



Company strategic change management in the open innovation system

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ABSTRACT

The article examines the management of strategic changes as a purposeful influence on the enterprise, which is a platform of strategic changes, to determine its position regarding strategic goals and conditions formed under the influence of a changing operating environment. The theoretical and methodological basis of the study is the provisions of the change management theory. The main study method is cognitive modeling aimed at the formalization of decision-making processes in the area of strategic change management. For the study, open access corporate reports of the Volkswagen Group were used. A cognitive model of the company's activity was built taking into account strategic changes to ensure strategic changes and study the mutual influence of concepts in the process of implementing changes. An evaluation of the results of modeling the influence of the indicators of the cognitive model on the factors of strategic change management was carried out. As a conclusion, it allows you to make a forecast of concepts. Thus, thanks to the introduction of strategic changes in the open innovation system, the indicator "Financing and other resource provision" will reach the desired value (an increase of 177.5 million euros) in 2 years.

1. Introduction

The functioning of the enterprise in modern conditions takes place as a process of continuous implementation of changes and maximization of beneficial consequences and efficiency from their implementation. That is why enterprise management is, in essence, management of changes of various kinds, levels, nature, scale, etc. The management system of the enterprise in such conditions requires the development of scientific foundations for ensuring change management in all areas, and especially in the field of strategic management, which is designed to ensure the long-term profitability of the enterprise and its competitiveness through the effective distribution of available resources and the implementation of the mission (Gassmann et al., 2010). The primary objectives are the definition and scientific substantiation of the theoretical-methodical foundations of the implementation of strategic changes, the content of strategic change management processes and their classification to specify the content of the process of implementing strategic changes in the conditions of specific enterprises (Lichtenthaler, 2011).

The implementation of the strategy of a company is impossible without the implementation of strategic changes, which form the basis of its implementation and hence achieving strategic goals in market conditions. In such conditions, the management of strategic changes has a close relationship with all levels of strategic management of the enterprise (from corporate to operational ones), concerns all links of its activity and functional areas, creating the effect of symbiosis of management systems, the existence of which is subordinated to the goals and mission of the enterprise (Lee et al., 2010).

In the process of developing new technologies and products, the company relies not only on its own internal laboratories or R&D centers, but also actively attracts innovations and competences from the outside. In contrast to closed innovations, the concept of open innovations implies gaining access to the best world technologies and competencies, as well as using their solutions and experience to enter new markets (Gambardella and Panico, 2014). Open innovations have a number of advantages over closed ones (Yun et al., 2020): the possibility of obtaining a greater number of solutions, faster terms of finding

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a solution and lower financial costs. Now more and more companies adhere to exactly this principle of working with innovations, because it opens up limitless opportunities and technological potential.

Some companies simultaneously use both closed innovations, stimulating their development within the organization, and open innovations, closely interacting with the innovation ecosystem (Nambisan et al., 2018). This hybrid format is the most successful and promising due to two sources of innovation.

It is necessary to separate the concept of the relationship between sustainable development and open innovations. As the history of the civilization proves, innovation is the most important factor in the sustainable and effective development of the economy. However, this relationship is not always observed. For example, innovations are associated with a significant risk for the entities of innovative activity. Innovations may be destructive, slowing down the growth rate of the economy in the short term. However, the lack of innovation leads to stagnation in the economies of countries and contributes to the destruction of ecosystems. It should be noted that the creation of prerequisites for sustainable development and the efficiency of the national economy is provided only by basic innovations (product or technology ones). Improving innovations provide short-term development and, in the end, lead to a slowdown in development.

From the standpoint of sustainable development, open innovations (OI) are understood as an organic set of results, processes and effects associated with the creation and spread of innovations in various areas of human activity, contributing to an increase in socio-economic efficiency and the formation of a system of sustainable development of society.

Taken together, innovation impacts sustainability in different ways. For example, technology OIs ensure the economic efficiency of the country's economy and most often contribute to the removal of the economy from crisis situations. Environmental OIs are inseparable from the rational use of natural resources, which is implied in the modernization of the economy. And social OIs contribute to the elimination of problems in the formation of civil society. The ability to carry out OIs is becoming a key component of the competitiveness of a modern organization, as well as one of the most important factors in its sustainability.

Innovative management is related to the strategic management system due to the innovative properties of strategic changes. The implementation of open innovations (OI) without change processes in the enterprise is not possible in the same way as the implementation of strategic changes, by its nature, is innovations of different levels and perceptions (Leckel et al., 2020). Even destabilizing changes by their nature are local innovations that require the implementation of innovative measures. Despite this, it is impossible to give a clear identification of changes and OI as:

- Changes are a broader category than innovations (complex). A change may refer to the implementation of several innovations (Hameed et al., 2021);
- Changes may include measures that are not fundamentally new (innovative) (Singh et al., 2021);
- Changes can be repeated over time, while innovation is a one-time, evolving phenomenon or process (Sun et al., 2019);
- Changes in the enterprise can be reversible, while innovations are not reversible (Sivam et al., 2019).

The implementation of strategic change management in the activities of a company takes place in the conditions of the complication of the formalization of final and intermediate goals and criteria for evaluating the results achieved at a certain stage of the implementation of strategic changes. Management decisions regarding strategic changes take place in the conditions of the prevalence of qualitative criteria and expert-heuristic methods of substantiating the directions of management influence and solving current and prospective problems.

With that, the possibility of using the method to analyze the activity of a business entity, which considers the economic aspects of its operation and is based on cognitive modeling, is practically not investigated, which indicates the relevance of this study.

The analysis of existing models of economic systems and processes of such assessment shows that the vast majority of them are mathematical models (Teece et al., 2016; Siggelkow, 2017). At the same time, the development of these and other models clearly demonstrates that the practical effectiveness of the model is determined not only by the inverse relationship between its simplicity and the complexity of the system, but also has limitations due to the complexity of the model itself. For example, very complex mathematical models almost always turned out to be unable to give answers to fundamental research questions due to the lack of essential, reliable statistical data required to create these models. Accordingly, these models have always been and remain abstract enough and weakly correlate with economic reality.

It is especially important to overcome this limitation now. This is because the economy is in the zone of macro- and microeconomic instability and the uncertainty and riskiness of innovative processes increases, which results in the reduced possibilities of assessing and forecasting the development of domestic energy industry. At the moment, more than ever, models are needed that give an idea of the main trends in the development of the industry and its innovative potential. This will make it possible to conduct appropriate assessments, make forecasts and, depending on their results, give recommendations for the future.

The purpose of this paper is to improve the methodical approach to the justification of managerial decision-making regarding the management of strategic changes based on cognitive modeling.

