Graphodynamic Modeling for a Multi-Agent Support System for Personnel Decision-Making in the Field of Human Safety

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Abstract

To ensure the effective implementation of projects, programs and project portfolios, the activities of all human resources should be rationally coordinated. To develop this information system, organizational structures should be analyzed in order to develop a model of an information analytical system to support personnel decision-making. The positive and negative sides of various organizational structures of organizations are considered. The subject of the study is resource management in projects of safety-oriented systems. The purpose of the article is to improve the effectiveness of project team management in the civil defense system. Research methods: the method of analyzing hierarchies, graphodynamic theory, empirical research, analysis and synthesis. The following results were obtained: It is proposed to use the graphical form of presentation of organizational models that belong to safety-oriented systems. Conclusions: A model of a multi-agent information system has been developed.

Keywords1

Multi-agent information system, project team, organizational structures

1. Introduction

Managers of educational, manufacturing, service and product organizations are often faced with a large number of complex interrelated projects. In connection with the frequent change of organizational structures (OBS) to the conditions of the external environment and the rapid development of information and communication technologies, virtual forms of team interaction have become actualized. Projecting by team managers, selection of candidates and selection of an effective OBS for it affects the successful completion of tasks, achievement of organizational goals and rationalization of the use of resources for projects, programs and project portfolios. Improvement of management methods and optimization of personnel structure depend on the development of organizational design. New external challenges and the integration of security-oriented systems of Ukraine to European standards stimulate the implementation of innovative projects, such as: reengineering and automation of personnel processes.

The modern paradigm of management is the use of flexible and adaptive management in order to improve interaction between units and effective allocation and management of resources. An important component in the implementation of the content of new projects, programs and portfolios of civil defense projects is the formation of virtual project teams, the organizational structure of which corresponds to the goals, tasks, and requirements of project stakeholders.

The complexity of implementing organizational design methods is proposed to be solved thanks to the application of scientific methods in the process of forming virtual project teams and modeling their organizational systems, using information technologies that provide managers and experts with analyzed and reliable information. Team formation is an important project management task. Creating a professional team for a new project is one of the main responsibilities of a project manager at the first stage of his work.

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2. Analysis of recent research and publications

In the conditions of rapid changes, the formation of new organizational structures and the application of innovative management, there is a need for flexible management. International project management experience should be used to optimize the organizational structure. The modern theory is based on the fact that there is no ideal model of the structure of the organization, but external situational factors (strategy, technology, size of the organization, environment) should be taken into account.

The scientific works of domestic scientists are devoted to the study of methods and models of project team formation: Lysenko D. E., Chumachenko I. V., Bushuev S. D. [1-3], Morozov V. V., Rach V. A., Archibalda R., Mazura I.I., Shapiro V.D., Koshkina K.V. In particular, the works of such foreign scientists as: J.R. Kemsenber, K. Lewis-McClear, D.K. Smith, M. Taylor. B. Tukman studied the main directions of the development of small groups. The work of M. Belbin is devoted to the study of the main roles performed by team members in the course of their work.

Peter Drucker focused on the effectiveness of organizational structures, in which a team that spends less effort on successful implementation of tasks is more effective than others. Therefore, a well-constructed organizational structure affects the efficiency in general and the rationalization of efforts in the organization itself. In recent years, a project organizational structure has been observed in European institutions of higher education. Also, in modern conditions, formalized structures are being transformed, namely, managers allocate specific tasks - projects, role powers are formed.

In his works, D. E. Lysenko developed methods and models for the selection and selection of the project team, as one of the factors for achieving the project goals, developed a methodology for the operation of the decision-making support system of the CSDP based on multi-criteria evaluation and the theory of precedents, during which the ranking of the degrees of "ideal candidate" with subsequent appointment to a position in the project. However, the application of this methodology cannot be applied in the selection of personnel for the civil defense service.

Scientist A.P. Medvid studied the mechanisms of personnel policy implementation in civil defense bodies as an important lever of development. He described the development of research methods for management and professional qualities of personnel for the analysis of certain groups of civil servants. The use of test results makes it possible to "de-rate" civil servants according to an integral indicator, and also, thanks to the analysis of certain individual qualities, to analyze what needs to be "tightened" by the staff for greater efficiency and to meet professional competence. This work requires further management development in personnel policy based on European standards.

Professor I. V. Chumachenko paid special attention to models of formation and management of human resources in a multi-project environment, programs and interaction between project stakeholders. He formed a competent approach to the formation of a project team with limited human resources, but this method has a number of limitations that are not suitable for use in the apparatus of military formations where the scale of human interactions is greater than typical projects.

