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FORMATION OF THE SCENARIOS TO MANAGE THE BEHAVIOR OF AN INDUSTRIAL ENTERPRISE: METHODOLOGICAL APPROACH AND MODELS

The stochasticity of the industrial enterprise market environment stipulates necessarily the choice of effective tools for managing its behavior. Therefore, economic and mathematical models that enable to predict the behavior of an enterprise with a high level of accuracy are of particular relevance. The article is devoted to the development of a set of behaviorial scenarios of an industrial enterprise on the basis of the construction of an optimization model of the redistribution of capital and labor resources, aimed at maintaining a stability trajectory of its development. Three classes of enterprise behavior stability are proposed, which are characterized by 1%, 5%, and 10% of its behavioral trajectory fluctuations from the stability trajectory. This enabled to form many possible states of the enterprise and to determine the most achievable of them according to its resource constraints.

Keywords: industrial enterprise, behavior, state, optimization model, behavior management scenarios, stability trajectory, resource constraints.

Introduction. Modern development of the world economy is characterized by rapid processes of globalization, which significantly changes the relationship between agents of economic relations. In fact, the world market of the 21st century is the only integrated environment where the affiliation of enterprises with national entities comes to a secondary role. Priority in these conditions is the quality of the goods or services, their compliance with the preferences of customers/consumers, cost optimization in the process of manufacturing the product, etc., that is, determinants that shape the competitiveness and competitive advantages of manufacturers. It is an environment where a large number of business entities operate with a great deal of interconnections that provoke a high level of competition and consequently a high level of unpredictability of their behavior.

In order to regulate the enterprise market behavior effectively, it is necessary to carry out its modeling to develop expedient and achievable tactical actions taking into account the strategic orientations of the enterprise development.

According to the degree of environment aggressiveness and the enterprise resource constraints, its behavior can be aimed at achieving two main goals:

to support the sustainable development of the enterprise. In this case, the behavior of the enterprise must satisfy the criterion of stability and its indicators must approach a steady path, which is sustainable behavior;

to build a new sustainable development path. In this case, the enterprise resources should be sufficient to create an artificial point of bifurcation, that is, leading the enterprise beyond the existing stability trajectory, which is aggressive behavior.

In turn, the choice of the future behavior of the enterprise determines the development of decision support system for the development of the enterprise in the strategic, tactical and operational contours of management and has a direct significant impact on the profitability of the enterprise and its market image.

Recent literature review. An analysis of the articles on the subject made it possible to conclude that the study of behavior is more related to human and social factors, while the economic behavior of the enterprise is more detailed.

Such foreign scientists as R. Acoff, G. Becker, J. Buchanan, M. Weber, W. Zombart , R. Coase, A. Marshall, F. Knight, D. North, G. Simon, J.-B. Sam, A. Smith, G. Schmoller, J. Schumpeter, E. Chandler, and I. Williamson devoted their works to the essence of the economic behavior definition, the definition of its various aspects in the strategic, tactical and operational contours of management, the development of systems for monitoring economic behavior.

A significant contribution to the study of this issue has also been made by Ukrainian scientists. Thus, Moroz O.V., Karachina N.P., Ostry I.F. consider that economic behavior is the universal dominant of the behavior of any entity[1]. That is, it is a combination of purposeful and spontaneous action that reflects the essence and nature of economic activity, which is conditioned by the influence of objective and subjective factors. Kaplenko G. notes that economic behavior of enterprises is a strategically determined direction of interrelated, purposeful tactical actions, methods, methods and reactions to the fluctuating development of external events[2]. Tsapenko V.Yu. emphasizes that economic behavior includes two aspects: on the one hand, an enterprise seeks to maximize economic results in a particular situation; on the other one its management is prone to risky actions[3]. Poltoratskaya O.V. proposes to shape the economic behavior of an industrial enterprise at three levels of management – strategic, tactical and situational[4]. At the same time, each level of management complements or shapes new aspects of the economic behavior of an industrial enterprise and adjusts it under the influence of external or internal factors. In accordance with the enterprise's ability to respond to these factors, the author proposes to distinguish active and passive economic behavior

A special place in the study of industrial enterprise behavior is modeling, as a method of constructing an effective tool for predicting and simulating behavior in accordance with fluctuations of the external and internal environment. Scientists conclude that existing methods and models are unsuitable for analysis, study, and understanding of the behavior of modern economies and enterprises.

Thus, A. Buzzone says human behavior is a key factor to implement realistic models for the security of the market behavior, which is very complex to be simulated. And, in this case, obtaining early test results is based on getting effective models[5].

The paper of P. Cacciabue discusses the needs and current trends of research in Human–Machine Studies (HMS) focusing on the role of simulation models in safety analysis and in design of decision support tools[6]. The perspectives and limits of application of complex approaches, such as cognitive models and dynamic simulationsof human–machine interaction, are reviewed, discussing existing methods and implementation architectures.

