Application of the Cognitive Approach in the Field of Project Management

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Abstract

The article describes the principles and methods of the cognitive approach to project management. The content of cognitive analysis as a tool for studying an unstable semi-structured environment is disclosed. An algorithm for a complex hierarchical approach to the construction of a cognitive system is presented. As a cognitive model, an example of a cognitive map is presented and described with consideration of the problems of mutual influence of factors in solving management problems, transforming knowledge, and verifying them to develop the most effective management strategy.

Keywords

Cognitive analysis, modeling technology, cognitive systems, project management

1. Introduction

A variety of approaches and methods are used to implement projects of creating modern information systems. In recent years, the cognitive approach has been actively used, which contributes to the solution of existing problems by methods that take into account cognitive aspects in the processes of perception, thinking, cognition, explanation and understanding. This approach focuses on the processes of knowledge representation, its storing, handling, interpretation and creation of a new knowledge.

Nowadays, obtaining reliable information and its operational analysis is the basis of successful management. This is especially relevant if the management object and its external environment are a complex of complicated processes and factors that significantly influence each other. Currently, it is important to use a soft approach in the management of complicated intellectual projects, the essence of which is self-governance and self-control methods. Weak, so-called resonant phenomena are extremely effective for self-governance, as they correspond to internal trends in the development of complicated projects and programs. The main problem is how to push the project to one of its own and favorable development paths with a small resonant influence, how to ensure self-governance and self-sustained development. One of the most productive approach to solve problems arising in the field of project management is the application of cognitive management. The basis of cognitive management is cognitive analysis, cognitive models, cognitive modeling, and cognitive system.

2. General principles of cognitive management

One of the main concepts of cognitive management is the use of the information space as an environment for the integration of cognitive management. This application is based on cognitive information interaction. This concept uses the principle of cognitive interaction between an object and

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a subject in the information space. Such interaction is based on the creation of a generalized information model, which includes an object and a subject and connected between each other the cognitive and information areas.

The principle of cognitive management is the use of information modeling to implement cognitive management The general principle of cognitive management is the use of specialized information models: information situation, information position, information need, wealth of information resources, etc. With regard to cognitive management, the information space appears as a heterogeneous environment. Sometimes the structure of a management information space is defined as a hierarchy of ordered information subspaces. This is what J. Caglioti says: "... the flow of ordered signals perceived by the senses is transformed into ordered states of our brain — visual and auditory images. " These ordered subspaces can be represented as stratified levels. At the lowest level of evaluation management is quantitative and sign information. The next level of scoring management is parametric scoring. It makes it possible to evaluate structured and homogeneous information. At the highest level of management, the main tool is cognitive analysis, and the objects of analysis can be images. This level is a start of making decisions on the basis of figurative knowledge and cognitive management. Hence, a hierarchically organized information space consisting of ordered subspaces can be considered as an area of study or an object of the science of cognitology, and these spaces are oriented, which allows them to be used relatively quickly in management.

3. Cognitive analysis

Initially, cognitive analysis was formed within the framework of social psychology, namely, cognitivism, which studies the processes of perception and cognition. Using the innovations of social psychology in management theory led to the formation of a special field of knowledge - cognitology, which focuses on the study of management problems and decision-making problems. Currently, the methodology of cognitive modeling is developing in the direction of improving the apparatus of analysis and modeling of situations. The theoretical achievements of cognitive analysis became the basis for the creation of computer systems focused on solving applied tasks in the field of management.

The examples of cognitive analysis are PEST and SWOT analyses. They are effectively used in strategic management. For example, PEST analysis (Policy, Economy, Society, Technology), which most often determines the condition of the resource according to the listed subsystems; SWOT analysis (Strengths – advantages, i.e. what can make the system under study exist; Weakness – disadvantages, weaknesses; Opportunities – possibilities of the system; Threats – dangers and threats to the existence of the system). Similar methodologies of strategic analysis are currently used in UN commissions, for example, during the selection of indicators for the purpose of assessing the sustainable development of territories, states, and cities. Using knowledge about the object, groups of experts conduct an analysis of the situation on the territory, choose targeted indicators and appropriate initiatives to prevent the unfavorable development of a particular scenario. Models of the object under investigation are often offered to experts in advance. Models create, as it were, a "frame" and are loosely structured, conceptual, that is, cognitive.