In his works, the scientist A. V. Olenich studied the peculiarities of the formation of project teams according to the old and new approaches. He described the issue of staff turnover, which forms a "bank" of collective acquired experience. He argued that modern success is achieved thanks to innovation and awareness of all participants in projects, which make it possible to achieve the set goals quickly and with minimal costs. But the paramilitary services do not need to publicize the entire database of information between personnel and candidates, and the implementation of innovative technologies requires effective solutions at low costs, which is not easy to achieve today.

Specialists of the Ministry of Internal Affairs developed automated psycho-diagnostic complexes for determining the suitability of candidates for military service and for higher military educational institutions of civil protection. In these studies, special attention was paid to the mental readiness of candidates in real stressful conditions for the formation of individual characteristics with further evaluation of service applicants. These complexes require refinement and new formalized and described models.

In order to implement these methods in the civil defense system, it is necessary to take into account the specifics of passing and carrying out the service. Attention should be paid to the project approach, which is becoming more and more relevant.

The organizational structure of management is a complete hierarchical system consisting of ordered components and levels of management, the elements of which are subdivisions. In which communication and effective functioning is organized through its interaction with the internal and external environment. Its competent construction can increase the effectiveness of the organization. The concept of organizational flexibility means the organization's ability to accept changes, adapt to events in the external and internal environment.

In the conditions of management automation, the methods of modeling objects of organizational design are gaining significant application. Methods and models of designing the organizational structure of the enterprise are analyzed in the work. In the design of organizational structures of enterprises, regression equations, simulation models, polynomials of various degrees and combined mathematical models are used to compare structural and functional relationships. The criteria for building the structure of the management apparatus are: the rule of control, the degree of centralization of functions, the number of levels of management, the number of links, the size of subdivisions, the order of subordination and interconnection. The task of managing the structure of the OS is formulated as the task of finding a set of structures that would contribute to the achievement of goals.

Linear organizational structures are considered simpler in complexity than matrix ones and are effective in situations in which external requirements change frequently. And the matrix ones are effective with unchanged external requirements for the OS. The process of transformation can be described as the creation or disassembly of new hierarchies.

Cooperation between different organizations in a highly dynamic environment is effective when using a network structure. With a generally accepted approach, a network structure connects different organizations that are united by a pool of resources and activities aimed at achieving a common goal. The network form does not require significant financial resources and investments due to the rapid creation of partnerships and the joining of new network members, which in turn led to the development of virtual teams.

Many researchers confirm that about 80% of respondents put the factor of human relations in the first place among all factors affecting the successful implementation of the project, so the priority of this area of activity is not in doubt. Many foreign scientists deal with the issue of team management, and in Ukraine, the issue of team management is considered as one of the elements of the project management process.

So, summarizing all of the above, the term "team" can be defined as a group of creative people united around one leader, engaged in a common cause with pleasure, combining their personal goal with the general one, and consciously interacting with each other to achieve it, and the result of their work is a qualitatively new product. As a result of the analysis of scientific works, it was found that such types of organizational structures as linear, divisional, matrix, project, network are actively functioning in practice.

3. The bulk of research

A review of the literature on management and leadership demonstrates the interrelationship, both of which are key aspects of PMI's talent triangle. Research shows that 75% of organizations believe that leadership is a critical skill, especially in an increasingly complex environment. Leadership skills enable people to motivate and direct others, increasing overall performance.

Successful implementation of the project requires leaders who possess the necessary competencies. There are many scientific theories of leadership that define leadership styles that apply in certain circumstances. Among modern scientific theories regarding the functions of leadership, we single out two: the value-content approach and the approach of I. Adizes. From the point of view of value-content orientations, which are formed on the basis of values, motives and goals in team formation, the following main functions are distinguished: symbolic, instrumental and emotional.