A. David and I. Zukerman substantiates the development of economic-mathematical models in the context of the user modeling enterprise and reviews the two main approaches to predictive statistical modeling: content-based and collaborative[7].

Peter P. Groumpos bases on the need to form new adequate economic and mathematical tools[8]. His proposals aimed to wide using optimization methods to work out the optimal behavior of enterprises in the market environment.

Yong Zhang, Tingsheng Zhao, Zhengzhu Zhang, Jun Wan, Xiaonan Feng, Xiangmin Liang, Aijiao Zhou prefer to construct of system dynamics models[9]. The authors claim that an important element of building

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[1] Мороз, О., Карачина, Н., Острі, І. (2017). Сучасність та перспективі`дослідження економічної поведінки підпри`ємств. *Економіка та держава, 4*, 16-20

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[9] Yong Zhang, Tingsheng Zhao, Zhengzhu Zhang, Jun Wan, Xiaonan Feng, Xiangmin Liang, Aijiao Zhou. (2017). Modeling and dynamic assessment on sustainable development of drainage enterprise: Application of a coupled

an adequate model of enterprise development is to determine the boundaries of the system. And this, in turn, allows you to build an effective model of system dynamics and to simulate the changing tendencies of stability with various environmental changes.

However, on our mind, the problem of the modeling of the enterprise's behavior is not fully disclosed in the literature sources and needs additional research.

The purpose and object of the study. The purpose of this article is to develop a methodological approach to construct scenarios of enterprise behavior in an unstable external environment and optimize the model of distribution of its capital and labor resources.

The following tasks to be solved to achieve this goal:

construction of methodological basis for determining expedient scenarios of enterprise behavior in conditions of non-stationary environment;

development of an optimization model of scenario formation taking into account the enterprise resources;

scenarios formation of enterprise behavior based on development of correlation graph of possible changes in the process of its future development.

Research methodology. A methodological toolkit for constructing enterprise behavior scenarios is a methodological approach to constructing enterprise behavior scenarios, which consists of four main stages (Fig. 1). A mathematical toolkit is a method of linear programming or linear optimization, the essence of which is to choose the best result of solving a mathematical model represented by a linear objective function and a constraint system.

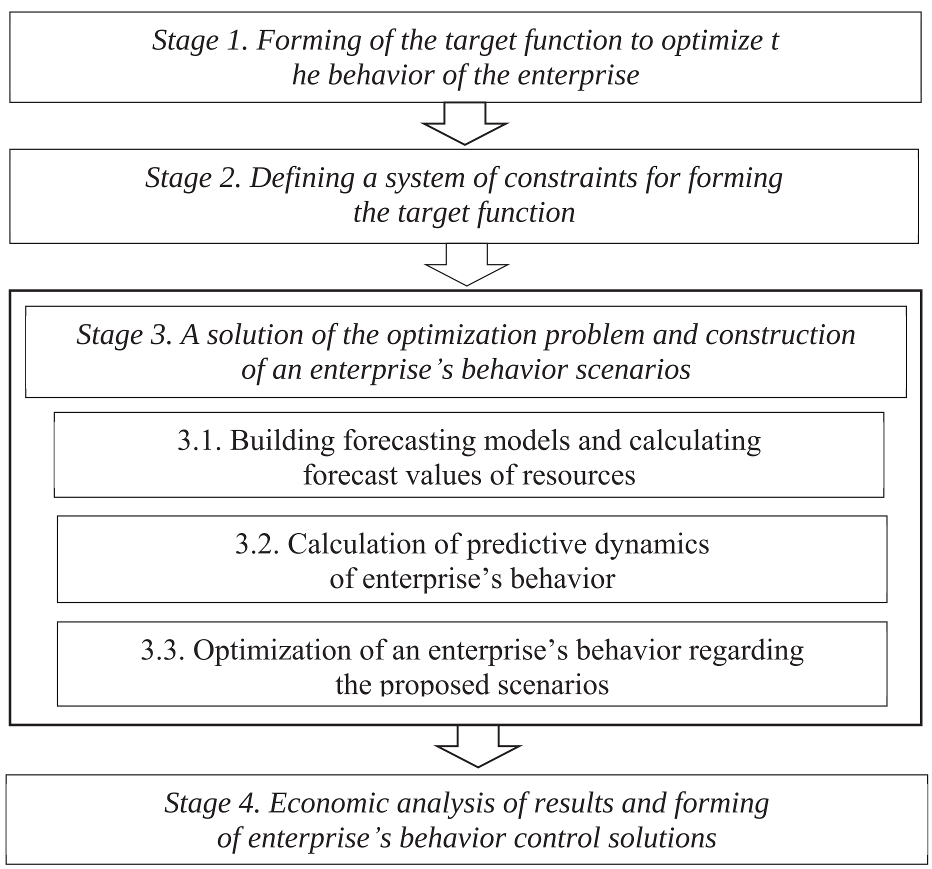

Fig. 1. Methodical approach to building an enterprise's behavior scenarios

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Consider the essence of the each proposed steps of the methodological approach.

