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PSYCHOLOGICAL MEANS OF THEORETICAL MODELING OF THE OPTIMUM NUMBER OF PROJECT STAFF

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ABSTRACT

The paper considers the project team management models, since they are most difficult to formalize in the areas of knowledge in project management. The study presents economic and mathematical models for managing the project team of threshold collective behavior using the example of the crew of a sea ship. In the implementation of specific projects, the experience of leadership and management of small groups often remains at the level of intuition, which leads to the individualization of knowledge and prevents the effective use of the potential of team management. In the science of management, there are personnel management methods that are considered separately, without taking into account the mutual influence of psychological processes and features, which does not allow to form a single, multifactorial concept of managing a small team in projects. And all the more so in the development of project team management, the influence of the project implementation conditions on the choice of project team management methods is rather poorly taken into account, this requires the experience and skills of a psychologist from the leader, manager or significantly reduces the manageability of such a heterogeneous project team – the crew of the ship.

Keywords: Project management, Project team management, Modeling the functional groups, Models shipping agents, Crew of the ship.

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1. INTRODUCTION

Of all the groups of human resources of the project, the project team to the greatest extent affects the success of the entire project. It is this group that forms the vision of the project, so the quality of its work to the greatest extent depends on the personality of each member of the project team. But the experience of successful project management in a certain industry, which was implemented in a certain environment, does not always guarantee the same success when moving to a project in another industry or in another environment.

Today, in a trend in the team format of project activities, as practice shows, despite careful selection and formation of project teams, such projects end in failure. Since the projects are implemented by people, in other words, the human resources of the project, which in a certain way affect the final result of the project.

Despite the great attention paid to the formation of project management teams, existing studies do not take into account the specifics and features in the conditions of operation of the ship's crew.

Analysis of publications and research problems. Study the issues of formation of project team dedicated a lot of scientific works [1-4]. They focus mainly on the general principles of forming project teams: communication, role, sociological, psychological, competency-based and others, and do not take into account the specifics of specific projects. The means and methods of forming project teams proposed by these authors can be divided into a group where the quantitative composition and necessary competencies of individual project participants are optimized. Firstly, specific models, methods and techniques for calculating the required number of ship crews are not available. The second problem lies in the development of the system of the international division of labor, which has led the shipping to create an increasing number of international crews. A different level of training, combined with a language barrier, psychophysical features, specific national customs and traditions sharply reduce the controllability of this team, especially in extreme situations in a confined space – a sea ship.

The aim of the study is to analyze and develop mechanisms for the formation of project teams, which will take into account both the features of the product and the project implementation environment using the example of the functioning of the project team – the crew of a sea ship.

2. MATERIALS AND METHODS

In accordance with the theory of project management, a project can be defined as a set of actions in which human, material and financial resources are organized to perform a unique set of work of a certain content under conditions of limited cost and time [4]. The project has a life cycle within which the necessary changes take place in accordance with established quantitative and qualitative goals. In various studies, you can find other definitions of the project [3, 5-8], however, all of them note signs common to all projects:

- clear goals that are achieved by simultaneously fulfilling a combination of technical, economic, financial, organizational and other requirements;

- internal and external relationships of operations, tasks and resources, which require coordination in the process of project implementation;
- clearly defined deadlines for the start and end of the project;
- limited resources;
- uniqueness of the conditions of implementation;
- the inevitability of various kinds of conflicts.

The definition of “project management” also does not have the same interpretation in the countries that are the founders of project management:

- project management – the art of managing and coordinating human and material resources throughout the project life cycle by applying modern management methods and techniques to achieve certain results in the project in terms of scope and scope of work, cost of time, quality and satisfaction project participants [5];
- project management – the management task of completing the project on time, within the established budget and in accordance with technical specifications and requirements. The project manager is responsible for achieving these results;
- project management – the unity of management tasks, organization, equipment and tools for the implementation of the project [6].

Project management in a broader sense is a professional activity focused on obtaining effective results through the successful implementation of projects as targeted changes. Project management, as a type of professional activity, includes planning, organization, monitoring and control of all aspects of the project in the process of continuous achievement of its goals [9]. Thus, project management is:

- on the one hand, the process (processes) of using the project manager(s) of knowledge, skills, methods, tools and technologies of project management in the implementation of the project in order to effectively achieve the project objectives with a given quality of results, on time and within the approved budget and meet expectations project participants [10, 11];
- on the other hand, by a group of people (roles) managing the project, i.e. providing management processes, communications and decision-making on the implementation of the project [12, 13].