2. Literature review

2.1. Analysis of the definition of strategic changes

Researching the essence of strategic changes and determining the scientific basis of their understanding requires clarifying not only the content of this particular category, but also clarifying the essence of changes as their root cause and the basis that determines the nature and content of strategic changes.

Scientists have been studying changes for a long time and in various fields of scientific knowledge. Regarding the changes, it is impossible to claim that they refer exclusively to management science, technology or economics. It is a general term used in various areas of human knowledge.

The study of the modern scientific approaches to the definition of the essence of the term "changes" and their characteristic features made it possible to group them according to some attributes.

The exponential growth of the term "innovation" can be observed. But it is no longer the central topic and is associated with other terms related to different ways of innovation characterizing open innovation variables (Baierle et al., 2021).

The first group of scientists (Chege et al., 2020; Cohen et al., 2019; Zhang et al., 2020) focuses attention on the sources of their origin when studying the essence of changes. The authors (Chege et al., 2020) note that changes are an issue that affects all organizations. The scientists (Cohen et al., 2019) prove that changes within the organization usually occur as a reaction to changes in the external environment. According to the authors (Zhang et al., 2020), changes are part of the existence of the enterprise but internal changes are secondary, while external changes are primary.

Das et al. (2018) interpret changes as the replacement of one state of the organization, work group, person, situation or other phenomena with a new state that differs from the previous one as a result of the influence of various factors of the external and internal environment. Therefore, the authors also consider the changes to be the result of the action of environmental factors and the process of replacing one state

with another, new one caused by the action of these factors. But the qualitative nature of such replacement is not indicated. The interpretation of the area of effect of changes (objects of changes) is interesting, which makes this definition universal, and changes multilevel depending on their objects.

Dellermann et al. (2017) when considering the essence of changes, define changes, as a process of transforming elements of the functioning of the enterprise under the influence of internal and external factors, which leads to the acquisition of a new (required) qualitative and quantitative state, capable of meeting the requirements of the environment for a certain period of time. This interpretation of changes as a process of transformation can be considered an evolutionary interpretation, the one that defines changes as a result of the impact of the environment on the enterprise.

The second group of scientists (Eling and Lehmann, 2018; Ganguly and Euchner, 2018; Khraisha and Arthur, 2018; Giudici, 2018; Gurd and Helliari, 2017; Hahn, 2020), when studying the essence of changes, considers them as innovations. In particular, they believe that changes are a set of changes in the organization that lead to the implementation of innovations and can take place in such areas: evaluation and change of the goals of an organization; change in structure (Eling and Lehmann, 2018). The scientists recognize the changes as a process of an innovative nature, which concerns the functioning of the organization and management.

The authors note that changes are the process of introducing innovations in the organization, they can apply to almost any aspect of its activity (Ganguly and Euchner, 2018). The purpose of the changes is to increase the competitiveness of the enterprise and the efficiency of its activities. This definition of changes is similar to the previous one, but outlines the main purpose of changes — to increase competitiveness.

The scientists (Khraisha and Arthur, 2018) note that changes are the organization's assimilation of new ideas or behavior patterns. These scientists consider changes as the introduction of novelties or as innovative transformations.

The authors note that, in general, "changes" mean the introduction of innovations to transform the company's activities in accordance with market requirements (Giudici, 2018). The authors also note that the term "change" can have several meanings in business. This term characterizes external changes in technologies, consumer tastes, conditions of competition, various social, political and other factors (Gurd and Helliari, 2017). This definition is an attempt to combine existing approaches to the interpretation of the essence of changes in the context of external and internal factors of their occurrence (Hahn, 2020). The thesis about the initiated nature of transformations, which are a consequence of changes in the enterprise, is of interest.

The third group of scientists (Mogos et al., 2018; Oliva et al., 2018; Piccarozzi, 2017; Richter et al., 2018) considers changes through the prism of changing, transformation processes and phenomena. In (Mogos et al., 2018), a meaningful interpretation of the term "changes in the enterprise" is given. This interpretation of changes is quite original, but, in our opinion, the issue of reducing changes only to the empirical observation of differences is debatable.

The authors (Oliva et al., 2018), who study the problems of organizational behavior, note that the concept of change means that between two consecutive moments of time there are noticeable differences in the situation, person, work group, organization or relationships. This interpretation of the essence of changes determines the differences in time of the catalysts of changes, the changes themselves and their consequences, and also equates changes with "differences" in the state of the subjects of changes.

The author (Piccarozzi, 2017) notes that changes in the enterprise can be defined as a purposeful transformation of the spatial, temporal, spatio-temporal state of the enterprise, its personnel, structure, internal relationships between elements and external relationships with the environment. This definition makes it clear that the author is a supporter of the fact that changes affect the internal and external

environment (but are not the causes of their impact) and are the result of purposeful actions of the management system.

The scientists (Richter et al., 2018) point out that changes determine the transition of the enterprise from the current state to the desired future state.

The fourth group of scientists (Pukala et al., 2018; Rane et al., 2019; Teberga et al., 2018) provides a comprehensive definition of changes, while combining the first and second of the previously mentioned approaches. The authors (Pukala et al., 2018) note that changes in relation to the organization (enterprise) should be understood as the introduction of innovations to transform the activities of an organization in accordance with market requirements. In the theory and practice of management, the scientists (Rane et al., 2019) consider changes from three positions: as a new condition; as a movement process; as a synonym for the terms "reorganization", "transformation", "innovation", "organizational changes", "reengineering", and "restructuring". But there is no single definition of changes in the modern management literature. According to the definition, changes are a way to bring the activities of a company to market requirements, which means to ensure competitiveness.

After identifying four directions of research in this subject area, the authors would like to single out one more scientific school. According to the balance of sub-entrepreneurship, the culture for open innovation dynamics can have different aspects, namely: the leading entrepreneurial culture for open innovation dynamics, the leading intra-entrepreneurial culture for open innovation dynamics, or the leading organizational entrepreneurial culture for open innovation dynamics (Yun et al., 2016; Yun et al., 2020; Yun et al., 2022).

The authors note that the concept of "change" can be interpreted as a transition to something else in the spheres of the internal and external environments of the organization, the emergence of something new (Teberga et al., 2018). This definition of changes confirms their occurrence as a result of the action of the internal and external environment and also actualizes the thesis that innovations are the result of changes.