Step 1. Formation of the objective function is aimed to optimize the behavior of the enterprise. The conducted researches allowed to form the aggregate model of forecasting the behavior of the enterprise in the conditions of a non-stationary external environment[1]. This model allows to determine the future values of the integral indicator of enterprise behavior (I_{pov}) depending on internal and external factors. However, it is important to determine the real capabilities of the enterprise and the measures to use them to achieve the forecast trajectory. Taking this into consideration, it is advisable to minimize the deviation between the projected trajectory of the enterprise, which includes the evolutionary component of its behavior, and the stable state of the enterprise, which forms its strategic orientations.

The proposed optimal function is in line with the principle of least squares, that is

$$\left(\hat{I}_{pov}^{t+i} - I_{pov}^{t+i}\right)^2 \to \min \quad (1)$$

where $\hat{I}_{pov}^{t+i}$ – predictive value of the integral indicator of enterprise behavior; I_{pov}^{t+i} – value of integral indicator of stable trajectory of enterprise behavior; $i = 1 \div 3$. In the study, the forecast periods correspond to 2019, 2020 and 2021.

It should be noted that in some cases, the predictive value of the integral indicator of enterprise behavior may be less than a stable value for the corresponding period of time, which indicates a destructive influence of the environment and a decrease in internal capabilities of the enterprise. In this case, it is important to plan the development of the enterprise on the basis of the planned indicators, that is, the management of the enterprise should strive to form an effective target indicator and to develop measures for its achievement or maintenance of the existing development indicator.

Thus, the universal target function has the following form:

$$\left(\hat{I}_{pov}^{t+1} - I_{pov}^{t+1} \cdot \tau\right)^2 \to \min \quad (2)$$

where τ – the boundary interval limit of a certain stability class that can take values from the next set of values {0,9; 0,95; 0,99; 1; 1,01; 1,05; 1,1}

Step 2. Identify the system of constraints within which the objective function is formed, taking into account persistent and aggressive behavior scenarios.

The functioning of the enterprise and, respectively, its behavior can be adjusted only by the internal resources of the enterprise, which include labor and capital resources. By managing these resources, the enterprise can adjust its behavior according to changes in the environment and the established strategic orientations of the enterprise. Therefore, it is proposed to build a constraint system for these two types of resources.

It should be determined that a change in an enterprise's resources may be conditioned by both the influence of time and the availability of memory in a number of appropriate resources, reflecting time series analysis models and the desire of the enterprise to strengthen its competitive position and increase resources, that is, stochastic changes. Thus, the upper and lower bounds of the change of indicators can be defined as the upper and lower bounds of the confidence interval when finding the predicted value of the resource indicator using time series analysis models.

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[1] Раєвнєва, О. В., Тоузані, Т.(2019). Модель прогнозування поведінки підприємства в умовах нестаціонарного середовища *Проблеми економіки*, *4 (42)*, 286-292. https://doi.org/10.32983/2222-0712-2019-4-286-292

$$\overset{low}{K}_{t+1} \leq K_{t+1} \leq \overset{upper}{K}_{t+1} \quad \text{and} \quad \overset{low}{L}_{t+1} \leq L_{t+1} \leq \overset{upper}{L}_{t+1} \tag{3}$$

where $\overset{upper}{K}_{t+1}$, $\overset{upper}{L}_{t+1}$ – upper bounds of change of the enterprise capital and labor indicators respectively.

Thus, the analytical form of the optimization model is as follows:

Target function: $\left(\hat{I}_{pov}^{t+1} - I_{pov}^{t+1} \cdot \tau\right)^2 \rightarrow \min$

The system of restrictions:

$$\begin{cases} I_{pov} = \alpha_1 I_{ob} + \alpha_2 I_{fin} + \alpha_3 I_{proiz} + \alpha_4 I_{trud} + \alpha_5 I_{inv} \\ Y_{t+1} = a_0 K_{t+1}^{a_1} L_{t+1}^{a_2} \\ I_{proiz,t+1} = f\left(I_{proiz,t}, Y_t\right) \\ I_{inf,t+1} = a_3 \exp\left(a_4(t+1)\right) \\ I_{fin,t+1} = f\left(I_{fin,t}, K_t\right) \\ I_{trud,t+1} = f\left(I_{trud,t}, L_t\right) \\ I_{ob,t+1} = f\left(TY_t, I_{fin,t}, TVdv_{t+1}, TExp_{t+1}\right) \\ \widehat{K}_{t+1} = f(t) \\ \hat{L}_{t+1} = f(t) \\ \overset{low}{K}_{t+1} \leq K_{t+1} \leq \overset{upper}{K}_{t+1} \\ \overset{low}{L}_{t+1} \leq L_{t+1} \leq \overset{upper}{L}_{t+1} \end{cases}$$

The parameters of this model are calculated for each enterprise separately.