One of the main concepts in project management is the concept of “project team”, and in project management – the project’s human resources management, which includes the planning, formation and creation of a team (Team Building), its development and support activities (Team Development), transformation or disbanding a team.

The project team is a specific organizational structure led by the project manager, which is created for the period of the project in order to effectively achieve its goals and objectives, and when it is completed, is dissolved.

The formation and creation of a team in the general case refers to the process of purposefully “building” a special way of people interacting in a group (called a team), which allows them to effectively realize their professional, intellectual and creative potential in accordance with the strategic goals of the organization. A team in this case is defined as a group of people complementing and interchanging each other in the course of achieving their goals [14].

In recent years, in project management, considerable attention has been paid to optimizing the composition and structure of project teams, as one of the main conditions for successful project implementation. The optimization is based on the different types of models discussed below.

Before analyzing various types of models of project teams, we analyze the definitions and characteristics of the team used in the literature:

- a group of people organized to work together to achieve common goals and sharing responsibility for the results [15];
- a small number of people with complementary skills, committed to common goals, practical tasks and approaches, for which they are responsible to each other;
- a group of two or more individuals who, in order to achieve a specific goal, coordinate their interactions and labor efforts [16];
- one or several small groups of people functioning as a whole, created to achieve a common goal, with a maximum level of cohesion, interaction, responsibility, identification of group members with it, the level of development of the group, the optimal distribution of mandatory and auxiliary functions;
- a group with a common goal, a clear hierarchy, standards of interaction and functional-role specialization;
- a group of people organized to jointly solve a common problem in such a way that each participant is responsible for the results of the work of the whole group [17, 18];
- a team is a small number of people who share goals, values and common approaches to the implementation of joint activities, have complementary skills, take responsibility for the final results, and are able to change the functional role correlation [19, 20].

In almost every publication devoted to teams, their characteristics are listed, and there is no well-established (generally accepted) list of them to date. So, for example, in [21] it is noted that the team has five key characteristics:

- a team exists to achieve shared goals;
- team members are interdependent within a common goal;
- teams are limited and stable in time;
- team members have the authority to manage their work and internal processes;
- teams operate in the context of a more general system.

In [22], the following three main characteristic features of a team are given: people are united to carry out work, the presence of a common goal, the presence of mutual and collective responsibility.

Seven key principles for organizing a team form of work are given in [23]:

- collective execution of work,
- collective responsibility,
- a single form of incentive,
- adequate incentive for the result,
- autonomous self-government,
- increased performing discipline,
- voluntariness of joining the team.

Separately, it is necessary to note such an indispensable attribute of a team as the synergy of interaction of its members, due to which, acting together, team members can achieve greater results than when acting alone. The synergistic effect of the team, the inseparability of the result of joint activities on the efforts of team members, the role of information and other aspects at the qualitative level are discussed in detail in many works (see, for example, [22]).

So, we can distinguish the following characteristics of the team:

1. unity of purpose;
2. joint activities;
3. the consistency of interests;
4. autonomy of activity;
5. collective and mutual responsibility for the results of joint activities;
6. specialization and complementarity of roles (including the optimal distribution of functions and volumes of work, as well as the synergistic interaction of team members);
7. the stability of the team (justification of the mutual expectations of its members).

Game theory is a section of applied mathematics that studies models of games – decision-making under conditions of non-coincidence of interests of the parties (players), when each side seeks to influence the development of the situation in its own interests. The hierarchical games theory is a section of game theory that explores hierarchical games.

Theory of contracts is a section of the theory of management of socio-economic systems that studies game-theoretic interactions between a shipowner and ship agents operating in conditions of external probabilistic uncertainty.