Table 1. The main functions of project management

Areas of project management knowledge	Functions of the project manager
Project resource management	Performance of functions related to planning, acquisition and management of technical, material and other resources necessary for project implementation; formation of an effective organizational structure of the project team, organization, management of its work, motivation of project team members, conflict resolution; monitoring the use of resources in order to optimize them.
Project quality management	Determination and adaptation of the policy of the organization of quality management processes regarding the planning, management and control of the project and the achievement of compromise solutions regarding the necessary level of product quality requirements to meet the expectations of stakeholders: coordination of requirements and quality standards for the project and its product, the procedure for testing and inspecting the product, ensuring resources and their necessary quantity to achieve the specified quality.
Project stakeholder management	Identifying and managing project stakeholders, planning and managing their involvement in the project, establishing quality communications with stakeholders to maximize their expectations, monitoring relationships and, if necessary, modifying their engagement strategies.
Project communications management	Development of a communications strategy and plan, taking into account the information needs of all project stakeholders, establishing effective feedback, communications management and monitoring.
Project schedule management	Performance of functions related to the timely implementation of the project: definition of the policy for the development and management of the project schedule, adaptation of management methods for a specific project, management of the process of definition of specific works and tasks for obtaining the project result, their sequence and duration, planning of providing human, technical, material and other resources (their optimization), analysis of existing limitations, monitoring of project status and making appropriate decisions regarding necessary changes.
Project content management	Management of the processes of determining the content of the project and the product of the project, determining, agreeing and managing the requirements of interested parties to achieve the goals of the project, coordinating the development of the hierarchical structure of work, monitoring the status of the project content and managing the necessary changes.
Project integration management	Development of a project management plan, providing the necessary knowledge in the process of project implementation, managing the execution of works, making integrated decisions regarding key changes, monitoring and controlling the project, collecting data on the achieved results in order to inform interested parties, managing the transition between phases, closing phases and completing the project .

Leadership in team management includes a number of key competencies that help a leader ensure the success of his team. Some of them:

• Defining the goal and direction. A leader must have a clear vision of the team's goals and objectives, as well as know how to achieve them. It is important to remember that goals should be realistic and achievable.

• People management. A leader must have the ability to manage people and create effective teams. This includes support, motivation and team development.

• Communication. A leader must be open and effective in communicating with his team. This includes the ability to listen, communicate and resolve conflicts.

• Planning and organization. The leader must be able to plan and organize the work of the team. This includes the allocation of tasks, control and evaluation of work results.
• Innovation and development. A leader must be able to generate new ideas and work on the continuous development of the team. This will help keep the team in good shape and increase their productivity.

Leadership skills can be developed through study, practice and experience working with teams. It is important to pay attention to the development of communication skills, a culture of cooperation and work with stress. It is also worth paying attention to personal development.

Table 2. Functions of the project leader

Function name	Functions of the project leader
Training, consulting and development function	Conducting the right work with team members and providing them with the necessary knowledge to develop in accordance with their expectations.
The function of forming a system of values in the team	Encouraging teamwork and forming a team's value system, establishing rules and norms of behavior for its members to create strong relationships. The leader must embody the ideal of adherence to the values established by the team.
Group dynamics management function	Management of the process of group interaction, including management of the emotional state of the team: maintaining a positive psychological climate within the team, resolving conflicts, establishing intra-group communications.
Adaptation function	Implementation of actions aimed at preserving the team and its adaptation to changes contributes to the development of the group in the long term.
Motivation function	Constant and purposeful motivation of members and the entire team and other project participants to achieve the necessary results. Ensuring that each team member is motivated to complete their tasks.
Communicative function	Building strong relationships within the team and with external stakeholders.
Instrumental function	Selection of the necessary methods and ways of coordinating the work of team members taking into account the situation for the team to achieve the set goals.
Purposefulness function, "vision" of the project result	Providing team members with a clear vision of project goals and strategies for achieving them, setting the team up to achieve results.

When solving problematic tasks related to the reorientation of organizational goals or changing the ways of achieving them, the most attractive form of organizational structure is a project team. These are formed groups where executors are attached to the project for the period of its life cycle and are fully subordinated to the project manager.

The organizational structure includes organizational forms and project management structures. The organizational form is the organization of interaction and mutual relations between all project participants. Forms of organizational structure are considered at the internal and external levels. The internal level reflects the relationships between individual managers and groups that execute the project. The external level implies the existence of a certain structure of relations between individual performers and groups involved in the implementation of the project, their parent units and departments.

Among the external organizational structures, the following main forms are distinguished: the form of a project team, a matrix organization, a hybrid organizational structure, a modular communication structure. The main forms of the internal structure are:

• internal functionalization,
• internal matrix structure,
• divisional structure,
• centralized or decentralized forms of organization of large projects.

Two approaches to the formation of the organizational structure can be distinguished:

• functional – specialists of one specialty, professions are united into functional divisions;
• targeted - performers of different specialties or functions are united and work together on a certain part of the project or task.