The analysis of modern scientific interpretations of the term "changes" made it possible to identify their characteristics, namely:

- Changes are a form of being, the transformation of its objects, an integral part of the existence of an enterprise (Dellermann et al., 2017);
- Changes are the result of action of factors of external and internal environments (Ganguly and Euchner, 2018);
- Changes are processes leading to novelties or innovations (Giudici, 2018);
- Changes are the result of the purposeful influence of the management system or forces external to the enterprise (Hahn, 2020);
- Changes by their nature are an uncontrolled process, the occurrence of which is caused by the very existence of the enterprise (Oliva et al., 2018);
- Changes exist in the conditions of differences in goals and results of activities (Richter et al., 2018);
- Changes are a way to achieve market goals and ensure results of activities (Rane et al., 2019).

Summing up the scientific approaches to the essence of changes in the enterprise, it is suggested to understand them as management processes that continuously take place in the enterprise, are formed under the influence of the operation environment (internal and external), and the result of which is the achievement of a qualitatively new (changed) state of the object of management.

The authors' review of the scientific literature on the study of the theory of change and change management demonstrated that most scientists don't separate such terms as "changes", "organizational changes" and "strategic changes" as independent objects of management influence and sometimes substitute these concepts without

distinguishing them by content. The authors believe such a generalization of changes is not appropriate, as it can lead to making erroneous management decisions regarding the organization, planning, motivation and control of changes in the activities of a company.

The strategic-substantive approach to the characterization of strategic changes (Kunisch et al., 2017) consists in identifying them with changes in both the strategy of a company and its substantive components. The scientists (Küng, 2016) recognize the unity of the processes of changing the strategy and structure of the enterprise, its organizational level, that these processes are connected by cause-and-effect relationships.

The strategic-action approach to the interpretation of the content and essence of strategic changes at the enterprise (Alqatawneh, 2018) defines them as a set of actions, measures and influences on the parameters of the activity of the enterprise aimed at achieving a certain goal (the future state (Benthaus et al., 2016), improvement and efficiency of the enterprise's activity (Lopes et al., 2017), adaptive functioning and development (Latan et al., 2018), etc.) through the implementation of strategic tools for its achievement (strategic actions (Talbot and Boiral, 2018), strategic vision (N'Cho, 2017), strategic set (Schoemaker et al., 2018), etc.).

The scientists (Battistella et al., 2017; Ocasio et al., 2018), whose approach the author defined as a planned one, identify strategic changes with planned changes determined by the mission, goals and influence of the external environment.

The authors (Teece et al., 2016; Siggelkow, 2017; Bartosova et al., 2022), whose approach is united by an environmentally-oriented characteristic, relate their content, existence and action with the environment of operation when characterizing strategic changes.

A loosely structured business entity includes architecture, cooperation, configuration, and capabilities, offering the following advantages (Rong et al., 2021): (1) better redistribution of roles and coordination of ecosystem resources, (2) better understanding of the dynamic and co-evolutionary nature of ecosystem development and (3) inspiration for further exploration of additional partners.

Three different types of architecture have been explored: open (market), star-shaped (hierarchical), and strong closed (adhocratic, ambidextral) architectures (Al-Kfairy et al., 2020). The open (market) architecture suffered from both high transaction costs and inefficient decision-making.

A comparative analysis of the interpretations of the essence of strategic changes in an enterprise (in an organization, firm, company) taking into account the existing approaches, made it possible to form the author's definition. According to the definition and considering the above, when defining the essence of organizational changes, the author believes that they should be understood as changes that take place on the basis of the enterprise as a platform for changes related to the introduction of new forms and methods of management, which are aimed at achieving the goals of the enterprise through the change of existing norms, values, rules and methods of activity. Organizational changes concern all aspects of the activities of a company, all levels of management and ways of achieving goals, including the implementation of a strategy.

Strategic changes are a component of organizational changes, as they are implemented within a certain organization (enterprise) and are a separate object of management influence. They are inextricably linked with the formation of strategic management as a basic element of understanding the functioning of the enterprise, and a strategy — as a single concept for predicting the future of the enterprise.

2.2. Enterprise strategic change management

Enterprise strategic change management requires the development of a number of specific approaches, tools and means aimed at achieving a dual goal: implementation of the general enterprise strategy and achievement of the goals of strategic changes. The components of the

goals are interrelated, take into account external and internal drivers of change, and can only be fulfilled simultaneously and in full (Hitt et al., 2017).

Making changes cannot rely on intuition, but requires a systematic approach. To manage changes, one should streamline the process, justify its structure. The structure of the change process has the nature of a multi-stage and repetitive process of problem solving. It includes the processes of problem recognition, their resolution, control actions and consolidation of changes.

The authors discuss these conceptual theories of change.

The change concept of Gareth Morgan regarding "organizational metaphors" (Morgan, 2011). This concept is based on the proposition that managers see the principles of the organization operation differently depending on their experience, education, management style, etc. (Morgan, 2011). These principles can best be expressed through metaphors. Four organizational metaphors are most often used: organization — machine; organization — political system; organization — organism; organization — constant movement and transformation (Morgan, 2011).

Theory E and theory O. The authors of the theories are professors of the Harvard Business School: Michael Beer (theory E) and Nitin Nohria (theory O) (Beer and Nohria, 2000).

The theory E departs from the primacy of financial goals and focuses on their effective achievement, considering the constant pressure of the organization shareholders (Beer and Nohria, 2000). As a rule, managers professing the theory E use hard methods, emphasizing the implementation of changes from the top down and paying the main attention to the creation of structure and systems (Beer and Nohria, 2000).

The theory O considers the organization as a system that develops by itself and is more oriented to the corporate culture, the goals and motives of the organization employees (Beer and Nohria, 2000).

The practical use of theories E and O made it possible to draw the following conclusions:

1. To achieve the maximum effect, it is advisable to combine hard and soft methods. However, the authors of the theories note that only the most talented and trained managers can combine these methods. In this case, conditions for the formation of a flexible and prosperous organization for the long term are provided.
2. With the least risk, it would be better to use either theory E or theory O.
3. Also, it is possible to use the "sequential approach": first implement theory E, and then — theory O. At the final stage of strategic changes, it would be better to use the theory O.

ADKAR change management model (Hiatt, 2006). The model characterizes the modern approach to making changes in business teams and other social groups. The model emphasizes the readiness of each individual participant to take part in the change project, which is assessed using 5 factors (Hiatt, 2006):

- 1) Awareness of the need for change. At the same time, it is necessary to consider the person's vision of the current situation, the problems they notice, the depth of their trust in the change manager, the presence of unreliable information and gossip about the change project, and personal factors affecting the motivation to implement changes.
- 2) Desire and readiness of each group member to support the changes and personally participate in them. For this, it is necessary to understand the nature of the changes (what is its essence and how its support will affect each person), their organizational and environmental context (how will the organization or the environment subject to changes perceive the changes), and personal motivation factors.
- 3) Knowledge about necessary changes, their content and the methods of their implementation. It is important to consider the current

knowledge of the individual about what can be changed and how can it be changed, the capabilities of the person in acquiring additional knowledge, what resources are available for education and training.