Step 3. Solution of optimization problem of enterprise behavior scenarios formation.

The optimization model is solved in three steps (Fig. 2).

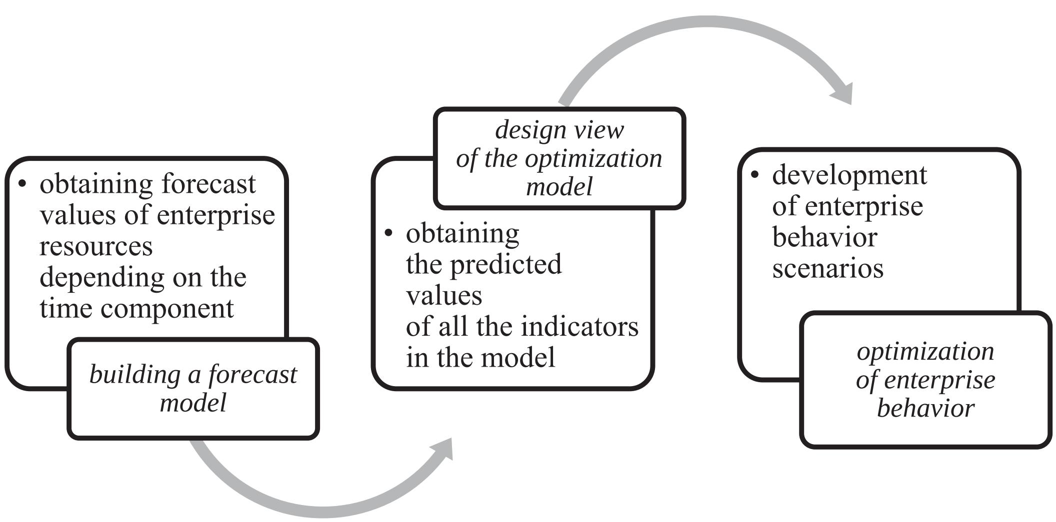


Fig. 2. Sequence of steps in the optimization model solution

Development of enterprise behavior scenarios is carried out through the use of Lyapunov's theory. According to this theory, a steady path is a trajectory that has a constant growth rate. This proposal is based on the assumption that the integral indicator of enterprise behavior is a resultant indicator, which by its mechanism of calculation, takes into account its resource potential and, as a consequence, determines the possibility of its corresponding reactions to fluctuations of the internal and external environment.

Statistically, there are three types of confidence intervals for fluctuations in the values of a certain indicator around the a steady path, namely 1%, 5%, and 10%.

– the first class of stability, when the actual / perspective behavioural path of the enterprise is within 1% confidence interval to the steady path. The oscillation interval value of the actual / prospective behavioural path – [0.99 ÷ 1.01];

– the second class of stability is characterized by a 5% variation of the actual / prospective behavioural path of the enterprise close to the sustainable path of development. The oscillation interval value of the actual / prospective behavioural path – [0,95 ÷ 1,05];

– the third class of stability is determined by actual / prospective behavioural path of the enterprise oscillation interval within 10% around the steady path. The oscillation interval value of the actual / prospective behavioural path – [0,9 ÷ 1,1].

Results of model experiments. The results of the proposed methodological approach are obtained within the third stage of this approach, based on the implementation of the identified three steps. The subject of the study was the Moroccan company Lafarge, a branch of a French company specializing in the production of crushed stone, concrete and cement.

Result 1. Construction of predictive models and obtaining of resources predictive values. Predictive models were constructed by means of MNCs and Statistica software. A linear model was used as the model type for the construction of the predictive model, based on graphical data analysis and empirical studies.

The parameters of the predictive models for enterprises are given in table. 1.

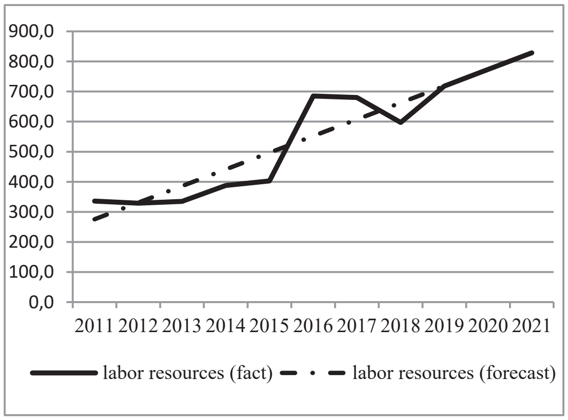
Table1

Predictive models for determining the labor and capital resources of the enterprise

Parameter	Parameter value	Standard error	t-criterion	p-probability
Lafarge – capital resources *(multiple correlation coefficient = 0,89)*				
Intercept	992,5714	238,6071	4,159856	0,005945
t	183,7619	47,2513	3,889038	0,008086
Lafarge – workforce *(multiple correlation coefficient = 0,89)*				
Intercept	220,1786	67,61763	3,256230	0,017330
t	55,3214	13,39029	4,131460	0,006137

The values of multiple correlation coefficients and Student's t-test indicate the statistical significance of model parameters and their adequacy, so the proposed linear models of forecasting labor and capital resources can be used to find their predictive values.

