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## CONTROLLING AS AN ENTERPRISE MANAGEMENT TOOL IN THE DIGITAL ECONOMY

**Purpose.** Expansion of the ability to implement an adaptation approach in enterprise management because of the implementation of the new controlling concept (NCC) in a digital economy. Development of the mathematical model of the adaptive approach.

**Methodology.** The study uses general and special methods of cognition: abstract-logical analysis – to determine NCC, its preconditions, new opportunities; inductions and deductions – to establish the importance of adaptation as a NCC component, to harmonize strategic and operational plans; mathematical methods – for presenting an adaptation in structural and logical form; generalization method – for proposing ways of implementing the adaptation; logical abstraction – for development of the scheme of implementation of adaptation approach, and study on the possibility of diversification of the strategy, with the coordination of enterprise sub strategy.

**Findings.** The definition of the new controlling concept is proposed, its preconditions are detailed. Ways of implementing an adaptation approach to managing the enterprise in conditions of dynamic changes are proposed. It is indicated that a new opportunity opened by NCC is the use of diversification of the company's strategy and the implementation of adaptive coordination of sub strategies in real-time conditions. It is stated that the indicator of development of diversification can be used as an indicator of the adaptation capacity of the enterprise. The requirements for the introduction of NCC and the two main methods for implementing the adaptation approach are specified.

**Originality.** A mathematical model of the adaptive approach for the implementation of NCC has been developed. A mathematized approach has been developed to coordinate sub strategies. A basic block diagram of the realization of the adaptation approach when introducing a new controlling concept has been developed.

**Practical value.** The results of the study can be used by scientists to improve the methods and tools of NCC and by practitioners in the development and implementation of management information systems. The proposed approaches will increase controlling efficiency.

**Keywords:** *controlling, enterprise management, digital economy, adaptation approach*

**Introduction.** Previously, the concept of “enterprise controlling” was identified with the concept of “management accounting” Indeed, in the early stages of the development of the digital economy, the tasks of controlling were to provide management, preferably in real time, with comprehensive information about the current activities of the enterprise: production and sales of products, profits and costs, etc. During the implementation, at a certain stage of the development of digital technologies, analytical data processing, the results of controlling began to make it possible to make more timely and more substantiated management decisions, which led to a certain increase in the efficiency of management activities. The rapid development of digital technologies provided an opportunity to significantly increase the level and volume of control of all production and accounting processes of the enterprise, to significantly deepen the analysis of activities, and to form new, in particular, prognostic perspectives with the compre-

hensive use of information. This led to a new understanding of the concept of “controlling the enterprise” and formed not only a new management tool, but, in fact, created the prerequisites for the introduction of a new concept of implementation of management activities. The above said determines, at the very least, the need to research a new management tool. For a broader understanding of the importance of this tool, the task of a deeper analysis of the specified new concept of implementation of management activity, its opportunities and prospects for development arises.

Prognostic perspectives, which are opened up by controlling the company's activities for the development of the digital economy, are of particular importance. In the conditions of the constant influence on the activities of Ukrainian enterprises of economic, political and social crises, threats of military actions on the territory of Ukraine, ensuring the possibility of forecasts, not even of a strategic nature, but of the nearest tactical perspectives, reduces the risks of management decisions and forms the prerequisites not only for the survival of the enterprise in difficult conditions, but even its development.

Prospects for the development of the enterprise are formed also due to the opportunities that the new controlling opens up for the management of the enterprise, in particular, regarding the increase in the efficiency of the management of the accompanying production processes – the introduction of more reliable and efficient logistics, the provision of new resource opportunities, new ways of saving the resources of the enterprise.

One of the main problems today is the reduction in the effectiveness of the implementation of the new concept due to the company's management not understanding the need for comprehensive control of the company's activities and, as a result, limiting its application to certain areas – only accounting, acquiring and accumulating information or coordination functions. It is system controlling that is able to ensure the highest level of efficiency of enterprise management if it is properly applied.

**Literature review.** The relevance of this problem is confirmed by a large volume of scientific works dedicated to the study on its aspects. Thus, in the article by Pisar and Bilkova [1], options for using controlling as a tool for managing the enterprise and increasing its competitiveness were studied, which was used in the presented work. Pisar and Bilkova [1] applied a statistical model for the coordination of innovative and strategic plans using the Return on Equity (ROE) as an indicator. Such a model is not sufficiently reliable, which is evidenced, in particular, by the questionable conclusion that improving the level of one key variable leads to the improvement of other controlled variables and, thereby, improves the result [1].