- 4) Ability to make changes. The participants must have the necessary skills and/or the ability to learn them. It is necessary to pay attention to the mental blocks of the individual that prevent the implementation of changes, the physical abilities of the person, the time needed to learn the necessary skills, the availability of resources to support the development of new abilities.
- 5) Reinforcement for intermediate and final results of changes. The changes should be attractive for each of the participants, and everyone's contribution should be evaluated and rewarded. This will provide the necessary support for the change process.

Theories of organizational change.

The model of Lewin (1977). The three-stage model of change is an example of a classic approach to change. It is still the most common "recipe" for implementing changes.

This model is based on the concept of "field of forces". K. Lewin suggested to consider any organization or situation as something that is at a certain balance or equilibrium between the driving and restraining forces of change (Lewin, 1977). From the analysis of the field of forces it follows that it is much easier to weaken restraining forces than to increase the driving forces of change. That is why such an important stage as "defrosting" is necessary (Lewin, 1977).

The change model of Greiner (1998). Although the management may feel the need for changes, a situation may arise when it will not be able to make an accurate analysis of problems and carry out the changes properly (Greiner, 1998). There may arise a need for mediation services of an external consultant capable of objectively assessing the situation. Or a company can involve its employees as intermediaries, but under the condition that they can be considered impartial and express an opinion that is unlikely to please the top management. In any case, for this mediation to be effective, it must result in a change in orientation.

Let's consider particular scientific studies in this subject area.

Strategic change management has a number of specific features inherent exclusively to this process:

- Presence of an organizational subsystem focused on the preparation, development, implementation and monitoring of change processes with its further consolidation (Jansson et al., 2017). This subsystem can be both a separate link of organizational design and its eclectic component formed for certain purposes (bureau, department, division, etc.). The subsystem doesn't change radically the organizational design of the enterprise, and its information flows are mediated and additionally filtered by the new link;
- Presence of a change team responsible for the entire cycle of strategic changes. Many scientists (Raguseo, 2018) emphasize the necessity of creating a change team at the enterprise, but usually they don't give its characteristics and functions.

According to the authors of this paper, the strategic change team should be understood as a set of persons involved in the processes of preparation, development, implementation, control and consolidation of changes. The change team is not a stable organizational entity. It is a dynamic structure, the members of which change depending on the stage of strategic changes and the results of their implementation.

The members of the change team can be involved from the outside of the organization for a certain stage of strategic changes or their coordination (for example, IT specialists, coaches, etc.) (Wright and Nyberg, 2017). Change team members external to the organization are essentially change agents.

The main differences between stakeholders (subjects of strategic change), the change team and the agents of strategic changes (bearers

of strategic changes) are their essential characteristics, organizational affiliation, specialization, main functions of the strategic change management process, the possibility of using coercion and the procedure for reporting on the results of activities (Bolisani and Bratianu, 2017).

Consolidation of the results of strategic changes is mandatory. Due to the insufficient development of strategic change management mechanisms at enterprises, this stage is replaced either by strategic change control processes or by goal achievement monitoring processes, which, in the case of significant dependence of the enterprise on market conditions of business and market situation, distorts the achievement of change goals, or, what is worse, reduce strategic changes to an endless cycle (Pagani and Pardo, 2017).

The prolonged nature of the results of the implementation of strategic changes, which is related to the very essence of the object of management, the specificity of which consists in mainly qualitative results of management influence and the long-term nature of the strategy of the enterprise and its components (Hecklau et al., 2016).

A significant number of today change theory researchers stress the unity of change management and strategic enterprise management. The scientists (Birkinshaw et al., 2016) point out that strategic changes in the process of enterprise operation become an integral attribute of modern strategic management, namely, competitive advantages for achieving a high level of operational efficiency, a better way to meet consumer requirements, etc. (Giannakis and Papadopoulos, 2016). The authors (Ren et al., 2018) note that strategic change management is a secondary phenomenon. A strategy is a top priority. The implementation of changes contributes to the creation of conditions necessary for the implementation of the selected strategy at the enterprise" (Kiel et al., 2017). Scientists emphasize that strategic change management is the main core of the entire enterprise strategic management system in the current conditions (Marler and Parry, 2016).

Considering the above, it can be noted that enterprise strategic change management is the key to the implementation of the strategy, the achievement of strategic goals and long-term stable operation on the market in the conditions of a polystructural activity environment and a two-loop management system. The implementation of strategic change management should be perceived as a process integrated into the general strategic management, which, at the same time, has autonomy regarding the tools and organizational decisions for implementation.

The implementation of enterprise strategic change management requires its organizational-institutional support and justification not only by strategic resources (which in this case act mainly as a tangible support subsystem), but also by organizational (intangible) support from the side of strategic management and change management.

3. Materials and methods

The analysis of existing principles and approaches to modeling clearly demonstrates the need to develop a special modeling methodology when building models of innovative development of energy-generating companies. The authors believe that at the same time, each model should be adapted to the specifics of the industry, to the state of its current innovative development (Bartosova et al., 2022).

For these purposes, a quite new approach is the most adequate. It is the construction of cognitive models, which is used for the analysis of loosely structured problems that arise in the process of functioning of complex systems (Giudici, 2018). Cognitive modeling makes it possible to "embed" various system techniques and methods into a single research program and thereby remove contradictions that usually arise when harmonizing and matching the results of research on various aspects of the development of a complex system (Chege et al., 2020).

Some scientists insist on the perspective of cognitive modeling techniques for solving complex economic problems. This approach, which is recognized effective in the process of improving the methodology for choosing state support tools, is usually focused (Zhang et al.,

2020) on the strategic or conceptual level of management and decision-making.

In the cognitive model, information about the system is provided in the form of a set of concepts (factors-concepts) connected by a cause-and-effect relationship. It is the so-called "cognitive map" (Khraisha and Arthur, 2018), reflecting the subjective opinions of experts about the laws and regularities inherent in the modeled system. It is the representation of ideas about relationships (in one form or another) that exists between attributes (notions, concepts) in this subject area.

For any business structure, an important task is the study of scenarios for its development, taking into account possible situations, as well as the determination of ways to achieve the desired level of indicators of its activity through purposeful managerial influences.

Solving these problems can be divided into the following stages (Martinez-Ferrero et al., 2016):

1. To build a mathematical model of the business structure, taking into account economic aspects.
2. To study the dynamics of the main indicators of the business structure activity for a given period.
3. To determine the management influence that helps achieve the desired indicators of the business structure activity for a certain period of time.

