizing the choice of management decisions to achieve sustainable development goals. An analysis of trends in structural changes in the implementation of the concept of sustainable economy using a systematic approach was conducted and it was found out that some indicators of sustainable development goals are not consistent and unconditional. Therefore, there is a need for operational analysis of the dynamic change in trends as indicators as well as their factors of influence and forecasting trends of structural changes for management decisions based on this analysis and forecast. Using a systematic approach, it is determined that the assessment of the achievement of the result of the implementation of the sustainable development concept separately for each of the goals does not allow to assess relevantly the effectiveness of the integrated impact of management decisions. Therefore, a vector approach to evaluation is proposed and the use of an integrated indicator of achievement is introduced. As a factor influencing the systemic nature of the achievement of the tasks set for the country as a whole, a significant uneven structure of financial resources for the implementation of the Development Strategy in 2021–2023 by region was revealed. The developed mathematical formalization can be used by scientists in related fields of economics and public administration. It may also be useful to suggest the use of dynamic indicators that are not part of the main group defined by accepted methods. This allows reducing the amount of computing resources and, most importantly, time for calculations, which will increase the timeliness of management decisions. As a practical example of an operational indicative approach, the results of analysis and forecasting of the dynamics of changes in household

incomes are presented, including average monthly disposable income, income structure, cost and savings structure, and others using the time series method and taking into account non-random effects. These data can also be used by scientists and practitioners.

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## Управління структурними змінами в системі формування економіки сталого розвитку

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**Мета.** Створити алгоритм системи підготовки та прийняття рішень управління структурними змінами в системі формування економіки сталого розвитку й математичну формалізацію для його блоку оцінки ефективності вибору набору стратегічних управлінських рішень. Запропонувати системний підхід для аналізу тенденцій структурних змін на шляху впровадження сталої економіки.

**Методика.** Для наукового дослідження був використаний комплекс загальних і спеціальних методів пізнання. Метод порівняння й наукового аналізу застосовано для розроблення алгоритму системи підготовки та прийняття рішень управління структурними змінами в системі формування економіки сталого розвитку. Метод математичної формалізації – для вироблення математичної моделі вибору найбільш ефективних рішень при застосуванні вказаного алгоритму. Метод економічного моделювання – для аналізу індикативного підходу до прийняття рішень системного характеру й вибору інтегрального значення результуючого індексу. Метод порівняльного аналізу, кількісного та якісного порівняння – для аналізу наявних трендів зміни економічних показників і виявлення, за їх використання,

тенденцій структурних змін на шляху впровадження сталої економіки.

**Результати.** Розроблено алгоритм системи підготовки та прийняття рішень управління структурними змінами для формування економіки сталого розвитку й математичну модель для реалізації блоку оцінки ефективності вибору набору стратегічних управлінських рішень вказаного алгоритму. Проведено аналіз тенденцій структурних змін впровадження концепції сталої економіки за використання системного підходу. Виявлена значна нерівномірність структури фінансових ресурсів, спрямованих на виконання Стратегії розвитку у 2021–2023 роках за регіонами України.

**Наукова новизна.** Уперше запропонований алгоритм і математична модель оцінки ефективності управлінських рішень для менеджменту структурних змін у системі формування економіки сталого розвитку. Удосконалено використання прогнозу динамічної зміни індикаторів і факторів впливу на них для вироблення ефективної стратегії управління. Уперше запропоновано для визначення результату досягнення країною певного рівня сталого розвитку використовувати не показники досягнення тієї чи іншої окремої цілі, а інтегрального індикатора комплексного системного досягнення результату.

**Практична значимість.** Розроблений алгоритм і математичний підхід може бути використано для наукових досліджень і виконання практичних задач пошуку ефективних управлінських рішень. Оскільки комплексний системний аналіз індикаторів за всіма цілями сталого розвитку потребує значних обчислювальних ресурсів, для оперативного аналізу запропоновано використовувати також індикатори, що не входять до основної групи індикаторів, визначених прийнятими методиками. Для практичного прикладу оперативного індикативного підходу використано аналіз і прогноз динаміки змін доходів населення, включаючи середньомісячний наявний дохід, структури доходів населення, структури витрат і заощаджень тощо за застосування методу часових рядів і врахування невідповідних впливів.

**Ключові слова:** регулювання, сталий розвиток, цілі, стратегія, управління, національна економіка

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