I.V. Prangishvili defines cognitive analysis as "a sequential cause-and-effect structuring of information about the processes taking place in the studied areas...". Such processes are described by a set of factors that are interconnected by causal chains "if..., then...". The cause-and-effect chain "if ..., then ..." in the algebra of logic was called a sequence and was used to formalize the task. Tasks of a qualitative nature, i.e. cognitive, are considered difficult. In this case, cognitive structuring (cognitive mapping) or, in other words, clarification of the "hypothesis about the functioning of the object under study" is necessary. This is achieved by using the above-mentioned "if ... then ..." chain.

Cognitive analysis is sometimes called "cognitive structuring" by researchers. Cognitive analysis is considered as one of the most powerful tools for researching an unstable and weakly structured environment. It contributes to a better understanding of the problems existing in the environment, the detection of contradictions and a qualitative analysis of the ongoing processes. The essence of cognitive modeling, the key point of cognitive analysis, is to depict the most complicated problems and trends of system development in a simplified form in a model, to investigate possible scenarios of crisis situations, to find the ways and conditions for their solution in a model situation. Cognitive analysis

consists of several stages, at each of which a certain task is implemented. The consistent solution of these tasks leads to the achievement of the main goal of cognitive analysis.

4. Cognitive modeling and cognitive system

Cognitive modeling is intended for structuring, analysis and acceptance of management decisions in complicated and uncertain situations (geopolitical, internal political, military, etc.), in the absence of quantitative or statistical information about the processes taking place in such situations. Cognitive modeling contributes to a better understanding of the problem situation, detection of contradictions and qualitative analysis of the system. The purpose of modeling is to form and refine a hypothesis about the functioning of the object under study, which is considered as a complicated system consisting of separate, but still interconnected elements and subsystems.

In order to understand and analyze the behavior of a complicated system, a structural diagram of the cause-and-effect relations of system elements is built. The analysis of these connections is necessary for the implementation of various approaches to manage processes in the project.

Cognitive modeling allows in express mode, in a short period of time at a qualitative level:

- assess the situation and conduct an analysis of the mutual influence of the current factors that determine the possible scenarios of the development of the situation;
- to reveal trends in the development of situations and the real intentions of their participants;
- to develop a strategy of using trends in the development of the political situation in the national interests of Ukraine;
- to determine the possible mechanisms of interaction of the participants in the situation to achieve its purposeful development for the benefit of Ukraine;
- to develop and substantiate directions for managing the situation in favor of Ukraine;
- determine the possible options for the development of the situation, taking into account the consequences of making the most important decisions and compare them.

The use of cognitive modeling technology allows to act in advance and not to turn potentially dangerous situations into threatening and conflicting ones, and in case of their occurrence, to make rational decisions in favor of the subjects of Ukraine.

For tasks related to organizational principles, problems of uncertainty in the description and modeling of the functions of participants are not methodological, but intrinsic to the subject of research. It is possible to formulate different tasks regarding the management of the situation depending on the completeness of the information available to the participants about it and other participants, in particular for the search for resonant and synergistic effects, when the improvement of the situation with the simultaneous influence of several participants on it is greater than the "unification" of positive effects from each of the participants separately.

The cognitive system is often associated with decision support systems (DSS) or executive support systems (ESS). A cognitive system is a structured, logically described or formalized model of a "soft" (weakly structured) system proposed for cognitive analysis.

The construction of the cognitive system includes the analysis of the modes of its work, the analysis of the surrounding environment. External and internal parameters of the cognitive system are distinguished. External parameters characterize the properties of the external environment. They are denoted by their vector X= (x1, x2,..., xn). Internal parameters characterize the properties of individual elements of the system, they are denoted by the vector Z= (z1, z2 , ..., zr). The set of external and internal parameters forms the input parameters. Values characterizing the properties of the cognitive system are called output (initial) parameters. They are denoted by the vector Y= (y1, y2,..., y t).

Sets expressing the dependence between input and output parameters are considered a mathematical description of the cognitive system:

$$Y = F(X, Z) \quad , \tag{1}$$

Expression (1) is a fuzzy relation between two sets of parameters A=(X, Z) and Y. The modified hierarchy method is often considered the main method for constructing a cognitive system. Each level

of the hierarchy corresponds to its own models. We present the algorithm of a complex hierarchical approach to the construction of a cognitive system:

Step 1. The number of hierarchy levels in the cognitive system is determined.

Step 2. The main criteria of each level are defined.

Step 3. The initial states of the components of the cognitive system and the input values of the parameters that determine the initialization of events are set, and the initial value of the simulation time t=t0 is set.