Models presented in table 1 have been used to predict the labor and capital resources values of the enterprises concerned, which are presented in Fig. 3.



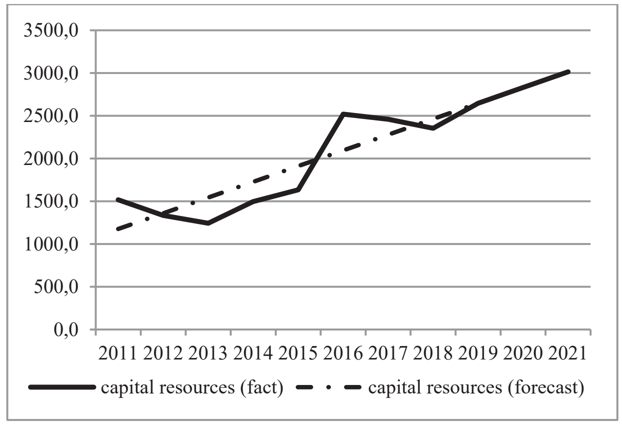


Fig. 3. Dynamics of capital and labor costs for Lafarge

Result 2. Calculation of labor and capital resources indicators of the enterprise. The developed model[1] calculates all local integral indicators and the overall integral indicator of Lafarge enterprise behavior (table 2).

Table 2

Calculation of enterprise behavior integral indicators

Year	Integral indicator of innovative component	Integral indicator of the production component	Integral indicator of financial component	Integral indicator of labor component	Integral indicator of image component	Predicted general value for the integral index	The actual value of the general integral index
2011	0,792	0,660	0,805	0,578	0,802	0,766	0,780
2012	0,799	0,500	0,794	0,554	0,728	0,719	0,661
2013	0,807	0,622	0,789	0,574	0,734	0,740	0,744
2014	0,815	0,554	0,803	0,669	0,769	0,751	0,755
2015	0,823	0,630	0,811	0,672	0,755	0,763	0,797
2016	0,830	0,688	0,862	0,647	0,813	0,804	0,785
2017	0,838	0,631	0,858	0,624	0,740	0,775	0,835
2018	0,847	0,664	0,852	0,447	0,738	0,769	0,772
2019	0,855	0,677	0,869	0,850	0,759	0,808	
2020	0,863	0,692	0,879	1,401	0,752	0,846	
2021	0,871	0,705	0,890	1,702	0,751	0,871	

Thus, the predicted and actual development trajectories of the integral indicator of enterprise behavior are shown in fig. 4.

According to the theory of stability and the proposed intervals of stability, if the actual / predicted trajectory is within 5% confidence interval of values fluctuations around a stable trajectory, i.e constant rate of growth, it can be concluded that the enterprise has a trajectory of 2-class.

[1] Раєвнєва, О. В., Тоузані, Т.(2019). Модель прогнозування поведінки підприємства в умовах нестаціонарного середовища *Проблеми економіки*, *4 (42)*, 286-292 https://doi.org/10.32983/2222-0712-2019-4-286-292