3. RESULTS AND DISCUSSION

Depending on the modeling apparatus used, several areas of research can be distinguished (Fig. 1):

- assignment tasks, using mainly the optimization apparatus to solve the problems of team composition, distribution of roles and volumes of work in the project;
- game-theoretic models using the apparatus of game theory [2, 24-26] to describe and study the processes of formation and functioning of teams. Today, this is perhaps the most developed area of formal research of teams, which includes (conditionally) such “branches” as the Marshak-Radner model, the model of collective stimulation, the model of reputation and performance standards;
- experimental studies of teams, including simulation experiments and business games;
- reflective models [27], using the apparatus of the theory of reflexive games to describe the interaction of team members who have dissimilar mutual ideas about each other's essential parameters.

Table 1 establishes the correspondence between the mathematical models of commands considered below and those properties of teams that are most clearly reflected in a particular model. In this table, the “+” symbol indicates that the model largely reflects the corresponding property, the “•” symbol – takes into account the corresponding property.

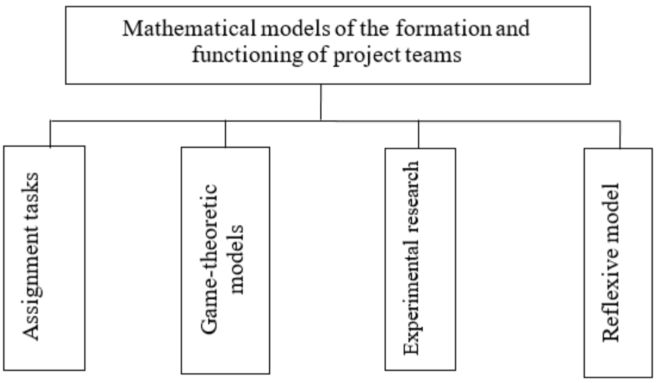

Figure 1 Classification of models of project teams

Table 1 Mathematical models and characteristics of project teams

Characteristic / Model	Unity of purpose	Cooperative activity	Consistency of Interest	Autonomy of activity	Collective and mutual responsibility	Specialization and Complementarity of roles	Team resilience
Distribution of the volume of work	+	•				•	
Distribution of functions	•	+				+	
Team building	+	•	•			•	
Synergistic effect	+	•	•			+	•
Model Marshak-Radner	+	+	+			•	
Stimulation in teams	+	+	•	+	+	•	
Institutional Management		+	•	•	+		•
Reputation	•	•	•	+	•	•	+
Experimental research	•	+	•				•
Homogeneous team	•	+	•	+	•		+
Inhomogeneous team	•	•	•	+	•	+	+
Autonomous decision-making	•	•	•	+	•	+	
Cost sharing	+	+		•	+		+
Adaptation in teams	•	+		•		+	+
Team training		+	•	+		•	

Any team model includes the following components:

- team composition - many agents included in the team;
- states of agents, including those performed by them (functions and volumes of work) and the set of permissible states. Sometimes the model description includes equations reflecting the relationship between the states of agents or the laws of state changes over time;
- the result of the team, which depends on the conditions of the agents and their individual actions;
- the target functions of agents may depend on their individual actions (conditions) and the result of joint activities. Moreover, the target functions of various agents can both coincide and vary.

Assignment tasks cover a wide class of optimization tasks, including the formation of the composition of teams, distribution of functions and volumes of work [28].

The listed types of tasks are interconnected and are solved “cyclically” – because in order to form a team, you need to know what functions will be performed by one or another agent included in the team; and for the optimal distribution of functions you need to know how much work it is advisable to perform this agent in the framework of a particular function (Fig. 2).

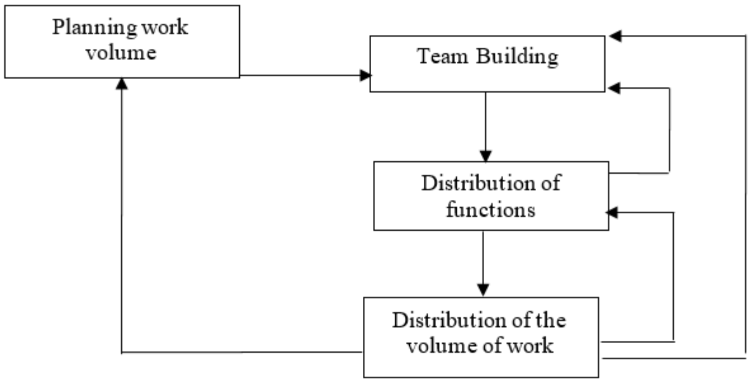

Figure 2 The relationship of the tasks of forming the team, distribution of functions and the scope of the project

The task of planning the volume of work on the ship follows from the goal of the project team, and for the case of the ship's crew will be discussed in detail below. As noted earlier, the crew of the vessel is inhomogeneous team, in which its members perform various functions, and each member of the team in the general case is characterized by certain effectiveness in the implementation of certain functions.