Step 4. Structural, heuristic, simulation and evolutionary models are built.

Step 5. The scale of fuzzy conditions is set and the simulation path is selected.

Step 6. The feasibility logic of all events at all levels of the hierarchy in the cognitive system is checked.

Step 7. A list of Lc events is formed for which the initialization conditions are met.

Step 8. If the Lc list is empty, then the transition is made to point 9. Otherwise, control is transferred to the execution of the service procedure for the first event with Lc. The time of this event is modified in the future and it is excluded from the list. Go to Step 6.

Step 9. The event with the minimum initialization time is found in the list of scheduled events and the time corresponding to this time point is adjusted.

Step 10. The comprehensive criterion of the entire cognitive system is defined.

Step 11. The condition for the end of complex modeling is checked. If it is not fulfilled, we proceed to point 6.

5. Cognitive model

A cognitive model is a mean of presenting the results of an analysis that demonstrates the determination of the strength and direction of the influence of factors on the transfer of the control object to the target state, taking into account the similarities and differences in the influence of various factors on the control object.

One of the most common cognitive models is a cognitive map. It is used in cognitive modeling of complex situations. A cognitive map (map of knowledge) is a type of mathematical model presented in the form of a graph, which allows to describe the subjective perception of a person or a group of people of any complex object, problem or functioning of a system.

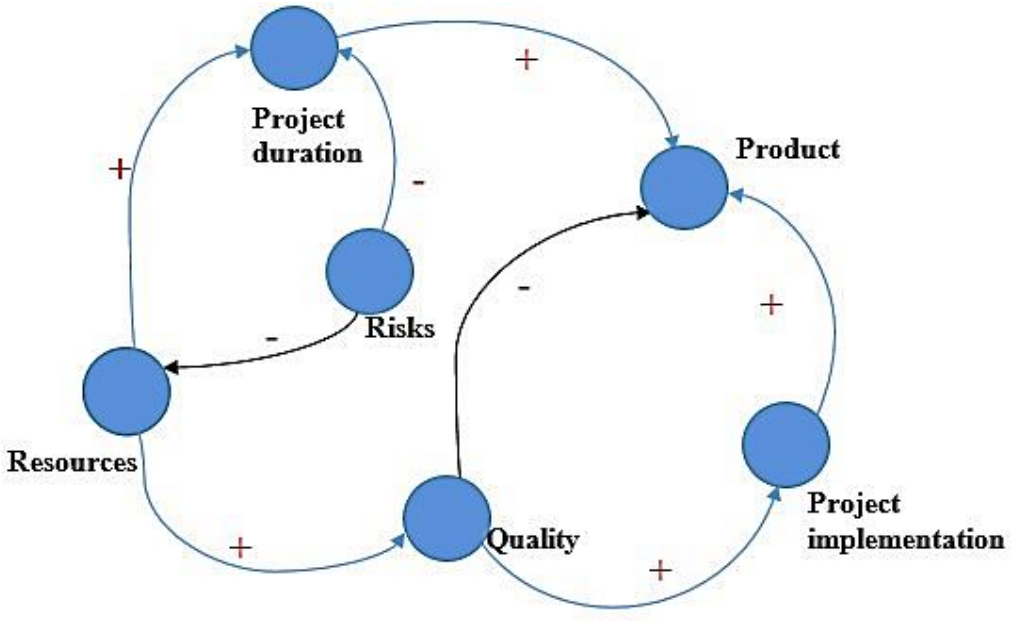

Figure 1: Cognitive map of project implementation at a conditional enterprise

It is designed to reveal the structure of causal relations between elements of the system, a complex object, components of the problem, etc. and to assess the consequences that occur under the influence of influence on these elements or changes in the nature of relations.

Lets take a look on the conditional model of project implementation (Figure 1). Here, the vertices of the graph are the factors of the situation, and the arcs are the cause-and-effect relations between them. A plus sign on the arcs between the vertices of the factors means that an increase in the value of the cause factor leads to an increase in the effect factor, and a minus sign means that an increase in the value of the cause factor decreases the value of the effect factor. The cognitive map reflects the functional structure of the situation being analyzed, since a change in the value of a factor of the situation leads to the emergence of a "front" of changes in the values of the factors associated with it. This front of changes is called an impulse process in the cognitive map and allows you to get forecasts of the development of situations.