The best type of organizational management structure for project work is a matrix structure, which corresponds to the programmatic and target nature of project activities to a greater extent. The matrix structure is based on a functional structure, in which relations are built on vertical connections - "leader - subordinate". To solve specific project tasks, temporary creative teams or temporary project groups headed by project managers are created in this structure. These groups are made up of specialists from the relevant functional departments. Interaction of project managers with functional departments is carried out horizontally, as well as through traditional vertical connections, resulting in a matrix of interaction.

The matrix structure makes it possible to flexibly maneuver human resources by redistributing them between projects, but with the condition of preserving their administrative belonging to the relevant functional departments. A feature of the matrix management structure is that the project manager does not have control over the personnel involved in the project. The project manager determines what needs to be done and when, and the functional manager decides who will do the work and how. Using this type of structure, it is important to constantly monitor that the actual data correspond to the planned, to establish a well-established control system for the progress of work on the project, the quality of execution, costs and deadlines.

There are the following types of matrix organizational structure:

1) functional;
2) balance sheet;
3) design;
4) contractual.

The structure of modular communication is used to ensure flexibility in companies, functions on the basis of modules, performers are full members of the project team, involved in projects for a certain period of time. Modules are introduced and withdrawn from the project as needed, combined and recombined into different systems. The hybrid organizational structure of the project is a combination of the above basic forms. It can be used for both large and small projects.

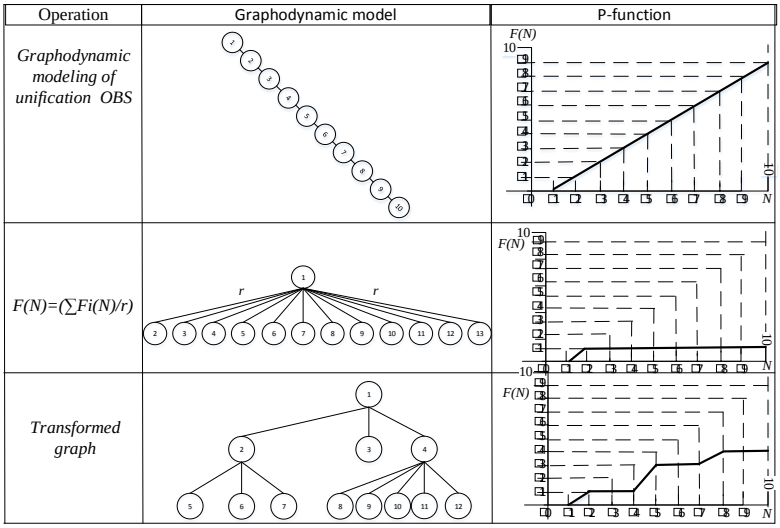

Figure 1: Iterative transformation of graphs and their P-functions

The orderly flow of resources in the organizational structures of management bodies and their effective interconnection ensure the achievement of the organization's tactical and strategic goals, regarding the protection of the population and the consequences of emergency situations.

The parameters of the quality of management of the organizational structure are:

- flexibility;
- levels of centralization of management;
- adaptability;
- effectiveness;
- manageability;
- efficiency;
- purposefulness;
- autonomy;

The effectiveness and transformation of OBS is determined by the influence of internal and external environmental factors on the organizational system. The process of organizational design consists of three stages: the choice of technology, the development of a management structure, and the development of management mechanisms.

In order to solve the task of finding the optimal organizational structure, it is necessary to define efficiency criteria according to which a comparative analysis of organizational structures will be carried out, for example, such a criterion can be the manager's expenses for the formation of a project team.

Let the set of candidates be given *P*, variants of the organizational structure $Os \in Os(P)$ and the cost function of creating an organizational structure $f(s): Os[0;+].$

Accordingly, you should choose the structure (St) with minimal costs:

$$St' \in Arg\min_{StcOs} f(s) \qquad (1)$$

An important characteristic of the hierarchical structure, which determines optimality according to the cost criterion of team formation, is the absence of duplication, in which two managers M1, M2 manage one group of team members $Pj,\ j = 1,\ldots,n$:

$$(\{P1, P2,\ldots, Pn\}M1)\ (\{P2.1, P2.2,\ldots, Pn\}M2) = \varnothing \quad (2)$$

To determine the qualitative characteristics of the optimization criteria of hierarchical structures, the approach of evaluating the topological properties of the organizational structure (stability, controllability, compactness) using graph theory is used.

