

Виявлено особливості командно-рольової структури проекту. Розглянуто застосування саморозвиваючих систем Лотки-Вольтерри–Гаузе з урахуванням типів взаємодії «співпраця» і «конкуренція» при формуванні команди проекту. Показано можливості математичного моделювання тенденцій рольової активності учасників команди проекту. Визначена точка рівноваги тенденцій рольової активності, в якій мінімальний вплив максимально визначає подальший стан системи

Ключові слова: проект, управління, функціонування, розвиток, рольова активність, співпраця, конкуренція, точка рівноваги

Выявлены особенности командно-ролевой структуры проекта. Рассмотрено применение саморазвивающихся систем Лотки-Вольтерри–Гаузе с учётом типов взаимодействия «сотрудничество» и «конкуренция» при формировании команды проекта. Показаны возможности математического моделирования тенденций ролевой активности участников команды проекта. Определена точка равновесия тенденций ролевой активности, в которой минимальное воздействие максимально определяет последующее состояние системы

Ключевые слова: проект, управление, функционирование, развитие, ролевая активность, сотрудничество, конкуренция, точка равновесия

THE RESEARCH ON ROLE DIFFERENTIATION AS A METHOD OF FORMING THE PROJECT TEAM

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1. Introduction

Forming and evaluation of the personnel competence in terms of the requirements of the project should be built in order to ensure the needs of specific roles in project activities. The team effectiveness is largely dependent on its members' personal qualities and relationship between them. Each team member must be willing to devote his skills and knowledge to solving the command task [1].

The role structure of each team member integrates role types in a constructive pattern of team behavior, which ensures a successful professional activity.

The group of professionals does not always form an effective team – it is necessary to know the conditions under which it becomes successful.

The role is a set of expectations about the team member or a person at work. Groups are often faced with problems caused by the difficulties that are associated with the way the team members define the roles and cope with them.

Currently, one of the most urgent tasks is to build up a model of developing the group to the command level on the basis of role differentiation. In assessing the current state of this issue elaboration, it should be noted that such a model does not exist, and the available options often not including all the possible stages are difficult to apply to a variety of real functioning groups.

Thus, the relevance of this work is determined by existing demands both in the theoretical and methodological level, which is expressed in the construction of the team building model, and in scientific and practical terms, namely in the development of this team building technology to assist in determining the conditions under which the group of professionals forms an effective team.

2. Analysis of published data and problem statement

Applicable to forming the project team role approaches are combined with common logic which determines their multi-diagnostic capabilities. On the one hand, the concept of “role” is the assignment of certain tasks and functions, the implementation of which the team members combined with joint activity expect. On the other hand, the successful execution of the role requires that a person knows not only about those expectations, but also has the desire and ability to fulfill them.

Traditionally functional and team (group) roles are distinguished. Functional roles relate to official duties and include skills, knowledge and experience, i.e. the team members' level of competence. The realities of project activities suggest that each member of the team, especially in large-scale integrated projects, tries to gain competency in all ar-

eas, in all project management functions in the right amount and in relative proportion in which a quality role-playing guide built on analysis of global best practices, best learned lessons requires [1]. The team role is a role in the group, it reflects the way in which team members carry out their work, and is determined by participants' congenital and acquired personal characteristics, as well as environmental circumstances and team requirements.

The model of the behavior type (directors, socializers, relaters and thinkers) and the Belbin's model are preferred to determine the roles in the project team, as during the classification of the roles they allow to use different criteria (behaviors and responsibilities that project participants perform) [2].

A cluster of specific behavioral characterizes each of these 9 roles. Role behavior is defined by six factors: personality, current values and motivation, mental ability, experience, role learning and field constraints. However, it was not shown how much of the variance in a team role is explained by each factor [3].

There are three examples of Impromptu teams. The three examples indicate that the teams are characterized by being triggered by an unexpected event, and formed through a bottom-up process, where joining the team is voluntary and the activities are based on a logic of appropriateness, rather than rule following [4].