Let's take a look on the triangle Resources-Project duration-Risks. After increasing the amount of resources, we get a positive impact on the terms of project implementation, and there is a possibility of their reduction. Conversely, a decrease in resources leads to an increase in project implementation terms. But the growth of risks has a negative impact on resources and project duration. What will be the total effect on the implementation of the project when the quality of the product changes? It is necessary to weigh this influence, that is, only a sign of influence is not enough. About her you can say "she is at the top", or "leaves much to be desired". The same can be said about various factors of the external world - "the product is in demand" or "the product is not promoted on the market". There are no natural quantitative indicators here, but a qualitative scale can be constructed. This is called "linguistic meaning", and the factor can be called a linguistic variable. All factors and, accordingly, their changes have a quantitative expression, this quantitative expression can be objectively measured, or have a linguistic meaning that has its own numerical interpretation. The interaction of factors, which is displayed with the help of cognitive maps, is essentially a "model of the studied system in the form of a weighted graph", and usually this map is filled by a "cognitive analyst".

Therefore, the cognitive model includes the cognitive map (oriented graph) and the weights of the arcs of the graph (estimation of mutual influence or influence of factors). When determining the weights of the arcs, the directed graph is transformed into a functional one.

Within the cognitive approach, the terms "cognitive map" and "directed graph" are often used interchangeably; although, frankly speaking, the concept of a directed graph is broader, and the term "cognitive map" indicates only one of the applications of a directed graph. A cognitive map consists of factors (elements of the system) and connections between them.

In order to understand and analyze the behavior of a complex system, a structural diagram of cause-and-effect relations of system elements (factors of the situation) is built. Two elements of the system A and B are depicted on the diagram as separate points (vertices) connected by an oriented arc, if element A is connected to an element of a cause-and-effect relation: A → B, where: A is the cause, B - consequence.

Factors can influence each other, and such influence, as already mentioned, can be positive, when an increase (decrease) of one factor leads to an increase (decrease) of another factor, and negative, when an increase (decrease) of one factor leads to a decrease (increase) of another factor. Moreover, an effect can have the variable sign depending on possible additional conditions. The construction of cognitive maps occurs in stages, which is shown in Figure 2.

The cognitive map reflects only the fact that factors influence each other. It does not reflect the detailed nature of these influences, nor the dynamics of changes in influences depending on the change in the situation, nor temporary changes in the factors themselves. Taking into account all these circumstances requires a transition to the next level of information structuring, that is, to a cognitive model of the information situation.

At this level, each relation between the factors of the cognitive map is revealed by the corresponding dependencies, each of which can contain both quantitative (measured) variables and qualitative (unmeasured) variables.