The method of analysis of hierarchies (MAI) and the method of analytical networks allows to analyze alternatives of structures with the aim of ranking them and choosing the best option. This method is a structural means of modeling the decision of choosing alternatives. The next step is to determine the weights of the alternatives, taking into account all the criteria, the theory of evidence of Dempster-Schaefer and expert ranking of the alternatives.

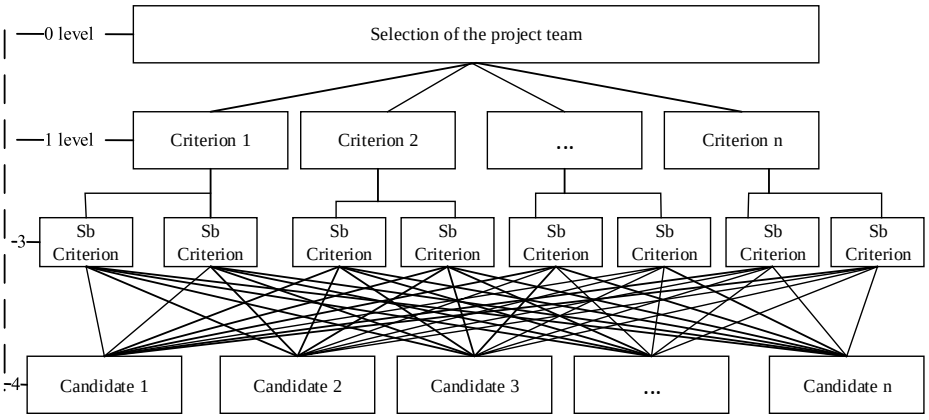

Figure 2:The method of analyzing hierarchies of criteria and sub-criteria (Sb) for evaluating candidates

The evaluation criteria of OBS are: flexibility, manageability, speed of reaction, degree of delegation of authority of project managers and influence of the project manager.

Table 3. OBS design methods of the structure of virtual project teams

Method name	Characteristic
The method of analogies	Application of effective management approaches and mechanisms of similar organizations.
Automatic	It is based on the use of computers at all stages of work.
Typical design	Methods aimed at fulfilling the project goal, for example: questionnaire survey, value analysis, selection of evaluation criteria.
Reengineering	Reconstruction of OBS and management on a modern technological basis.
Program-targeted	Programmatic and structural correspondence of the tree of goals and executors to the given goal.
Expert	On the basis of a survey of a number of experts, an analysis of activities and recommendations for OBS is carried out.
Structuring of goals	Qualitative and quantitative formation of the system of goals, analysis of OBS for compliance.
Original	Creation of individual projects for the organization.
Block	Rapid integration of blocks into a complete OBS that provides flexibility.
Disorganization	Inconsistency of OBS activities with the mission and strategy of the organization and the needs of society.
Normative	The criteria for the construction of OBS are: the rule of control, the degree of centralization of functions, the number of management levels, the number of links, the size of subdivisions, the order of subordination and the relationship.

The main models of OBS design are: grapho-analytical models, grapho-analytical, mathematical-cybernetic, natural models and mathematical-statistical models. Organizational structures of organizations are divided into formal and informal. They are classified according to the following characteristics: according to the temporal conditions of existence (permanent, temporary); according to the degree of flexibility (mechanistic, adaptive); by the level and depth of decision-making (one-dimensional, multi-dimensional); by interaction with a person (corporate, individual); by work technology (real, virtual). The linear structure (LS) has the form of a tree in which the relationships between participants characterize the subordination of team members to only one higher-level manager. Instead, the matrix structure (MS) is characterized by relationships in which team members of the organizational system (OS) are simultaneously subordinate to several higher-level managers of the system.

		Characteristics of the project				
		Powers of managers	Resource	Budget control by the manager	The role of the project manager	Administrative staff for project management
	Functional structure	low	small	Functional	partial	temporary
Matrix	weak	limited	limited	Functional	partial	temporary
Matrix	balanced	limited	limited	by several	permanent	constant
Matrix	strong	high	enough	Project manager	permanent	constant
	Project-oriented	high	enough	Project manager	permanent	constant

Figure 3: OBS template of the structure of the virtual project team of the central office

Oriented graphs are used to represent organizational hierarchies $G =< W, E >$, which are given by the set of vertices W and the set of arcs $E \subseteq WxW$. A set of arcs is an ordered pair of vertices. Hierarchical structures are described by acyclic directed graphs.

The purpose of the organizational hierarchy is to coordinate the actions of managers.

Their technology is allocated to the planning of the organization. Let's mark $N = \{k1, \ldots, kn\}$ - multiple team members $(n > 1)$, M-set of project managers.