Roffia and Dabić [2], using the theory of dynamic capabilities and a multivariate regression model, studied the use of controlling and integrated information systems to ensure the stability of enterprises under conditions of significant external challenges. In the study, the data was divided into groups according to the directions of controlling. But the mutual influence of these groups is not taken into account, which reduces the reliability of the analysis.

The articles by Levitsky [3] and Grinko, et al. [4] researched some aspects of the formation of a new concept of controlling. In particular, Levitsky [3] studies changes in the use of controlling in the process of generating strategic information, and Grinko, et al. [4] studied the effect of increasing the analytical component of controlling on the intellectualization of enterprise management. The approaches of the specified authors were used in the given study.

Kyzenko and Hrebeshkova [5] studied the prerequisites and main trends of the transformation of strategic controlling in accordance with the development of the digital economy. The authors pay the main attention to only one area of controlling - accounting and consider only the directions of modernization of the accounting system, which somewhat narrows the use of their conclusions.

The article by Kaplina [6] provides an extended list of structural components of controlling. This is in the interpretation [6]: goal setting; planning; Managerial Accounting; system of information flows; control of indicators; analysis of the plan, results, deviations. This is partially used in this study. But, even with the expansion of controlling functions [6], its application as an integral element of strategic and operational management is not mentioned.

The article by Boiko and Vinnyk [7] indicates the need to reduce the risk of uncertainty in the adoption of management measures. It is the reduction of this risk that is paid attention to in the presented article. Boiko and Vinnyk [7] used a SWOT analysis of the performance of controlling at Ukrainian enterprises. A coordination matrix was applied to improve the interaction of various management components. These modeling methods do not seem to be reliable enough.

Buzhymyska and Tsaruk [8] indicated that controlling should reduce uncertainty in forecasting the company's activity and contribute to the company's adaptation to external influences. This is considered in the presented study. But Bu-

zhymyska and Tsaruk [8] did not provide the mechanisms and tools for implementing these tasks.

Wang and Chen [9] indicate that the use of controlling in the process of digital transformation by enterprises of the PRC has become the main tool for ensuring stability in crisis conditions and "increasing uncertainty in the external environment". Wang and Chen [9] compared the influence of "endogenous and exogenous factors" and indicated the need to strengthen the control of external factors in crisis conditions and increase attention to stability analyses. This was taken into account in the process of performing the presented research.

In the work [10], Klymchuk, et al. presented a functional-structural model of controlling external and internal influences and analyzed the use of digital transformation to ensure the sustainable development of Ukrainian enterprises. With the use of this model, an outline of the implementation of management on the basis of digital transformation, in particular, investment management, has been developed. The functional-structural approach proposed by Klymchuk, et al. [10] is promising in analytical data processing.

Demochani's article [11] examines the types and kinds of controlling activities. Consideration is being given to spreading the use of vertically integrated controlling by Ukrainian enterprises. Demochani [11] indicated that digital transformation leads to the spread of a complex control implementation scheme, which, while maintaining vertical integration, stimulates the horizontal integration of controlling procedures, which is used in the presented article.

In the work by Degtiarev [12], the "conceptual principles and structural elements of energy controlling" are considered. The work confirms the necessity of rethinking the concept of controlling, the structural elements of controlling are analyzed and classified. Despite the narrow branch focus of the scientific work [12], certain aspects of it were used in the presented research.

The work by Veresklia, et al. [13] indicated that the digital transformation of controlling is not an end in itself, but a way of strengthening the analytical component of management, reducing uncertainty, and wider coverage of opportunities for both development and risk protection of enterprises. Veresklia and others [13] also indicated the joint evolution of controlling and business processes, that controlling has grown from performing an auxiliary function of accounting data processing to a system that determines new methods of management activity.

**Unsolved aspects of the problem.** The review of scientific works shows the predominantly qualitative nature of the assessment of the effects of external and internal factors that cause changes in the parameters of the enterprise's activity or only fixation in the process of controlling the existing state of the parameters of the enterprise. Under the conditions of the digital economy, the use of IT opens the possibility of using mathematical approaches to the implementation of controlling, to the concept of its application, which will provide the prerequisites for quantitative methods of analysis. This problem needs research and solution.