It is argued that both the surface-level demographic diversity and deep-level trait diversity of team members are negatively related to team helping behavior. Also, the team cohesion and cooperation will mediate the effects of team members' demographic characteristics and trait diversity on team helping [5].

It's highlighted that a complementary perspective, namely the idea that cultural diversity and cultural differences can be an asset rather than a liability [6].

The synergistic effect of teamwork occurs on a voluntary and common consent basis, the informal distribution of various roles and functions related to the level of specialization and competence required for the implementation of projects. However, the advantages of teamwork are associated with the competition of its members for resources, influence and image. It can lead to conflicts which can lead to reduced productivity and disruption of the interaction between the team members [7–10].

Historical and evolutionary approach provides principles of description of self-developing systems, one of which includes the parameters of the interaction of two opposing tendencies of the system functioning – the conservative tendency, reproduction of system generic experience and the changing tendency as a kind of “extended reproduction” providing the appearance of a variety of innovations in the system [11].

These principles of the system functioning are described by the system of Lotka, Volterra and Gause's equations, which is also used in the justification of the law on competitive project properties, where specie acts an enterprise that supplies its product on the market and competes with other companies, as well as the population is the product amount. Thus, the theoretical component of the project management knowledge in the approval of competitive relationship attributed to the rank of law was further developed [12].

The definition of a conceptual model of the rational individual's role in the project team, described in the paper

[13] is the basis for the development of the algorithm of applicants' psychological testing procedure when the selection of the project team and determining the most rational functions for the project team members.

However, within these papers the correlation between the psychologically important personal qualities and the possibility of a compensational effect of the conservative and changing tendencies when certain combinations of psychological characteristics have not been investigated and, therefore, an optimal set of psychological criteria for assessing the project team members is not formed, that defines perspective directions of further research.

3. Purpose and objectives of the study

The key purpose of this paper is to develop a method of forming a project team based on differentiation of roles in the conditions of implementations of innovations on the basis of mathematical types of interaction patterns in self-developing biological systems, such as “cooperation” and “competition”.

In accordance with the set goal, the following research objectives are identified:

1. To identify which team roles participants are appropriate.
2. To determine the ratio of conservative and changing tendencies of system operational parameters based on Lotka, Volterra and Gause's model.
3. To calculate the equilibrium point in which the most minimal impact determines the subsequent state of the system.

4. Research of role differentiation based on the model of Lotka, Volterra and Gause in self-developing systems of “cooperation” and “competition”

4. 1. Methods of research of project team members' activity tendencies

Mathematical modeling of the project team is necessary to determine the conditions of effective work in management of project operation and development.

Operation and development are two sides of the same process.

Operation is the current work, performance of traditional functions required for the continuation of the project life cycle, i.e. fulfillment of standard tasks in relatively constant conditions. Development is progress, the formation of new features of the object, the establishment of its new structural characteristics. The development means evolution, improvement of the object and it can also mean its growth and expansion. According to the project development means sustainable changing of activity orientation, functions and the level of project efficiency (Fig. 1).

According to the basic principle of self-developing systems, one can distinguish the interaction of two opposing systems of operation of the system – the conservative tendency and the changing tendency [14], which explains the balance of the two activity tendencies of team members – the ability to conserve and the ability to change. Team members who have the conservative ability participate in the operation process, and team members who have the changing ability participate in the development process.