Business structures that carry out production and economic activities, actively using natural resources, are weakly structured systems. Their operation is described by a large set of factors, and not all of these factors are known in advance. The relationships between factors are also often implicit. Sometimes, both the factors themselves and the relationships between them can only be determined through research. Therefore, to solve the set problem, it is advisable to use cognitive analysis, which is designed specifically for the study of weakly structured systems.

A cognitive approach to the modeling and management of weakly structured systems involves the development of formal methods and

models that include or take into account cognitive capabilities (understanding, perception, explanation of ideas), supporting the intellectual process when solving managerial tasks (Vaara et al., 2016).

The essence of this approach is that complex processes and systems are displayed in a simplified, intuitively understandable form, which allows you to study possible scenarios of system development.

The main areas of using cognitive models include the following: impact analysis; analysis of the dynamics of state change (forecast of the development of the situation); stability analysis; scenario analysis; search for managerial influences; evaluation and interpretation of forecasts of the development of the situation.

The scientists (Suddaby and Foster, 2017) give different stages of cognitive analysis. But all of them, differing in details, agree in the main thing (Drobyazko and Hilorme, 2022).

Fig. 1 shows the stages of study.

Therefore, when conducting a cognitive analysis, it is necessary to follow these steps:

1. To formulate the purpose and objectives of the study.
2. To study the problem situation from the standpoint of the purpose, which means the collection, systematization and analysis of existing statistical and qualitative information about the system and its external environment, the definition of the requirements, conditions and limitations inherent in the situation under study.
3. To identify the main factors affecting the development of the situation.
4. To determine the relationship between factors (build a cognitive map in the form of an oriented graph).
5. To study the strength of mutual influence of various factors. For this, both mathematical models, describing some precisely identified quantitative dependencies between factors, and subjective views of an expert regarding the formalization of qualitative relationships between factors are used.
6. To check the adequacy of the cognitive model of the real situation obtained in the previous steps (verification of the cognitive model).

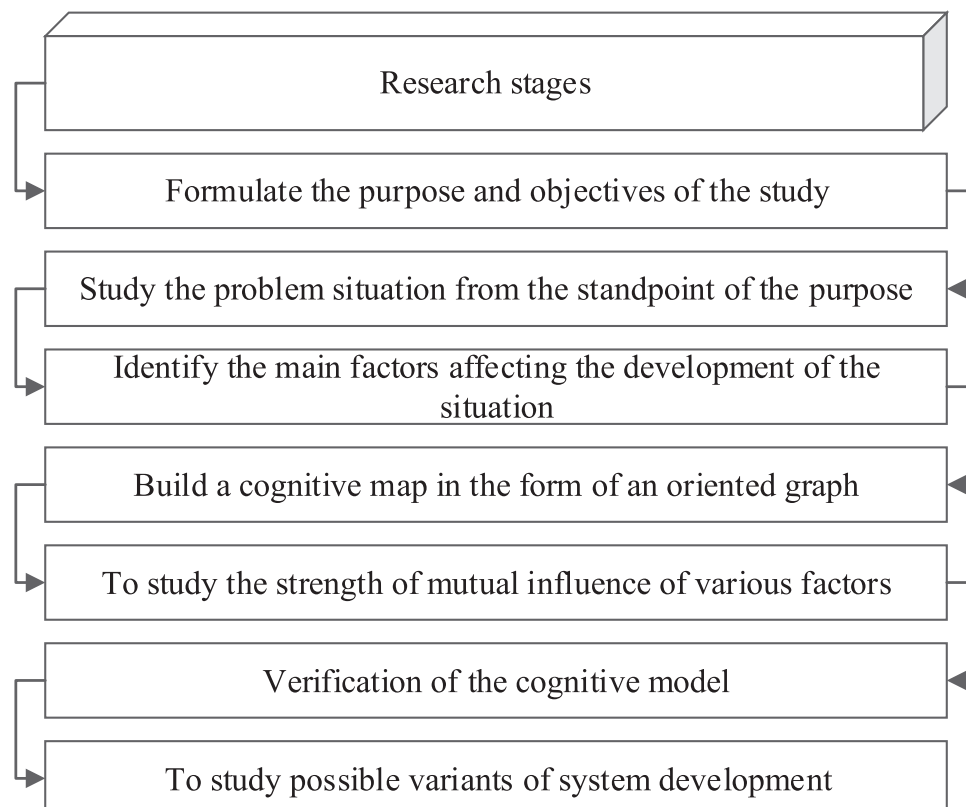


Fig. 1. Study stages.

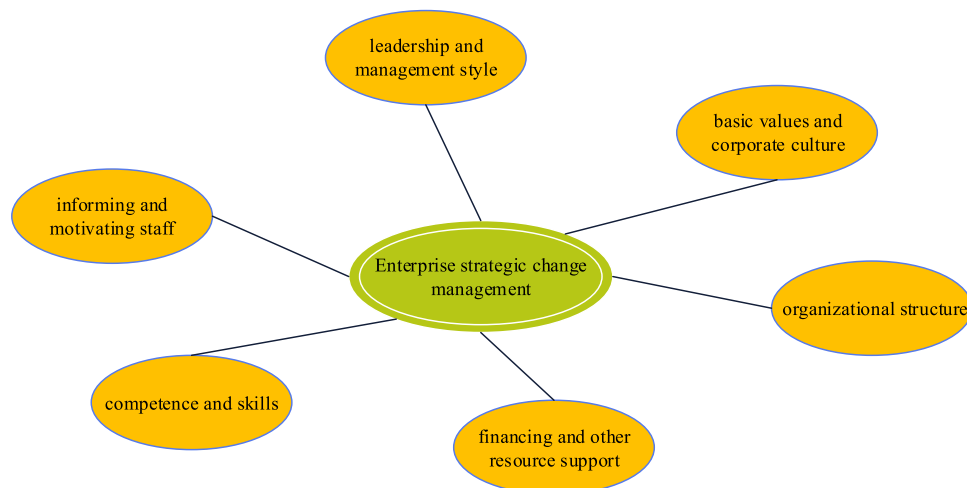


Fig. 2. Cognitive map of the activity of a company concerning strategic changes.

7. To study possible variants of system development using a cognitive model and identify the ways, mechanisms of influence on the situation to achieve the desired results.

The steps 3–5 describe building a cognitive model in the form of a weighted graph, and the steps 6–7 — the study and use of the obtained model.

It should be noted that scientists are faced with two main problems when building a cognitive model.