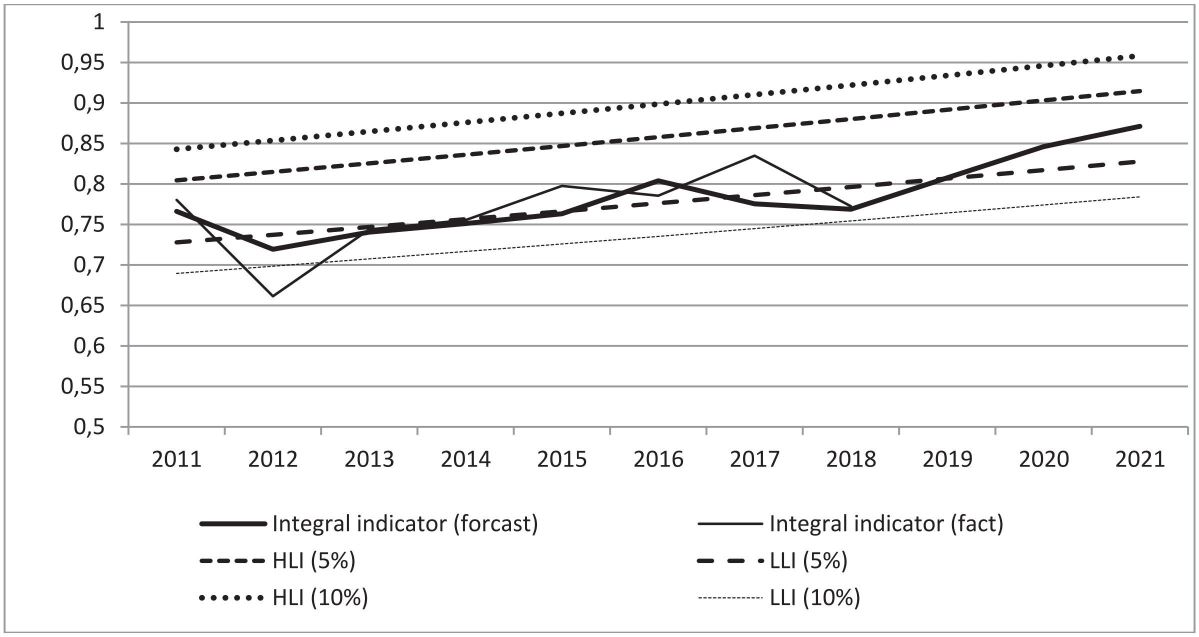


Fig. 4. Predictive and actual trajectory with 5% and 10% confidence intervals

Result 3. Optimization of enterprise behavior under stable and aggressive scenarios. When optimizing the behavior of the company, we introduce a number of assumptions that will enhance the quality of the optimization problem.

Assumption 1. Three experiments are performed for each state of enterprise behavior towards the optimization. This limits the calculation of the least likely scenarios.

Assumption 2. The transition of the enterprise is possible no more than in two states, which determines the limited resource base of the enterprise.

Assumption 3. Conducting experiments is an empirical, scenario-based study that allows to obtain possible variants of enterprise behavior according to the forecasted values of capital and labor resources. The final choice of options remains with the management of the enterprise, based on a careful analysis of its resource capabilities.

Within the framework of the defined assumptions, let us consider the process of optimizing the behavior of the enterprise for the studied enterprises. For this purpose we define possible experiments in this study (fig. 5).

In accordance with the forecast data given in table 2 and fig. 5 the following states of the enterprise and experiments on strengthening of the existing stability or formation of a new steady enterprise development trajectory are identified in table 3.

The experiments were carried out using Excel software. The results of the experiments are given in table. 4.

Result 4. Economic analysis of the results obtained and the formation of tactical and operational measures of enterprise behavior. In order to conduct economic analysis of the obtained results, we construct a transition graph for the enterprise, which identifies the possibilities of individual transitions between states, their economic effect and possible changes in resources, which are the basis for the formation of tactical measures to enhance the behavior of the enterprise. The graph is shown in fig. 6.

The data shown in fig. 6 reveal a number of conclusions:

the most probable is the transition to the predicted state of the enterprise behavior, which determines its development;

in some cases, the transition requires a significant increase in the enterprise capital resources (transition from Experiment 13 in 2019 to other experiments in 2020) and some reductions (transition from Experiment 14 in 2019 to Experiments 7 and 8 in 2020). Such changes should be adjusted to the enterprise resource capacity.