Consider the command $N = \{1, 2, \ldots, n\}$, consisting of n agents. Suppose that a successful team operation requires a set of $M = \{1, 2, \ldots, m\}$ different operations in a specific technological sequence. We denote by $rij \geq 0$ the efficiency of the i-th agent performing the j-th operation, i $€ N, j € M$. For simplicity, we assume that the efficiencies take values from zero to unity [29].

From an economic point of view, the costs of the ship's agent or the crew of the ship can be interpreted as the monetary equivalent of the efforts that the agent must make to achieve a particular action. Within the framework of such an interpretation, the idea of cost compensation seems quite natural – remuneration from the center should at least compensate for the costs of the ship's agent (see description below).

If the costs of the ship's agent are measured in some units of "utility" (taking into account, for example, physical fatigue, moral satisfaction from the results of labor, etc.), other than monetary units (and not reduced to them by a linear transformation), then in order to have the ability to add or subtract the utility when introducing an objective function of type (1), it is necessary to determine the utility of the reward [2]. For example, if material incentives are used, then the utility function $u\sim(\sigma\ (y))$ can be introduced, which would reflect the usefulness of money for the ship agent in question. The objective function of the ship agent will then take the form: $f\,(y) = u\sim(\sigma\ (y)) – c(y)$.

The direct task of synthesizing the optimal incentive system for the crew of the vessel is to choose an acceptable incentive system that has maximum efficiency:

$$K(\sigma) ® max \quad (1)$$

The inverse task of stimulating the labor force (crew) is to find a set of incentive systems that implement a given action, or in a more general case, a given set of actions A^* Í A. For example, with $A^* = \{y^*\}$, the inverse problem may be to find a set $M\ (y^*)$ incentive systems that implement this action, that is, $M\ (y^*) = \{\sigma\ M \mid y^*$ Î $P(\sigma)\}$. Having determined $M\ (y\ ^*)$, the center has the opportunity to find in this set the “minimal” stimulation system – that implements a given action with minimal stimulation costs, or a stimulation system that has some other specified properties, for example, monotony, linearity, etc. The representation of the ship agent about its possible income on the labor market reflects such a value as the reserve wage [2], that is, a special case of the individual rationality condition is the limitation of the reserve wage armor.

The conditions of consistency and individual rationality similar to those given above for a ship agent can be formulated for the center – the ship-owner company. If there is a single ship agent – an applicant for a contract, then the contract will be beneficial for the center – the owner of the vessel, subject to two conditions.

The first condition (similar to the incentive coherence condition) reflects the consistency of the incentive system with the interests and preferences of the center, that is, the application of the incentive system that appears in the contract should deliver the maximum objective function (utility function) of the center (compared to using any other acceptable incentive system).

The second condition for the center is similar to the participation condition for the ship agent, namely, the conclusion of a contract with this ship agent is beneficial for the center compared to maintaining the status quo, that is, refusing to conclude a contract at all. For example, if we assume that the profit of a shipping company (the value of the objective function of the center) without a contract is zero, then when concluding a contract, the profit should be non-negative. Having qualitatively discussed the conditions for concluding a mutually beneficial labor contract by the crew, we return to the formal analysis, that is, the solution of the stimulation problem (1). Note that the solution of this problem "head on" is quite laborious. But, fortunately, you can guess the optimal incentive system based on substantive considerations, and then correctly justify its optimality.

We give a formal proof of this statement. The condition that the choice of the action x delivers the maximum objective function of the ship's agent when using the incentive system *s (×)* can be written as follows: the difference between the incentive and the costs of the shipowner will be no less than when choosing any other action of the ship's agent:

$$y \hat{I} A \, \sigma(x) - c(x)^3 \, \sigma(y) - c(y).$$

Since the shipowner seeks to minimize payments to the ship agent, provided that the latter chooses the required action for the ship owner, the optimal point within the benevolence hypothesis should lie on the lower boundary of the compromise area, that is, the stimulus should exactly equal the sum of the costs of the ship agent and the reserve utility. This important conclusion is called the "principle of compensation for the costs of the shipowner".