The first problem is to define and rank factors, i.e. elements of the system, which are essential for the study of the given situation (*Interim Reports and Half-Yearly Financial Reports, 2022*).

The second problem is to identify and describe the relationship between the factors (*Hess et al., 2016*). In the simplest case, one can name only the direction of this relationship. It is can be positive (when one indicator increases, the value of another also increases) and negative (when one indicator increases, the value of another decreases). But sometimes, it is difficult to detect even such relationship. This is because factors may not be connected directly, but through a chain of other factors. To determine the weighting coefficients that describe not only the direction, but also the strength of the influence of one indicator on another is a more difficult task.

A classic cognitive map (CM) is a weighted directed graph where the vertices correspond to the factors (indicators) essential for the situation under study, and the arcs describe the relationship between the factors.

As a rule, there are one or more target vertices, i.e., the ones that correspond to the indicators that we have to investigate. And there is a certain set of vertices that we can manage, i.e., apply certain management influences to them to achieve the desired values of the target vertices.

Thus, cognitive maps allow for static analysis, that is, analysis of the situation under study by exploring the structure of mutual influences of the concepts of the cognitive map, and dynamic analysis, which consists in the generation of possible scenarios for the development of the situation over time.

4. Results

It is strategic changes that are the main carriers of new quality during the development of the organization and represent a key management object in the process of implementing each functional and specialized strategy, as well as a corporate strategy as a whole. Strategic changes condition the transition of an enterprise from one strategic state to another (*Wirtz et al., 2016*).

Therefore, the following main indicators (factors) were selected for the activity of a company as an economic system. These indicators will

be the vertices of the cognitive map (CM): personnel awareness and motivation; leadership and management style; basic values and corporate culture; organizational structure; financing and other resource support; competence and skills.

For the study, open access corporate reports of the Volkswagen Group were used (*Volkswagen Group makes solid start to fiscal year, with strong increase in revenues and underlying operating profit (2023)*).

At the first stage, the direction and presence of a relationship between the selected factors were assessed by interviewing experts. Thus, it was discovered that the following relationships can be traced: with an increase in the cash flow, the amount that the company can invest in strategic changes of the enterprise increases (CM edge 2–1); since financing and other resource support represent one of the main factors in the formation of the income of a company, its increase leads to an increase in the net cash flow (CM edge 3–2).

Based on the above, it is possible to build this cognitive map (CM) (Fig. 2).

For this, based on the statistical data, a regression analysis of the factors corresponding to the CM vertices is carried out. It can be done, for example, using the Analysis ToolPak in MS Excel.

It should be noted that the analysis is conducted only for vertices that are connected by edges in the CM. For these vertices, the regression coefficients are determined and their significance is checked using the Fisher's exact test. If the regression coefficients are significant and logically correspond to the essence of the relationship between the vertices, these coefficients are accepted as the weights of the corresponding edges.

The authors consider this step using the example of the relationship between the factors "Financing and other resource support" and "Leadership and management style". Using the "Regression" tool of the MS Excel Analysis ToolPak, the authors obtained the following results based on the samples of values of the above factors (Table 1).

As you can see, the regression coefficient is 0.088914, while the coefficient of determination (R^2) is 0.916443712. This means that the calculated parameters of the model explain the relationship between the parameters under study by 91.64%. The coefficient of determination is greater than 0.8, which indicates the high accuracy of selecting the regression equation (coefficient).

According to the Fisher's exact test, all regression coefficients were significant for the considered model. Having analyzed the sign of the regression coefficients and the direction of the relationship in the signed CM, one can conclude that they also logically reflect the influence of the factors. Therefore, it is possible to take these coefficients as the weights of the CM arcs.

In the current time of economic and political instability, the indicators of the company's activities may change. Suppose that the

Table 1

Regression analysis of the relationship between the factors "Financing and other resource support" and "Leadership and management style".

Results output					
Regression statistics					
Multiple R 0.957310667					
R-squared 0.916443712					
Normalized R-squared 0.716443712					
Standard error 231.7329133					
Observations 6					
Variance analysis					
	df	SS	MS	F	F significance
Regression	1	2944910.51	2944910.517	54.839	0.0017
Remainder	5	268500.71	53700.142		
Total	6	3213411.23			
	Coefficients	Standard error	t-test	Upper 95%	Lower 95%
Y-intersection	0	X	X	X	X
X1 variable	0.08814	0.0120067	7.4053967	0.11977	0.0580502

company increases production by 0.5% every year. Suppose that the state of the company at each moment of time is evaluated by a set of indicators, the coordinates of the vertices of the CM, and their initial values are known. The company's management is interested in studying the company's development scenario to identify the need for targeted management actions. That is, it is necessary to forecast the main indicators of the company's activities for 5 years, taking into account the assumptions made when building the cognitive map.

To solve this problem, the authors use the rules for changing the values of the coordinates of the cognitive map during the autonomous impulse process, which are described by Warner and Wäger (2019), namely:

$$y_i(t + 1) = y_i(t) + \sum_{i=1}^n V_{ij} \Delta y_i(t), \tag{1}$$

where $y_i(t + 1)$ — the value of the coordinate y_i at the moment of time t ; V_{ij} — the weighting coefficients describing the influence of the coordinate y_i on $\Delta y_i(t) = y_i(t) - y_i(t - 1)$; $i = 1, 2, \dots, n$ — the change of the coordinate y_i at the moment of time t .

In the vector form, the Eq. (1) can be represented as follows:

$$\Delta \bar{y}(t + 1) = \sum_{i=1}^n V^T \Delta \bar{y}(t) \tag{2}$$

where V —the weight matrix of CM adjacency.

The CM adjacency matrix has the following form:

$$V = \begin{pmatrix} 0 & 0 & 0 & 0 & -0.03 & -0.04 \\ 0.089 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.59 & 1.05 & 0 & 0 & 0 \\ 0 & -0.27 & 0 & 1.05 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

The ranges of characteristics-indicators of enterprise strategic change management are presented in Figs. 3–4.

Suppose that the state of the business structure at each moment of time is described by a certain set of economic indicators, the coordinates of the CM vertices, their initial values are known and certain desired values are set that must be achieved for the stable operation of the company.

The company's management is interested in increasing the efficiency of production and economic activity and developing a management strategy that will ensure that the economic entity achieves the set level of economic indicators.

It is necessary to determine the optimal management strategy that will bring the business structure to the desired state. In the formal formulation, this is the task of developing a system for stabilizing the unstable process of coordinates of the CMC vertices at the set levels. Arnold et al. (2016) developed the model of the CM controlled impulse process of the "input-output" type, taking into account external control influences, which has the form of (3):

$$(U - A_w^{-1}) \Delta \bar{y}(t) = B_w^{-1} \Delta \bar{u}(t) \tag{3}$$

where q^{-1} — the operator of inverse shift for one quantization period, matrix A consists of CM coefficients, $A = V^T$.