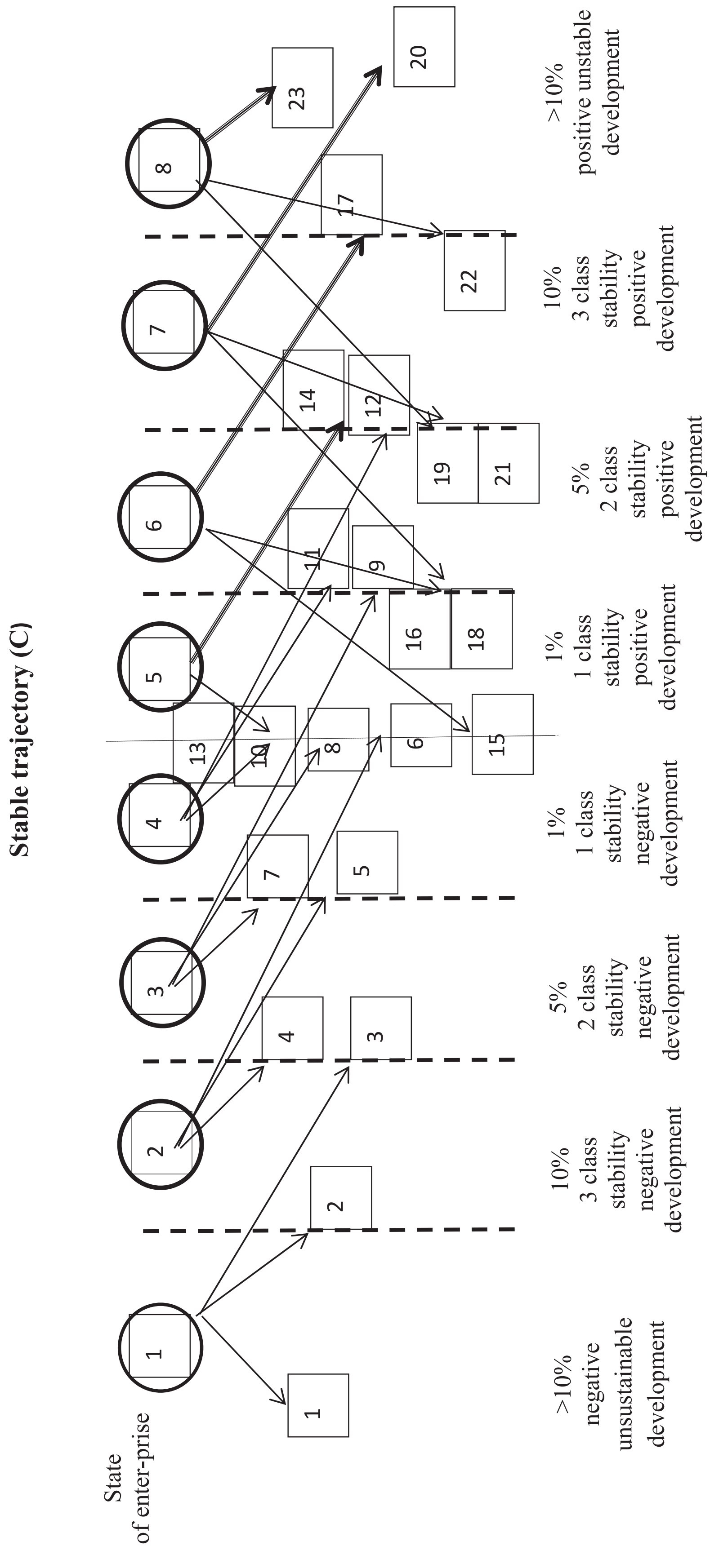


Fig. 5. State of the enterprise and experiments to strengthen the stability of the enterprise behavior

Table 3

States and experiments to enhance the resilience of enterprise behavior

Enterprise	Year	Condition of stability	experiments
Lafarge	2019	3	7, 8, 9
	2020	4	10, 11, 12
	2021	Stable trajectory	-

Table 4

The results of experiments to enhance the stability of Lafarge enterprise behavior

Experiment number	Constraint type	The lower limit	Predicted value	Upper border	Optimal value	Predicted value of the integral indicator (deviation)	Optimal value of integral indicator (deviation)
Lafarge (2019)							
Experiment 7	Capital constraints	2062,578	2646,429	3230,279	**2646,396**	0,808 (-4,88%)	**0,841 (-1,00%)**
	Labor constraints	552,6171	718,0712	883,5258	**773,3056**		
Experiment 8	Capital constraints	2062,578	2646,429	3230,279	**2647,812**	0,808 (-4,88%)	**0,849 (0,00%)**
	Labor constraints	552,6171	718,0712	883,5258	**783,9475**		
Experiment 9	Capital constraints	2062,578	2646,429	3230,279	**2580,256**	0,808 (-4,88%)	**0,857 (1,00%)**
	Labor constraints	552,6171	718,0712	883,5258	**796,9984**		
Lafarge (2020)							
Experiment 10	Capital constraints	2141,1	2830,19	3519,2	**2773,368**	0,846 (-1.62%)	**0,862 (0,00%)**
	Labor constraints	578,17	773,3926	968,6	**795,6042**		
Experiment 11	Capital constraints	2141,1	2830,19	3519,2	**2796,535**	0,846 (-1.62%)	**0,870 (1,00%)**
	Labor constraints	578,17	773,3926	968,6	**802,8914**		
Experiment 12	Capital constraints	2141,1	2830,19	3519,2	**2836,656**	0,846 (-1.62%)	**0,903 (5,00%)**
	Labor constraints	578,17	773,3926	968,6	**832,3556**		