Matrix $r = || rij ||$ characterizes the potential capabilities of the ship's crew to perform a given set of functions. We introduce the numerical indicators of the team calculated on the basis of the matrix *r*:

- the professionalism of the i-th ship agent – the average value of the effectiveness of its various functions:

$$r_i = \frac{1}{m} \sum_{j=1}^{m} r_{ij}, i \in N ; \tag{2}$$

- professionalism of the team – the average efficiency of the team performing various functions:

$$r = \frac{1}{m\,n} \sum_{i=1}^{n} \sum_{j=1}^{m} r_{ij}; \tag{3}$$

- average team qualification for each of the functions:

$$H_i = \frac{1}{n}\sum_{i=1}^{n} r_{ij}, j \in M \quad ; \tag{4}$$

- heterogeneity of qualifications of the i-th agent – a standard deviation of its effectiveness in performing various functions:

$$d_i = \sqrt{\frac{1}{m-1}\sum_{j=1}^{m}\left(r_{ij} - r_i\right)^2}, i \in N \quad ; \tag{5}$$

- heterogeneity of the team, crew – the normalized value of the sum of the differences in the effectiveness of agents:

$$d = \frac{1}{2mn(n-1)}\sum_{i,k=1}^{n}\sum_{j=1}^{m}\left|r_{ij} - r_{kj}\right|; \tag{6}$$

- specialization of the team, characterizing the presence in it for each function of agents specializing in the implementation of this function. This indicator is defined as the ratio of the number of team members performing any functions in the optimal distribution of functions to the total number of team members *n*.

Using trivial mathematical models, such as the "knapsack task", "assignment task" or "transport task" in our case is impossible, since we are dealing with technologically related operations [27]. For a given network schedule that reflects the relationship of work, the duration of each work depends on the resource used to carry it out. Therefore, due to the distribution of volumes of work and resources between agents, it is possible to influence the length of the critical path that determines the duration of the project. The corresponding tasks (allocation of resources on networks) are considered in the calendar-network planning and management [1, 29, 30]. The results of their solution can also be used in the distribution of the volume of work between the agents included in the team.

Today, mathematical economics and operations research [29-31] have accumulated considerable experience in formulating and solving various resource allocation problems, which is also worthwhile to use when analyzing the processes of effective formation and functioning of teams.

Having distributed the functions and volumes of work, we can begin to form the optimal team composition by setting the objective function.

We introduce the following notation:

N_0 – many agents - candidates for inclusion in the team, $|N_0| = n_0$;

N is the composition of the team (a solution to the problem of forming the composition), $|N| = n \leq n_0$;

$\Phi(N)$ is the efficiency functional, which associates with each possible composition $N € N_0$ a real number. Note that the efficiency functional can be obtained as a result of solving (in the general case for each of the possible compositions) problems of the distribution of functions and volumes of work.

Formally, the task of forming a team is to find its composition N^*, which has maximum efficiency:

$$N^* = \arg \max_{N \subseteq N_0} \Phi(N) \tag{7}$$

Problem (7) relates to discrete optimization problems. The admissible team compositions may additionally be superimposed both with the requirements for the mandatory inclusion of certain groups of agents (ensuring the implementation of certain functions), as well as prohibitions on the inclusion of certain groups of agents. Solving problems of this type is possible in one of several ways. Based on the analysis of various optimization models of the project management team, it is advisable to use conceptual models in solving the problems of forming a ship's crew.

The first way is to "frontal" consideration of all possible combinations of potential crew members. Its advantage is finding the optimal solution, the disadvantage is high computational complexity.

The second approach is based on local optimization methods (sequential enumeration of lineups from a certain neighborhood of a specific lineup). The heuristic methods used in this case, as a rule, have transparent meaningful interpretations, but in the general case they do not provide an optimal solution and therefore require an assessment of their guaranteed effectiveness.