In the model (3) the vector of growth of external controls is introduced:

$$\Delta \bar{u}(t) = \bar{u}(t) - \bar{u}(t - 1) \tag{4}$$

These directly affect the CM vertices and are formed according to a separate control law.

At the same time, the diagonal matrix B can be taken as a single one. The CM model (3) is distinguished by the absence of dynamic control links and complex dynamics between the coordinates (vertices) of the CM.

It should be noted that the stability of the impulse process cannot be guaranteed in the built model. Therefore, to stabilize the unstable transient process of the CM in full coordinate values, the authors use the method based on the application of the reference model.

The control law for the problem of stabilization of the unstable process of the coordinates of the CM vertices at the given levels will have the following form:

$$\bar{u}(t) = (U + A + A_{p1} + (A_{p2} - A)q^{-1}) \times [\bar{G} - \bar{y}(t)] \tag{5}$$

At the same time, the dynamics of the CM vertices is described as follows:

$$\bar{y}(t) = -A_{p1} \bar{y}(t - 1) - A_{p2} \bar{y}(t - 2) + (U + A_{p1} + A_{p2}) \bar{G} \tag{6}$$

where A_{p1}, A_{p2} — the parameters of the reference model; G — the vector of parameters describing the given state of the system. It is necessary to stabilize the CM vertices at the level of the components of the state.

At the same time, the transient process in the controlled CM will be determined by the formed dynamics of the reference model.

For the cognitive map described above, in the accepted notation, we get the following:

$$A = V^T,$$

$$A = \begin{pmatrix} 0 & 0.89 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.59 & -0.27 & 0 & 0 \\ 0 & 0 & 1.05 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1.05 & 0 & 0 \\ -0.03 & 0 & 0 & 0 & 1 & 0 \\ -0.04 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

$$B = U = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

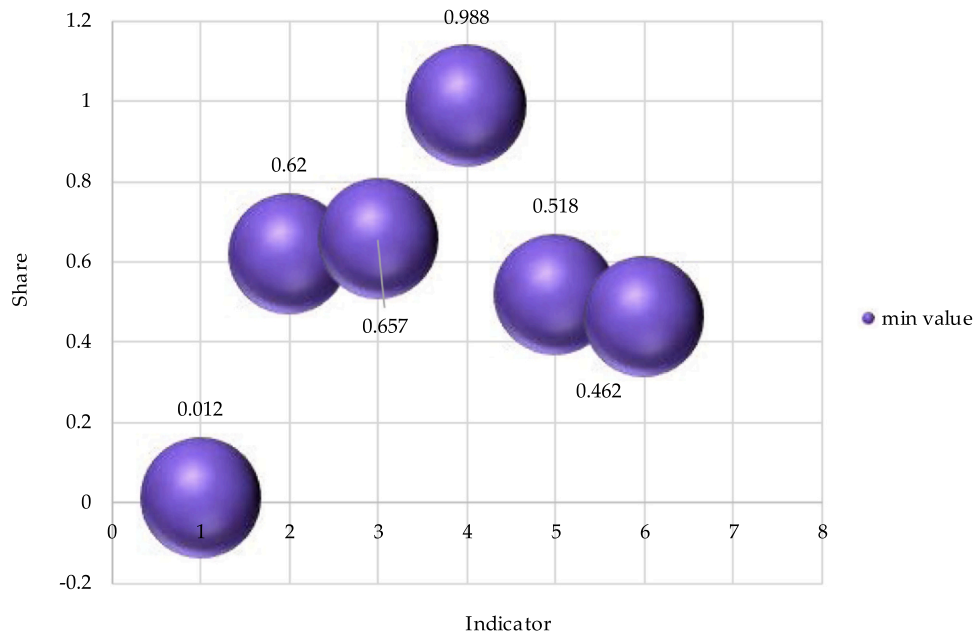


Fig. 3. Minimum value of enterprise strategic change management factors.

A diagonal matrix polynomial with the same polynomials on the main diagonal was taken as a reference model of a closed system, with the coefficients $A_{p1} = -0.31$, $A_{p2} = 0.021$.

An example of the graph of the change of the coordinate "Financing and other resource support" is given in Fig. 5.

As we can see, thanks to the management, the indicator "Financing and other resource support" reaches the desired value (increases by 177.5 million euros) already after 2 years.

So, as a result of solving the problem, the values of the CM vertices, i.e. the indicators of the company's activity, were stabilized at the desired levels. Different indicators require different time for stabilization, but it can be confidently stated that over a period of 5 years all indicators will stabilize at the desired levels, and control errors in all vertices are equal to zero.

5. Discussion

Scientists actively use a system-situational approach in the study of production-economic processes, economic and environmental phenomena, management problems at the level of independent entities.

In Hess et al. (2016), in order to develop the respective theoretical foundations in the system of anti-crisis management of production-economic structures, the basic patterns of their functioning and development are substantiated, provided the crisis situation occurs. The paper (Hanelt et al., 2021) is focused on the importance and introduction of innovative approaches to the management of production-economic systems.

The concept of "ecological-economic system" makes it possible to take a systematic approach in the study of the problem of interaction of

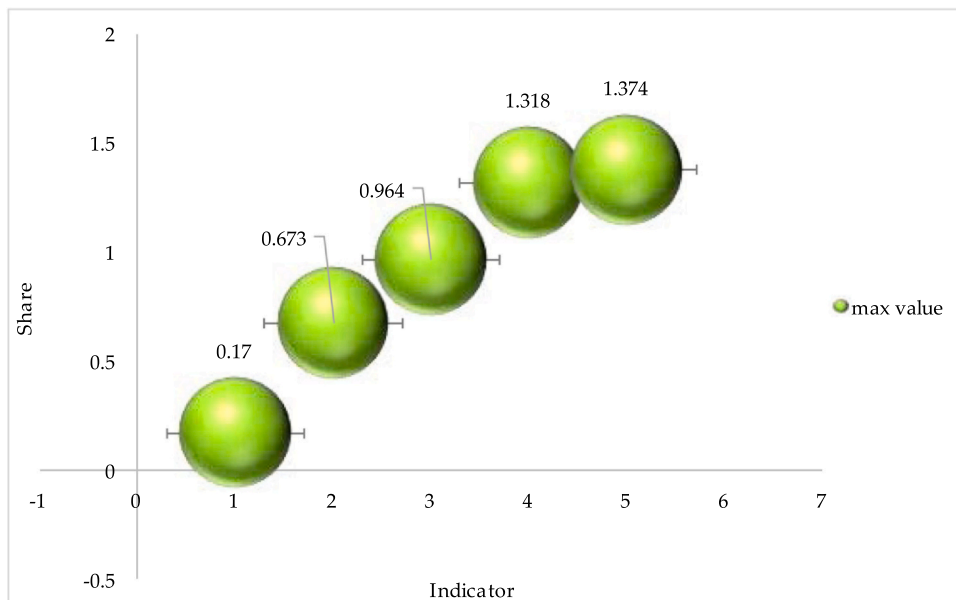


Fig. 4. Maximum value of enterprise strategic change management factors.