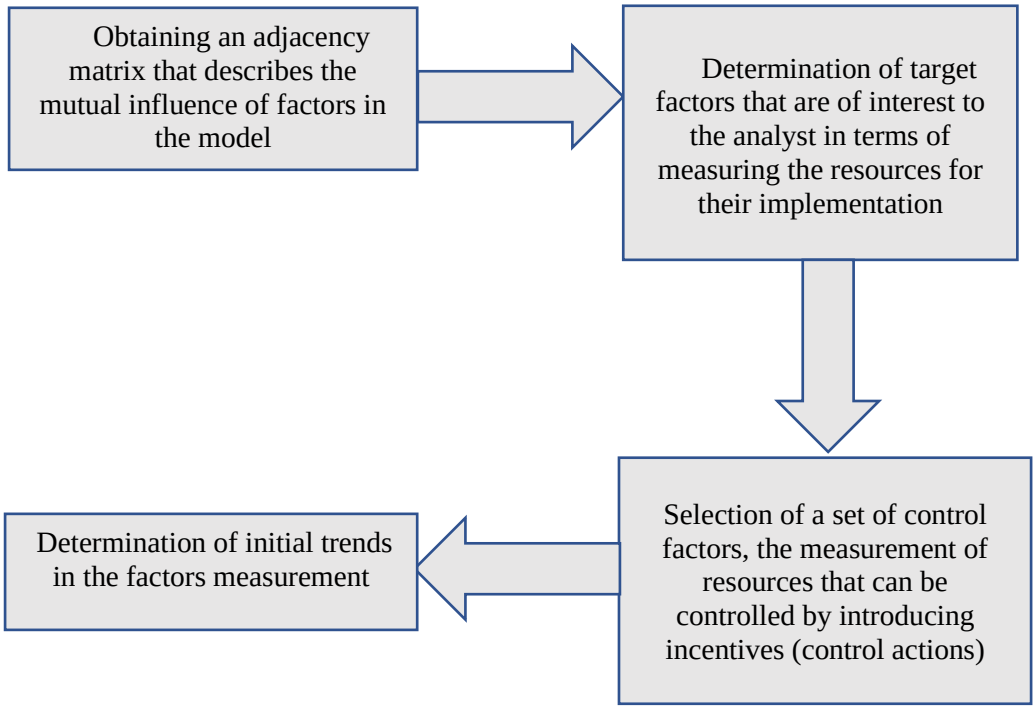

Figure 2: Analysis steps for building cognitive maps

With the accumulation of knowledge about the processes which happened in the studied situation, it becomes possible to reveal the nature of the relations between factors in more detail.

A cognitive map in a simplified form represents a flat block diagram of cause-and-effect relations of system elements (situation factors). In this scheme, the elements are depicted as separate vertices connected by oriented arcs lying in the same plane. The arc displays a causal relation. This determines the disadvantage of the cognitive map model. The significance of the factors in the scheme and the cause-and-effect relation are set by the expert. Naturally, different experts may have different cognitive maps, which violates one of the important scientific principles - comparability. The plane of constructing a cognitive map characterizes the flat thinking of an expert.

Factors always influence each other, which is reflected by the orientation of the graph. The cognitive map reflects only the fact of the presence of the supposed, according to the analyst, influences of factors on each other. It reflects neither the quantitative nature of these influences, nor the dynamics of changes in influences depending on changes in the situation, nor temporary changes in the factors themselves. Taking into account all these circumstances requires a transition to the next level of information structuring, that is, to a model of a dynamic information situation or a multidimensional cognitive model. In this situation, relation between the factors of the cognitive map moves from a flat model to a multidimensional model. The multidimensional model becomes practically inaccessible to the single analyst.

Further development of the model becomes cognitive-informational, that is, the analysis of "black boxes" outside the plane can only be carried out by a computer together with a team of analysts with the help of an appropriate system, which is called the "situational room". In the situational room, cognitive dynamic analysis is carried out by a team of analysts supported by a powerful multimedia system. The process of multidimensional cognitive control is cyclical. Cognitive modeling of experts sets a number of scenarios. Scenarios are modeled by a computer system and presented by a multimedia system. The results of the multimedia presentation are at cognitive expert analysis, new development scenarios are set, and so on. The situational room is used to manage large-scale, complex organizational and technical systems, like an industry, a transnational corporation, a large bank.

Certain problems arise during constructing a cognitive model: identification of factors causes difficulties; allocation of essential and secondary factors; ranking factor; identifying the degree of mutual influence of factors.

The last problem is often solved by the use of correlative analysis. The allocation of essential and secondary factors can be solved on the basis of the theory of preferences. Identification of factors forms the basis of latent analysis.

The identification of significant factors is possible on the basis of impact analysis. The use of cognitive models qualitatively increases the validity of accepting management decisions in a complicated and rapidly changing atmosphere, relieves the expert of "intuitive wandering", saves time for understanding and interpreting events occurring in the system.

6. Conceptual scheme of cognitive management

The task of finding the optimal strategy in today's business environment is extremely difficult. It can be fully attributed to the class of complex tasks, the solution of which is beyond the competence of the traditional theory of strategic management. The “complexity phenomenon” is due to the five most important features of modern strategic management, with which management practice faces everywhere today. Such features are: the uniqueness of each of the strategic projects, multifactoriality, multidimensionality (multidisciplinarity), dynamism and uncertainty of the task of strategic choice, the high role of the mentality of the developers of the strategy, as well as those who make strategic decisions. There are known attempts to create universal tools of cognitive support for persons solving strategic problems. However, practice shows that in such a complex and diverse environment in which modern enterprises operate, the creation of universal tools is futile and does not justify itself. What is needed is not universal tools, but some unified methodology that allows to construct cognitive models for specific projects, for a specific period of time, taking into account the strategic vision of the owners and managers of this project.