Below we will use the following model of preferences and awareness of the ship agent. Let the agent's preferences on the set of possible results of activity be given by his utility function *v (×)*, and the result of activity *z A0* depends on the action *y A* and the situation *q Θ* in a known manner 16: *z = w (y, q)*. The use of such a description does not reduce generality, since in multi-element systems the partners of each agent can be considered as an external environment for him and their strategies will form a "state of nature" (which, however, will be different for each agent). Then the law *WI (×)* is determined by the function *w (×)*, which reflects the structure of the passive controlled object of the project, and the information *I* that the agent had at the time of making decisions about the chosen action [26]. A mapping linking actions and the environment with the results of an activity can be considered as a "technology" of functioning of an object managed by an agent. The structure of the agent's decision-making model in the project is shown in Figure 3.

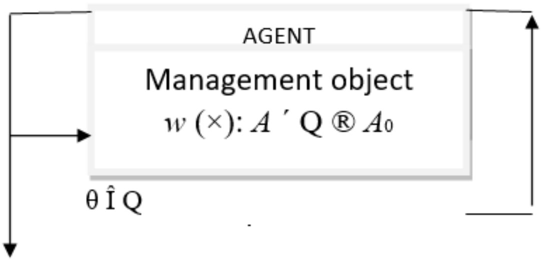

Figure 3 The structure of the decision-making model by the agent in the project

Note that the so-called input-output structure shown in Figure 3 is typical of the classical theory of project management, studying the problems of managing passive (technical) systems. In this class of tasks, in many cases (excluding models of human-machine systems), the control subject (control body) is also passive [26; 32].

We detail what is meant by information and how the uncertainty of one type or another is eliminated. The "limit" for all the types and types of uncertainty listed above is the case of a deterministic change in the result of an activity – when it does not depend on the situation (or, what is the same, when the set Θ' consists of a single element), that is, when each action *y A* corresponds to the only result of activity is *z = w (y) A0*. In this case, we can immediately assume that the preferences of the agent are given on the set of his actions. If *v (×)* is the utility function of the agent, then its objective function *f (×)* in the deterministic case is defined as *f (y) = v (w (y))*.

The rule of individual rational choice in the deterministic case consists in the choice by the agent of actions that bring the maximum of his objective function, that is:

$$PWI\ (A\ ,A,I)\ =\ Arg\,max\ f\ (y).$$

Thus, the determinism hypothesis is manifested in the fact that the agent, eliminating the uncertainty of the project.

The third approach is to exclude obviously ineffective combinations of agents based on an analysis of the specifics of the task. For example, if it is possible to prioritize the applicants for inclusion in the team in decreasing order of their performance or the marginal contribution made to the team, then the problem of the optimal composition will be reduced to the problem of the optimal team size, which has much less computational complexity. An analysis of the theory of project management made it possible to prove the possibility of applying the project-oriented approach and the general project management methodology to solving the problem of forming the optimal crew of a vessel depending on its type, technical condition, age, features of planned voyage, etc.

4. CONCLUSION

Despite the great attention paid to the formation of project management teams, existing studies do not take into account the specifics and features in the conditions of operation of the ship's crew.

The advantage of this optimal approach to team building is its focus not on the adoption of generalized recommendations for managing average agent teams, but on decision-making on the tasks of effective planning and development of each team for the conditions and specifics of a particular project.

Summing up, it can be noted that psychology and economics are closely related to the social sciences. But at the present time, there is also a connection and the trend of the economy with technical sciences, and specialties including project and program management. This can be explained by the fact that a person is a “soft component”, a participant in technological and production processes, including in the marine business.

It should be noted that shipping companies are organizations focused on project management. Despite the absolutely correct conclusion that the minimum crew should be determined on the basis of the conditions for ensuring the safe operation of all ship systems and mechanisms.

Crew selection is carried out by crewing companies, which far from always prioritize the quality of their work, that is, the total level of training and coordination of the ship's crew. Indeed, especially the behavioral competencies of seafarers are the most essential and important in relation to the formation of crews of ships as project teams. This necessitated the solution of the research tasks: 1) modeling the behavior of individual project agents when performing design tasks on the ship; 2) determine the method of forming the project team taking into account the behavioral characteristics of individuals and functional groups of the crew of the ship.

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