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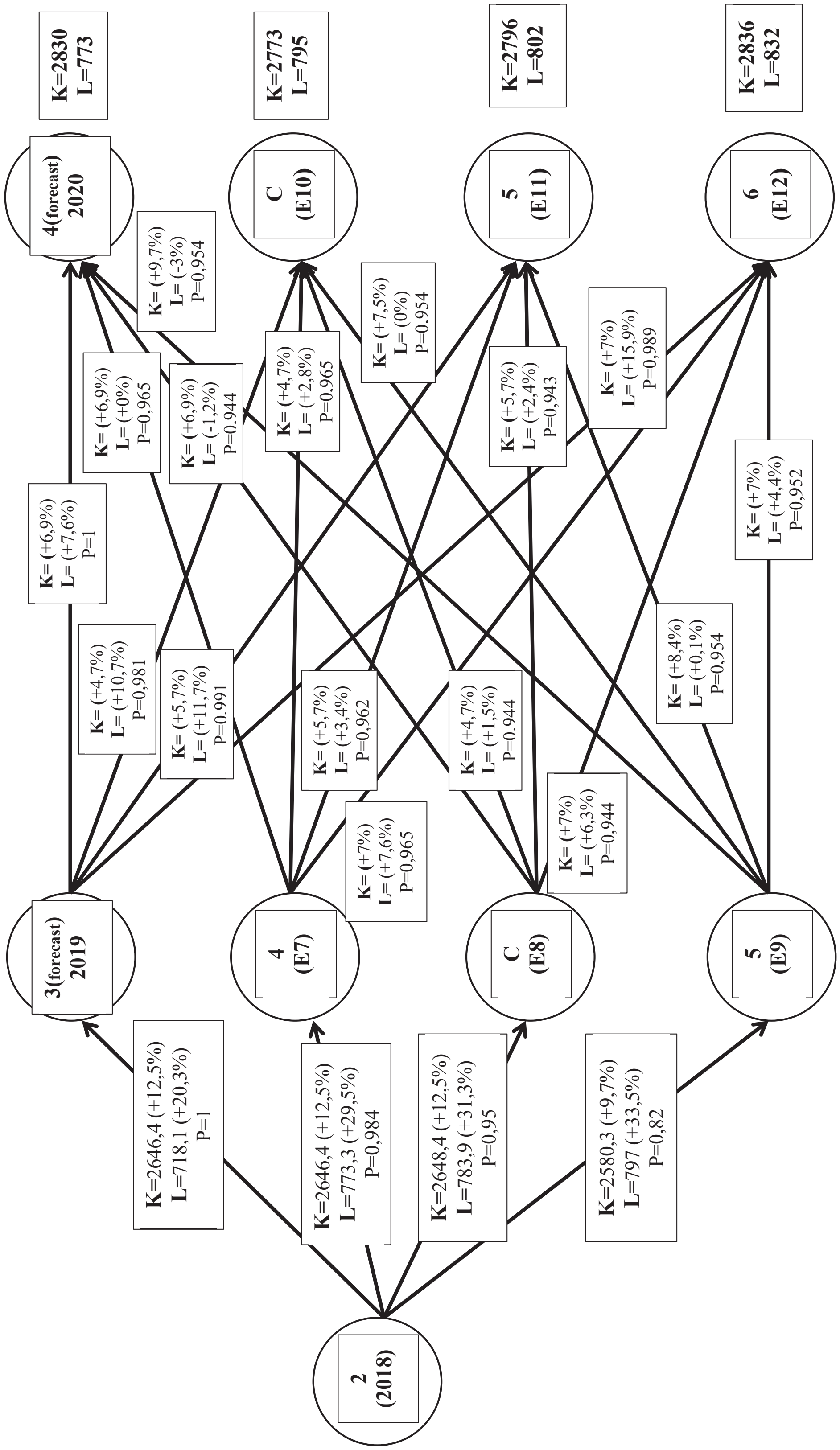

Fig. 6. Transition graph for enterprise "Lafarge"

Discussion questions. It requires further investigation of the use of optimization models, which is substantiated by the need for optimal redistribution of resources in terms of determining the resource capabilities of the enterprise for the long term and the formation of planned landmarks of changes in resources.

Optimizing the behavior of the enterprise is carried out in the conditions of limited capital and labor resources of the enterprise, so it is important to identify such resource constraints. In the study is proposed that resource constraints are formed on the basis of the analysis of the confidence interval of the predicted value of the resources.

Formation of the behavior scenarios is important in the study of enterprise behavior. Therefore, it is advisable to determine the criterion for choosing between aggressive and persistent behavioral scenarios. In the work such criterion is the transition probability determination to a more steady or unsteady state in order to maintain an existing development path or to form a new sustainable one.

Conclusions. As a result of the researches the following conclusions were obtained:

a methodical approach to the construction of enterprise behavior scenarios in the conditions of a non-stationary environment is proposed, the mathematical toolkit of which is a linear programming method, which in the conditions of possible combinations calculation of capital and labor resources enables to create aggressive and sustainable scenarios of enterprise development;

investigated the behavior of Lafarge, which is in the range 5% and 10% confidence intervals, that indicates the existence of 2nd grade stability as well as 3rd class sustainability. This state of limitation reflects the ability of an enterprise to improve the stability of its behavior as well as move to a worse class. Therefore, it is important to carry out additional studies to enhance the resilience of the enterprise;

an optimization model of enterprise behavior is proposed in the conditions of non-stationary external environment, which allows to find the optimal balance of capital and labor resources in order to ensure sustainable behavior or to form a new sustainable development path;

conducted experimental studies of changes in the behavior of the enterprise, which identified the possibility of achieving the behavior and implementation of the developed scenarios;

Enterprise development scenarios have been developed to determine the managerial impact on enterprise behavior to improve its development.

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