The new concept of controlling, its prerequisites and new opportunities opened up by its implementation also require additional research. Determining the prerequisites and consequences of the introduction of the new concept of controlling will ensure the proper level of its application in the practice of enterprise activity. The introduction of a new concept of controlling opens up an opportunity to more effectively implement an adaptive approach in enterprise management in conditions of dynamic changes. Therefore, the adaptation approach also needs additional research.

**Purpose.** To study the expansion of the possibilities of implementing an adaptive approach in enterprise management as a result of the implementation of a new concept of controlling in the conditions of the digital economy. To develop a mathematical model of the adaptation approach.

**Methods.** In the study, the results of which are given in the presented article, general and special methods of cognition

were used. Thus, by applying the method of abstract-logical analysis, the definition of the new concept of controlling was formulated, its prerequisites were detailed, and the new possibilities that it opens up were indicated. The use of the method of induction and deduction made it possible to reveal the importance of the adaptation process as a component of the new concept of controlling, for the harmonization of strategic and operational plans and the integration of horizontal and vertical monitoring of controlled factors. This led to the application of mathematical methods to present the adaptation approach in a structural and logical form, suitable for use in information systems. The use of the generalization method made it possible to propose ways of implementing an adaptive approach to enterprise management in conditions of dynamic changes.

The application of the method of logical abstraction made it possible to establish that one of the consequences of the introduction of the new concept of controlling is the use of the practice of diversifying the company's strategy, to develop a mathematical approach to the coordination of the company's sub-strategies. Also, using the method of logical abstraction, a basic block diagram of the implementation of the adaptation approach when introducing a new concept of controlling was developed.

**Results.** The need for controlling is undeniable today. Under controlling, the investment attractiveness of the enterprise increases by ~40 %, document flow improves by ~27 %, financial stability improves by ~20 %, planning is optimized by ~25 % [14]. But until now controlling in the conditions of the digital economy is sometimes considered by management only as the development of information collection and processing through the implementation of information systems to support decision-making using data analysis tools for directory and advisory support of management activities.

The role of controlling is significantly increasing due to the spread of Industry 4.0 and Industry 5.0 approaches in production activities [15]. As it is known, the transition from mass production of industrial products to responding to individual needs of consumers is one of the features of Industry 4.0 [16]. This is impossible without a significant increase in the effectiveness of controlling, the use of the latest digital technologies of controlling in all areas – payment processing, financial and tax reporting, reliable control and ensuring the implementation of production and organizational procedures, etc.

Changes in the functions of controlling and its tools are directly related to changes brought about by the development of the digital economy, in particular, blockchain, digital banking, the Internet of Things, digitization of production and management processes, the need to use and process Big Data, etc. [17]. So, for example, since blockchain technologies consist in the use of certain types of internal protocols of IT systems, their control and arrangement, consistency with the accounting and reporting procedures of enterprises require not only new controlling tools, but also a rethinking of the controlling mechanism in this area.

All of the above forms the prerequisites for accelerating the implementation of the new controlling concept.

Controlling today in the current mode must provide information in the most objective and most complete way to a structured single database for its storage, analysis, analytical processing and automatic formation of management decision options based on it. That is, controlling in the current sense is a natural development of traditional controlling, which is transformed and acquires new qualities under the influence of digital technologies and adaptation to new conditions of production and management activities.

Controlling is needed by every direction of the company's activity, for the following systematic analytical study on the entire volume of not only the company's internal information, but also that external information that directly or tangentially relates to the company's activity. First of all, external and internal risk factors need to be analyzed, and the most effective ways to neutralize them or reduce negative impacts are needed, given the available

resources and opportunities. All this should be realized by introducing a new concept of controlling into management activities.

The new concept of controlling allows considering controlling as a systematic coordination of management influences, ensuring self-regulation of production and management activities through the implementation of constant adaptation of production and management processes to changes in external and internal factors with permanent harmonization of strategic and operational plans and integration of horizontal and vertical monitoring.

The prerequisites for the formation of a new concept of controlling are: speeding up, due to the development of digital technologies, the integration of various management functions, individual databases; emergence of new instrumental methods of information gathering; formation of new opportunities for the coordination of management activities both when covering different links of the management vertical, managers of different divisions of the enterprise, and when covering different time intervals, implementation of tasks of both tactical and strategic plans; strengthening the capabilities of system analysis and forecasting; freeing management from routine reporting work and providing new creative opportunities. The possibilities of ensuring more effective management are strengthened by a constant systematic integrated analysis of not only the factors of external and internal influence on the company's activities, but also the strengths and weaknesses of both its own and competitors', the detection in real time of new threats and new opportunities, options for changing the directions of activity, and, even, enterprise goals, etc.