The first step in the formation of this kind of methodology is the development of a conceptual scheme of cognitive management, which is the same for all its applications. At the same time, it is a principle that the development of a conceptual scheme in such a complex problematic environment cannot be done on the basis of traditional formal-axiomatic approaches. More appropriate here, apparently, is the empirical approach widely used in "knowledge based" technologies. Within the framework of this approach, the conceptual scheme of cognitive management can be represented as follows:

$$\mathrm{P(CM)}: \mathrm{S^o(C)} \Longrightarrow \ \mathrm{S^c(C)}|_{U(P)}, \tag{2}$$

where P(CM) – is full knowledge of the problem area of cognitive management;

So(C) – the current state of the analyzed business situation, set on the cognitive map;

Sc(C) – is the target state of the analyzed business situation, set on the cognitive map;

U (P) – is a management strategy that establishes a sequence of strategic steps that ensure the transfer of a business situation from So to Sc.

It is clear that full knowledge of P(CM) should reflect the accumulated theoretical and practical experience of the problem area. The study and critical analysis of extensive material devoted to cognitive modeling of managerial tasks, as well as the personal experience of the authors, give reason to believe that complete knowledge of P(CM) can be represented as an ontological project, including the following sections:

1. Applied problems that can be solved with the help of cognitive management engineering. In this case, tasks can be presented as separate questions that can be answered and, thus, they are the subject of engineering.
2. A set of postulates or axioms that show what assumptions were made during the development of engineering. Axioms or postulates describe the conditions and limits of engineering applicability.
3. The list of concepts of strategic management that have developed at the present time in management science and practice.
4. A systematized library of applied tools that make it possible to implement these concepts in specific strategic projects.

4.1 Support tools for choosing the concept of strategic project management.

4.2. Support tools for choosing the language of representation (formalism) of cognitive maps.
4.3. Support tools for structural-functional identification and parameterization of cognitive maps.
4.4. A set of methods for analyzing cognitive maps for solving applied problems.

The presented P(CM) structure is, in fact, "aprotoframe" of engineering and solves two important problems.

Firstly, it expands the traditional idea of the schemes for solving applied problems of strategic management by including the stages of postulating cognitive analysis, choosing the concept of strategic management, choosing an adequate language for presenting cognitive maps, carrying out structural and functional identification and parameterization of cognitive maps. Without addressing these issues, cognitive business analysis in most cases loses all practical meaning.

Secondly, it systematizes the directions of efforts to develop and accumulate the applied capabilities of cognitive analysis in solving issues important for management practice. These include, in particular:

- identification of contradictions between the goals set by the subjects of management;
- analysis of the effectiveness of the controlled factors of the cognitive map and their importance in terms of the degree of influence on the set goals;
- designing various options for management strategies ("self-development strategy" and various options for "managed development strategies");
- simulation of the dynamics of alternative management strategies under various scenarios of the development of the external environment and the choice of the optimal (in one sense or another) strategy;
- study of the stability of the chosen strategy in critical situations due to possible threats to the external environment;
- monitoring the strategy during its implementation;
- retrospective analysis of the adequacy of the cognitive map and its adjustment.

The production part of the ontological project today includes a lot of publications related to the solution of the main task of strategic management - the choice of an enterprise development strategy. Preliminary systematization of these works can be done with the help of descriptors characterizing their engineering efficiency:

- the horizon of analysis to which the instrument is oriented (short-term, medium-term, long-term);
- the nature of the external environment of enterprises for which the tool was developed (static, dynamic);
- the stage of strategy development for which the tool is intended (strategic identification of the external and internal environment of the enterprise, conceptualization of the strategic vision of owners and top management, formalization of the strategic vision in the form of a cognitive map, development (selection) of methods for analyzing the map, testing the cognitive model);
- level of tool development (theoretical proposal, demonstration prototype, research prototype, operating prototype, industrial version).

We use this systematization to characterize the cognitive models developed during the implementation of the four mentioned projects.

7. Conclusion

The essence of cognitive project management is to help the expert develop the most effective management strategy, based on his experience and, most importantly, on orderly and verified knowledge about the management object. The scope of application of the cognitive management is constantly expanding. First of all, it is making decisions during the implementation of development projects of states, territories, and communities; simulation of information warfare and conflict resolution procedures. After all, this is the task of information stability of systems, states, communities; communities, as an average statistical element of these groups, and modeling human behavior as a complex biosystem during the implementation of a project to create products. In our opinion, the development of the entropy approach for evaluating and structuring information used in cognitive project management is a perspective direction.

The use of cognitive models qualitatively increases the validity of managerial decision-making in a complex and rapidly changing environment. The cognitive map is a flat model with a low level of verification. A better level of decision-making is provided by multidimensional cognitive model. The application of cognitive management is to reduce the lack of structure and fuzziness of information and, thereby, improve the quality management.

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