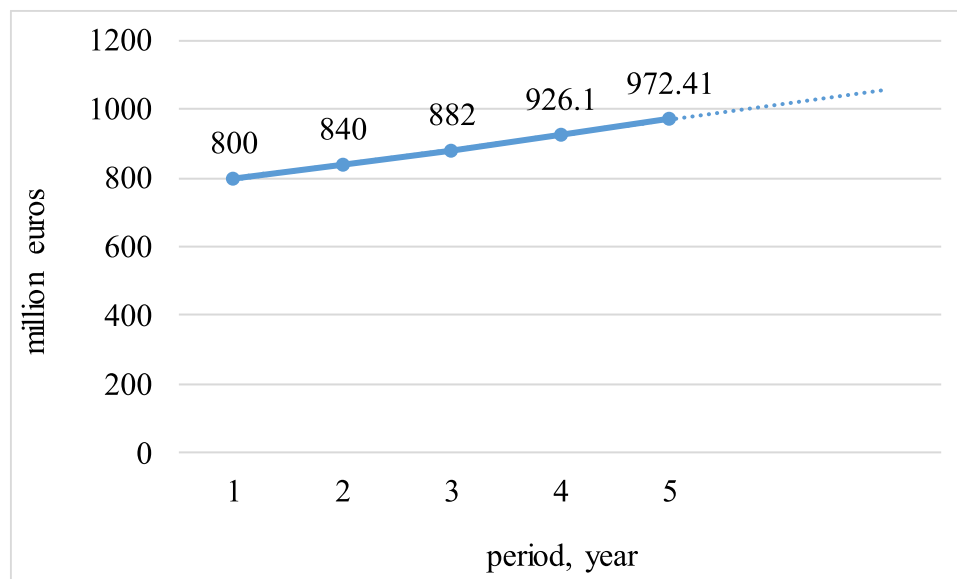


Fig. 5. Graph of the change of the indicator "Financing and other resource support".

the production enterprise with the environment (Oliva, 2016). The authors of (Roome and Louche, 2016), while determining two inter-related subsystems in the ecological-economic system, ecological and economic ones, emphasize that the unifying link between them is the sphere of nature management as a basis that ensures the implementation of economic processes, since without the development of natural resources it is impossible to carry out business activities.

The specificity of using cognitive modeling methods is their focus on specific conditions of development of the situation in one or another subject area (Guthrie et al., 2017).

The authors of (Wirtz et al., 2016) identified the advantages of cognitive modeling in the management and forecasting of sustainable development of integrated business structures. In the paper (De Angelis et al., 2018), it is suggested to create strategic scenarios of innovation management of machine-building enterprises on the basis of cognitive modeling.

In cognitology, the theory of artificial intelligence is understood very widely including the theory of information, the theory of decision-making and recently — theoretical informatics. Currently, the tasks of ensuring the technological synthesis of the intellectual capabilities of a person and computers, the development of interactive information visualization systems and decision-making support systems are set, and the cognitive modeling methodology develops towards improving the analysis and modeling of the situation (Luftman et al., 2017).

The presentation of complex systems of different nature in the form of cognitive graphic models is an increasingly common technique of research of poorly structured problems of their functioning in a dynamically changing external environment. The developed cognitive models, for example, those of the socio-economic system (industry, organizations, etc.) make it possible to explain the processes that occur in them, forecast development, create the best development strategies. Analysis of the results of research makes it possible to use these models in the blocks of management solution support in intellectual systems (Mohelska and Sokolova, 2018). But cognitive research and scenario modeling for existing socio-economic systems is often difficult due to: deficiency of materials, the impossibility of accurate forecasting of the alleged influences, the difficulty of real-time checking of the effectiveness of the proposed management solutions, and, moreover, the influence of the consequences of these solutions on the management system (Annarelli and Nonino, 2016).

The issue of the reliability of cognitive maps is important in cognitive modeling of strategic changes. Solving this issue largely depends on the correct choice of basic factors and cause-and-effect relationships

of the built map. To date, in the theory of cognitive modeling, this question remains open.

We consider it necessary to emphasize that the article presents precisely the demonstration prototype of the cognitive model, which, in our opinion, quite convincingly indicates the high potential of the applied capabilities of this class of models. The creation of industrial prototypes, which take into account the numerous characteristics of a particular enterprise and its external environment, is usually labor-intensive and can significantly exceed the costs of developing a demonstration prototype.

6. Conclusions

It was established that business structures that carry out production and economic activities, actively using open innovations that affect strategic changes, are weakly structured systems. First of all, this is due to the fact that the system of factors and the relationships between them is not defined with sufficient completeness. Therefore, to achieve the set purpose, it is advisable to use cognitive analysis, which is designed specifically for the study of weakly structured systems.

During building the cognitive model, the main factors affecting companies in the policy of introducing strategic changes were determined. Provided that management influences are applied, the specified economic indicators can be achieved in a much shorter period of time (all results are achieved in 4 years) If no management influences are applied, the results are not achieved even within 5 years). Therefore, it is advisable to use cognitive modeling to increase the validity of management decisions when developing a scenario for achieving the desired state of the business structure.

For a deeper analysis of the model described in the form of a weighted cognitive map, it is necessary to apply special assumptions about the impact of changes in the value of the parameters of one vertex on the parameters of other vertices. And these assumptions significantly affect the conclusions that will be obtained when using the model. For example, if we assume that the basic data (for example, the initial values of the parameters in each vertex and weights) are unclear, the final conclusions will also always be unclear.

Therefore, any obtained result should be considered as preliminary and should be subjected to additional analysis, which may also include repeated modeling and, possibly, other rules for changing parameters.

Prospects for further research are the creation of alternative scenarios for the management of strategic changes of enterprises

depending on the influence of various factors on the basis of cognitive modeling, the determination of appropriate tools for organizational changes.

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Data availability

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Declaration of Competing Interest

The authors declare no conflict of interest.

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