It should also be taken into account that even a talented manager in the conditions of dynamic changes in external and internal factors is unable to make an effective decision due to the need to take into account all its possible – both positive and negative consequences without the help of a modern information system equipped with a full set of updated data. The breadth of analytical coverage of all aspects and directions of enterprise activity and all related areas and companies ensures the formation of the widest range of prospective management solutions.

In general, this creates new management opportunities for more effective management of the enterprise at a qualitatively new level.

The formation of a new concept of controlling through the implementation of a system analysis will allow one to effectively implement an adaptive approach in the management of the enterprise in the conditions of dynamic changes by implementing:

- adaptation of the company's strategy and sub-strategies to new challenges in real time;
- constant coordination of changes in operational and strategic planning stages;
- adaptive coordination of production and management processes at all levels;
- adaptive coordination of corporate information security requirements with the need for unhindered provision of necessary analytical information to managers of all management levels and all enterprise structures;
- adaptive coordination of tasks of monitoring the implementation of changed plans and corresponding adjustment of functions and tasks of management systems;
- ensuring adequate flexibility of the controlling system to organizational changes.

Emphasis on the importance of the adaptation process to changes in external and internal factors under the permanent harmonization of strategic and operational plans and the integration of horizontal and vertical monitoring determined the need to develop a mathematical model of the adaptation approach. This model consists of the following.

The strategic plan can be represented mathematically as a smooth curve on the response surface in the space of states, the dimension of which is determined by the total number of external and internal influencing factors and possible management actions.

This curve starts from the starting point of planning and ends at the point whose coordinates are defined as the parameters of the strategic planning goal. It can be presented analytically as

$$f = f(\vec{X}, \vec{Y}),$$

where  $\vec{X}$  is a vector of influence parameters;  $\vec{Y}$  is a vector of possible management actions.

The smooth nature of this curve is determined by the fact that the presence of a break on it by any of the parameters means a crisis or is the result of the influence of an unexpected threat. In case of an expected threat, measures to prevent it will ensure the smooth nature of this curve.

Constant monitoring should control changes in basic parameters. The safe operation of the enterprise occurs if changes in the controlled parameters  $\delta$  are not greater than the value of the permissible interval limit  $\delta \leq \delta_s$ .

But the detection of an excessive rate of change in any of the parameters will also indicate a threat – the appearance of an unaccounted influence, the causes and consequences of which require analysis.

A mathematical indicator of this is the non-variability of

the sign of the first-time derivative of the parameter  $\left| \frac{\partial x}{\partial t} \right| > 0$ .

A tool for forecasting the threat is the calculated achievement of the limit of the safe interval by the parameter, given the extended, stable nature of its change. A set of possible management actions  $\vec{Y}$  is offered upon detection of a dangerous trend of the controlled parameter or reaching the limit of the safe interval of its change. The decision is taken to minimize the resources needed for their implementation and to minimize the likely negative consequences.

The problem in formulating a mathematical approach is that the influence parameters are often uncertain values, especially under conditions of crisis. As it is known, uncertain parameters are represented by triangular and trapezoidal values [18]. In this case, it is worth moving to the tensor representation of the problem. Then the fuzzy tensor can be displayed as a result of multiplying the vector of parameters  $\vec{X}$  by the vector of the membership function  $\vec{\mu}_x$

$$T_x = \vec{X} \vec{\mu}_x^T, \quad \vec{\mu}_x \in [0,1],$$

where  $T$  is a transposition symbol.

This allows proceeding to the analysis of the first derivative of the tensor with respect to time and to the analysis of the impact of interval changes in the parameter vector and the membership function vector on the need for management actions  $\vec{Y}$ , which, from a mathematical point of view, return the system to a state close to the functional dependence defined at the stage of strategic planning.

After identifying the negative result of the influence of external and internal factors, the task of implementing adaptive operational management arises. Then a set of planned management actions  $\vec{Y}_{bg}$ , is used, which is usually called the base group, and which is usually represented by a matrix

$$\vec{Y}_{bg} \in \nabla^{m \times n} \cdot (m = m_1 m_2; \quad n = n_1 n_2),$$

where  $m, n$  are basic sets, respectively, of external and internal influencing factors;  $m_1, n_1$  and  $m_2, n_2$  are sets, respectively, of external and internal factors influencing the first and second set of management actions.