Accordingly, the organizational hierarchy will have the form of an acyclic graph $< W, E >$ with many vertices $W = N \cup M$ and a set of arcs $E \subseteq WxM$. Thus, a directed cyclic graph $G =< NM, E >$ with multiple subordinate arcs $E \subseteq (N \cup M)xM$.

The formation of virtual teams allows you to effectively manage the project's human resources. They are formed from a group of applicants who are united by a common goal.

In the project team where a temporary virtual organization is formed, it is allowed to use special expert knowledge and at the same time the experts do not cross each other.

Also, this format allows you to form teams that have geographic restrictions and at the same time save resources. Such cross-functional teams are characterized by flexibility, which is an important parameter in an open organizational system, as well as self-management.

The role of leader can be transferred between all team members.

Thanks to the virtual format, the speed of recruiting candidates and restructuring the composition of the team is high.

Virtual organization (VO) can be considered as a complex socio-technical system of virtual teams that interact thanks to the Internet and artificial intelligence methods.

Object-oriented design, database and knowledge management systems have evolved into multi-agent systems (MAS) technologies.

Such systems have successfully proven themselves in the tasks of eliminating the consequences of emergency situations and modeling social structures and units.

The reasons for the urgency of transforming organizational structures into more modern ones, their functioning as multi-agent systems, are related to the complexity of modern systems and organizations, inefficient management of information flows and time spent on decision-making.

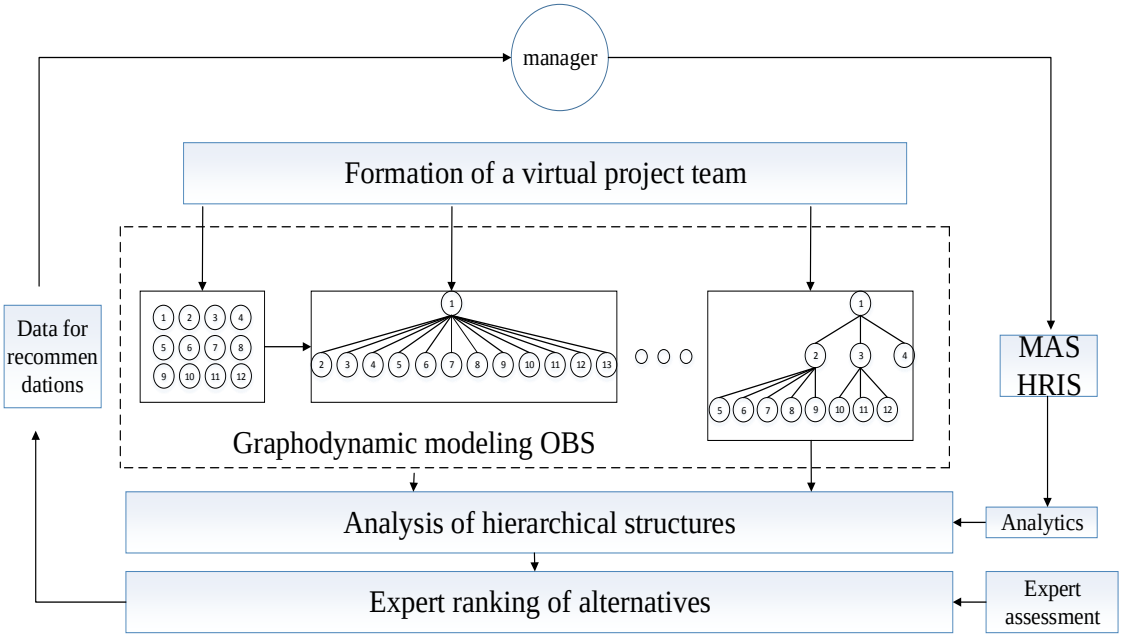

Figure 4: Multi-agent personnel decision support system

MAS are designed and integrated by separate intelligent systems that are based on knowledge. The elements of MAS are:

- agents who manipulate multiple objects;
- task;
- environment;
- relations between agents;
- actions of the agent.

Tasks are distributed among agents, each of which is considered as a team member. The distribution of tasks involves the assignment of roles to each member of the group, the determination of the extent of his responsibility and the requirements for experience.

4. Conclusions

Organizational structures for project teams were analyzed and classified. The proposed models can be used for the development of information technology and the design of organizational systems. Thanks to this system, the manager is provided with recommendations for making personnel decisions, which are generated from a set of alternatives of organizational structures according to a set of criteria.

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