Next, the specified set of planned management actions  $\vec{Y}_{bg}$  should be compared with other variants of sets of management actions ( $Y_1, Y_2$ )

$$\{Y_1 \in \nabla^{m_1 \times n_1}, Y_2 \in \nabla^{m_2 \times n_2}\}.$$

Options for new sets of management actions to simplify calculations should be compared in pairs with each other and with the basic option

$$\varnothing(Y_1, Y_2) = \|\vec{Y}_{bg} - Y_1 Y_2\|_F = \|\hat{Y}_{bg} - \text{vec}(Y_1) \text{vec}(Y_2)^T\|_F = \min,$$

where  $\hat{Y}_{bg}$  is the vector matrix of the base set, and the vectors ( $\text{vec}(Y_1)^T, \text{vec}(Y_2)^T$ ) form alternative variants.

Next, the method of least squares is used. But using this method will increase the number of computer resources required for calculations.

With clear values of the parameters  $m_1 \times n_1$  and  $m_2 \times n_2$  the solution is linearized, which allows one to apply the singular decomposition method [ $USV$ ]  $\text{svd}(Y_{bg})$  and obtain the best option for a set of management actions

$$\left( \begin{array}{l} \text{vec}(Y_1^{opt}) = (\sigma_1)^{1/2} U(:,1) \\ \text{vec}(Y_2^{opt}) = (\sigma_2)^{1/2} V(:,1) \end{array} \right), \quad f \rightarrow opt.$$

Evaluation of the effectiveness of options for management actions can be carried out using a formula similar to the evaluation of the effectiveness of projects [19]

$$\varepsilon = \frac{(S_1 + S_2)_t}{q} - B,$$

where  $\varepsilon$  is the effectiveness of management action options;  $S_1, S_2$  respectively, are profit and/or avoidance of losses from the introduction of effective management actions;  $q$  is a discount rate;  $t$  is the time interval during which the result is obtained;  $B$  – costs for performing controlling procedures.

With a significant level of negative influence of external and internal factors stretched over time, the selection of alternative sets of management actions can be carried out in several stages, which allows implementing the adaptive approach to reduce the stress factor for the enterprise.

The proposed mathematical model is compared with well-known models used by domestic and foreign companies to analyze the impact of external and internal factors and coordinate operational and strategic management actions to neutralize them. Thus, genetic models, specialized models of artificial intelligence perform the specified tasks in a sufficiently relevant manner. But they require significant computing resources, calculation time and special knowledge for their correct application. The advantage of the proposed model in comparison with genetic models and artificial intelligence models is that it does not require the use of significant computing resources and can use standard computer hardware.

Models that use economic-mathematical modeling or are built on game theory do not require significant numbers of these resources. But they are not able to operate with large volumes of heterogeneous data, the relevance of their results is often insufficient. Also, their application is complicated by changes in the conditions of their application, for example, game theory is sensitive to the correct construction of the preference function, which is difficult for multi-objective and multi-parametric problems. Also, the methods of economic and mathematical modeling are limited in functionality compared to the proposed option, for example, for multivariate management problems.

In the process of controlling research, the need to implement not only widely declared tasks, strategies and management tactics, but also the need to coordinate the interests of all stakeholders (managers, owners, suppliers, buyers, etc.) in an operational and strategic plan is often left out of consideration, taking into account the requirements of institutional structures, balancing the implementation of the company's goals with the interests of formal and informal individuals and organizations related to this process.

It is also advisable to include this issue in the list of functions to be realized during the implementation of the new controlling concept.

This task can also be formalized in the presented model. The increase in information and analytical capabilities allows processing the flows of information necessary to solve this problem as well.

One of the consequences of the introduction of the new concept of controlling is the use of the practice of diversifying the company's strategy. This practice greatly complicates the tasks of controlling, because the diversification of the company's strategy requires coordination and adaptation to the challenges of not a single strategy, but a system of sub strategies. The requirements for the performance of controlling are also increasing from the point of view of coordinating the tasks of operational management and the implementation of each of the sub strategies. This determines both the need to coordinate sub strategies for their use, and the opportunity opened up by the new concept of controlling in relation to the coordination of sub strategies – namely, the implementation of coordination in real time. This significantly increases the efficiency of the application of the adaptive set of sub strategies.

The implementation of the sub strategies system also significantly increases the number of calculations regarding the forecasting of strategy implementation scenarios and the amount of necessary information that should be provided by controlling. The possibility of implementing such practice is due to the improvement of the information and analytical tools of controlling and the evolution of the organizational support of controlling.

The following approach is proposed for matching sub strategies. Each sub strategy can be represented mathematically as a line  $f_k$  (where  $k = 1, 2, 3, \dots$  is the index of the corresponding strategy), which reflects the trajectory of movement along the above-mentioned response surface in the space of states. This line in the state space is proposed to be described by a polynomial of the seventh degree (as it is known, such a polynomial can describe a very wide range of curves), where the degree of the polynomial variable and, accordingly, the coefficients of this variable  $i = 1, 2, 3, \dots, 7$ . The coefficients of polynomials are suggested to be adjusted in successive iterations after certain time intervals. Controlling should be carried out constantly and regarding the directions and rates of change of the vectors  $\frac{\partial f_k}{\partial t}$ . The indicated vectors, which can be interpreted as tangents to the corresponding lines  $f_k$ , must have one sign.

The formation of a system of sub strategies leads to an increase in the adaptability of the enterprise to sudden changes in external and internal influencing factors.

Since, “diversification development indicator”, proposed in the article by Hrabovenko, et al. and Zayed, et al. [20, 21], which is determined by the resource capacity of production, the ability to transform and efficiency, then, by definition, it allows assessing the adaptability of the enterprise. The given fact of the similarity of the two mathematical approaches allows one to state that the mathematical apparatus presented above is consistent with the methodological toolkit of diversification of the company's strategy available in the scientific literature.

From a mathematical point of view, strategy diversification consists in the formation of a tree of paths on the response surface in the space of states of external and internal influencing factors and facilitates the “strategic navigation of the enterprise” [20].

The algorithm of management activity, which allows controlling to be implemented, can be presented as [22, 23]: formation of a decision tree; organization of events, structure of controlling and evaluation of allocation of necessary forces and means for it; identification of changes in factors of external influence and factors that determine the internal activity of the enterprise; assessment of the level of challenges and threats; assessment of the number of resources: change in plans, adjustment of the operational goal; development of corrective management measures; formation of a new decision tree; reorganization of production and management processes in accordance with new conditions (this can be defined as an effective adaptation process to changes in circumstances and operating conditions). The diagram of the operation of this algorithm, namely the basic block diagram of the implementation of the adaptation approach for the introduction of a new

concept of controlling, is presented in the figure. This block diagram shows an important feature of the implementation of the adaptation approach – the establishment of numerous feedback loops between the various stages of the implementation of the specified approach, taking into account the level of influence of external and internal factors and the need for constant correction of adaptation management measures.

An adaptive approach to the introduction of a new concept of controlling can have two main methods of implementation. The first method allows for early detection of the consequences of unexpected deviations of controlled indicators to introduce such ways of avoiding or reducing the level of predicted threats that will minimize the expenditure of available resources and management efforts. But this method is suitable only for a moderate level of influence of external and internal factors.

In the case of a significant level of influence, or a significant dynamic nature of this influence, it is worth applying the second method, which consists in the necessity of [24, 25]: revision of the strategic plan; adjustments and even changes in strategic goals; a possible partial or even complete change in the nomenclature of the company's products/services; a possible partial or complete change in the main sales markets. The proposed mathematical model will also be useful after the implementation of the above measures.

Effective implementation of the adaptation approach is possible only with the introduction of systematic and comprehensive monitoring of changes in external and internal factors affecting the company's activities, their analytical processing and the formation of forecasts of their changes.

At the same time, the adaptive approach does not exclude the study and comparison of options for management actions to improve everyday production and management procedures, even for changes in controlled indicators in acceptable intervals.

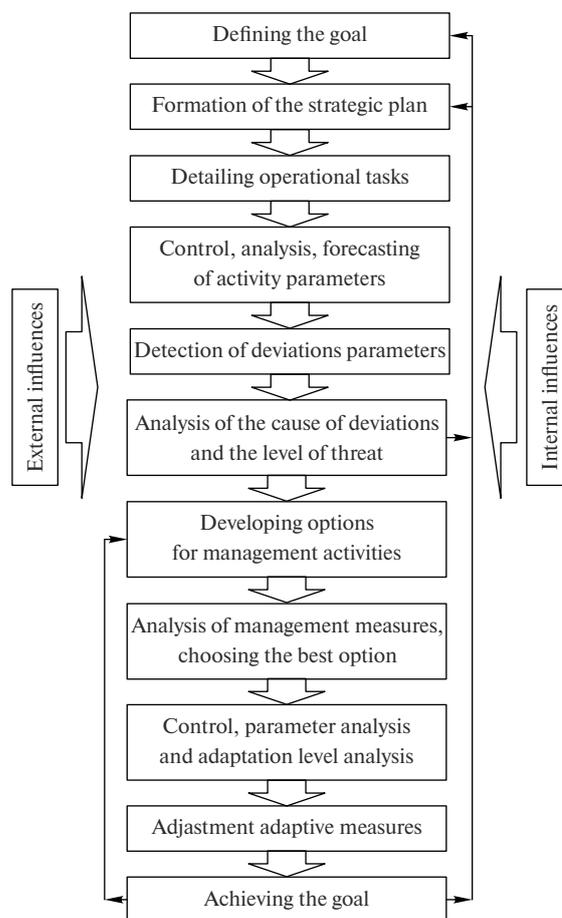


Fig. Block diagram of the implementation of the adaptation approach for the introduction of a new concept of controlling

The wide access of the company's employees to the results of the analytical processing of controlling data and their participation in the discussion of possible options for management actions, participation in the detailing of the specified options by managers of different levels and different divisions of the company in real time will also contribute to the strengthening of the effectiveness of the adaptation approach. In fact, this is an improvement and network implementation of the classic brainstorming method with a significant level of information support and fast analytical processing of proposals.

The adaptive approach also contributes to the introduction of a new approach to data collection and analysis in controlling. In contrast to the established methods of analysis, today the transition from the absolute values of the controlled indicators (the need to fix them, of course, remains, for example, for the formation of tax reporting) to the analysis of their relative values and the rates of change in these relative values is implemented nowadays. At the same time, it is necessary to take into account the need to observe the system principle when conducting an analytical study on controlled data. Improvement or deterioration of the relative values and rates of change in individual controlled indicators or, even, of individual groups thereof, does not always indicate the efficiency or inefficiency of enterprise management, in contrast to the above-mentioned conclusions of the study by Pisar and Bilkova [1]. For example, the relative cost indicators can turn out to be dangerously high in the event of a tactic of temporarily lowering the price of the company's products in order to capture a promising market. Only a comprehensive assessment of changes in the controlled parameters can correct a wrong assessment.

This is also a sign of a new concept of controlling.

The implementation of a new concept of controlling will require planning and organizational support for its implementation:

- the possibility of its current modernization and addition of new system blocks to perform new functions;
- proper implementation and continuous improvement of security functions, first of all, information security;
- compatibility of data from past periods with data that is expected to be collected in the future for the proper performance of retrospective analysis;
- focus not only on ensuring a state of dynamic equilibrium in the company's activities, but, first of all, on its development.

The expansion of controlling functions and a significant increase in its effectiveness is ensured by the rapid development of new information technologies. First of all, it should be noted that the increase in the volume of controlled parameters and the deepening of the analysis of various data is due to the use of big data technologies. Reducing the cost of accumulating large data sets, checking them for compliance, analysis, development of possible options for management actions is ensured by the spread of management use of cloud information technologies. In Ukraine, the so-called "complex information systems", the subsystems of which already perform part of the functions provided by the new concept of controlling, are getting widely used. Traditional information support systems for management functions such as, for example, SAP R/3 are improved by the manufacturer to perform system controlling tasks to achieve the highest level of enterprise management efficiency. This allows one to state that the impact of IT on the implementation of controlling tasks is not one-sided. There is also feedback – because the introduction of a new concept of controlling poses new challenges to the developers of modern IT systems.

**Conclusions.** The conducted research confirmed that, although controlling in the current sense is a natural development of traditional controlling, it is transformed and acquires new qualities under the influence of digital technologies and adaptation to new conditions of production and management activities. Therefore, the greatest efficiency of management can be achieved only with the introduction of a new concept of controlling. The definition of the new concept of controlling is formulated, its prerequisites are detailed.

The new concept makes it possible to consider controlling as a systematic coordination of management influences, ensuring self-regulation of production and management activities by implementing a constant adaptation process to changes in external and internal factors with permanent harmonization of strategic and operational plans and integration of horizontal and vertical monitoring.

Emphasis on the importance of the adaptation process to changes in external and internal factors under permanent harmonization of strategic and operational plans and integration of horizontal and vertical monitoring led to the development of a mathematical model of the adaptation approach.

This model consists in the mathematical representation of the strategic plan as a movement along the response surface in the space of external and internal factors. For the detection of excessive deviation from the plan, in real time or according to forecast data, a set of possible management actions is proposed, and, in case of a negative result the method of adaptive operational management is introduced. A mathematical approach is proposed for choosing the best option of management actions by comparing them in pairs according to results and consequences with each other and with the base option.

The expansion of opportunities for the implementation of an adaptive approach in enterprise management as a result of the implementation of a new concept of controlling is pointed out. In particular, proposed ways of implementing an adaptive approach to enterprise management in conditions of dynamic changes are: adapting the enterprise's strategy to new challenges; constant coordination of changes in operational and strategic planning stages; adaptive coordination of production and management processes at all levels; adaptive coordination of corporate information security requirements with unimpeded provision of the necessary analytical information to managers of all management levels and all structures of the enterprise; adaptive coordination of the tasks of monitoring the implementation of changed plans and corresponding adjustment of functions and tasks of management systems; ensuring proper flexibility of the controlling system to organizational changes.

It is indicated that one of the consequences of the introduction of the new concept of controlling is the use of the practice of diversifying the company's strategy. The implementation of a number of sub strategies will require their adaptation to changes in external conditions. The possibility of implementing such a practice is due to the improvement of the information and analytical tools of controlling and the evolution of its organizational support. A mathematized approach has been developed to coordinate sub strategies and it is specified that the indicator of the development of diversification can be used as an indicator of the enterprise's adaptability.

The requirements for the introduction of a new concept of controlling, its planning and organizational support for implementation are indicated. Two main methods of implementation of the adaptation approach are also indicated.

A basic block diagram of the implementation of the adaptation approach when introducing a new concept of controlling is proposed.

Further research is planned to be conducted in the direction of developing a software complex based on the proposed models and adapting this complex to work as part of existing information support systems for management functions.

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## Контролінг як інструмент управління підприємством в умовах цифрової економіки

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**Мета.** Розширення можливостей упровадження адаптаційного підходу в управлінні підприємством як наслідок реалізації нової концепції контролінгу в умовах цифрової економіки. Розробка математичної моделі адаптаційного підходу.

**Методика.** У дослідженні використані загальні та спеціальні методи пізнання: абстрактно-логічного аналізу для визначення нової концепції контролінгу (НKK), її передумов, нових можливостей; індукції й дедукції для встановлення важливості адаптаційного процесу, як складової НKK, для гармонізації стратегічних і оперативних планів; математичних методів для представлення адаптаційного підходу у структурно-логічному вигляді, придатному для використання в інформаційних системах; методу узагальнення для пропонування шляхів реалізації адаптаційного підходу; логічного абстрагування для розроблення принципової схеми реалізації адаптаційного підходу й дослідження можливості диверсифікації стратегії, за узгодження субстратегій підприємства.

**Результати.** Запропоноване визначення нової концепції контролінгу, деталізовані її передумови. Запропоновані шляхи реалізації адаптаційного підходу до управління підприємством в умовах динамічних змін. Указано, що новою можливістю, яку відкриває НKK, є використання диверсифікації стратегії підприємства й реалізація адаптаційного узгодження субстратегій в умовах реального часу. Указано, що як індикатор адаптаційної спроможності підприємства можна використати показник розвитку диверсифікації. Указані вимоги запровадження НKK і два основні методи виконання адаптаційного підходу.

**Наукова новизна.** Розроблена математична модель адаптаційного підходу за реалізації НKK. Для узгодження субстратегій розроблено математизований підхід. Розроблена принципова блок-схема реалізації адаптаційного підходу при запровадженні нової концепції контролінгу

**Практична значимість.** Результати дослідження можуть бути використані науковцями для вдосконалення методів і інструментів НKK і практиками при розробці та впровадженні управлінських інформаційних систем. Запропоновані підходи дозволять збільшити ефективність контролінгу.

**Ключові слова:** контролінг, управління підприємствами, цифрова економіка, адаптаційний підхід

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