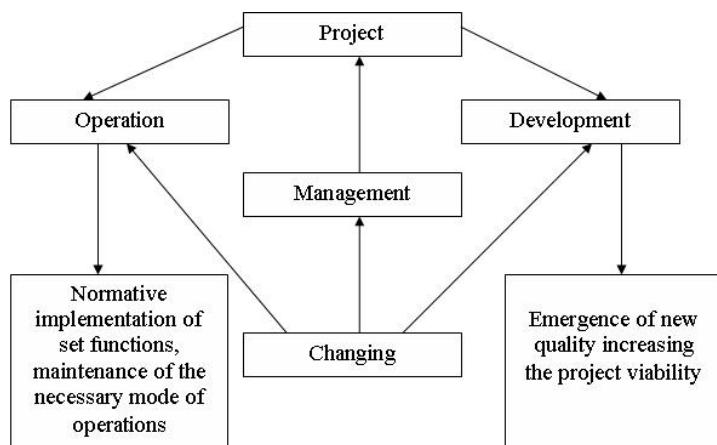


Fig. 1. Operation and development in project management

Being the bearer of these two tendencies in the design of the system development, personality shows different system characteristics such as utilitarian functional characteristics, in which the personality and team act integrally; distinctive individual integrated system characteristics, occurring due to participant's involvement in project relationship system. Thus, they are responsible for the search of further ways of its development. Team member's system functional characteristics provide behavior expressions which are characterized as stereotyped, reproductive and adaptive, for example, conformal adaptive behavior in the project team, reproductive thinking, skills and habits. Personal system individual characteristics provide its productive and non-adaptive manifestations as actions of individuality, imagination, creativity, intellectual initiative, etc.

Participation of project team members can be differentiated according to the operation and development processes in project management on the basis of the role approach.

Forming of the project team on the basis of the role approach provides discussion and negotiation among team members about their roles; it is assumed that the roles of team members are partially overlapped. Team behavior can be changed as a result of changes in their execution as well as the individual perception of roles.

The role in the team is defined as the tendency of people to behave, to contribute to the work and to interact with others in a certain way [2].

The task that cannot be performed by one person can be fulfilled successfully by the command, whose personal characteristics comprise features necessary for the implementation of all 8 roles. This does not mean that the group should consist of eight people certainly. Everyone can combine the multiple roles. The main thing is that all functions are carried out. Full role-structure forms the basis for the effective operation of the team entirely.

According to the diagnostic of managers' activity in teamwork "Coordinator", "Monitor Evaluator", "Implementer" and "Completer Finisher" have the conservative tendency. "Plant", "Resource Investigator", "Shaper" and "Team worker" have the changing tendency.

To find out which role in the team the participant corresponds to, you need to determine the number of points for

each role of each team member according to the Belbin's test and convert 'raw' scores into standardized points (S_r) by the formula [15]:

$$S_r = 2 * \frac{x_r - \bar{x}_r}{\delta} + 5,5. \tag{1}$$

In this formula, x_r are points value for each participant's role \bar{x}_r is the arithmetic mean of the points for each role, δ is the standard deviation, which is calculated by the formula:

$$\delta = \sqrt{\frac{\sum (x_r - \bar{x}_r)^2}{n - 1}}, \tag{2}$$

where $n=8$ (8 roles).

The calculation of standardized points for each role of one team member is given in Table 1.

Table 1

The calculation of standardized points for each role

Role (points)	Coordinator	Shaper	Plant	Monitor Evaluator	Complete Finisher	Resource Investigator	Team Worker	Implementer
1 block (points)	0	1	0	2	6	0	0	1
2 block (points)	0	4	1	2	2	0	0	1
3 block (points)	1	2	1	2	1	1	0	2
4 block (points)	0	0	1	2	3	2	0	2
5 block (points)	2	1	0	1	4	2	0	0
6 block (points)	0	0	1	1	6	0	0	2
7 block (points)	0	3	0	3	4	0	0	0
Total	3	11	4	13	26	5	0	8
Standardized points (S_r)	4	6	4	7	10	5	3	5

Mathematical modeling of various indicators of management activity is carried out on the basis of the system of Lotka, Volterra and Gause's differential equations. One of the equations describes the conservative tendency, the other one is the changing tendency [10].

$$\frac{dn_1}{dt} = r_1 n_1 \frac{K_1 \pm n_1 - \alpha_{1,2} n_2}{K_1}, \tag{3}$$

$$\frac{dn_2}{dt} = r_2 n_2 \frac{K_2 \pm n_2 - \alpha_{2,1} n_1}{K_2}. \tag{4}$$

In any systems states tend toward equilibrium, when small external influences are either constant or do not change over time during the investigation of the system. This means that the derivative will tend to zero. In this case, the solution is found of such linear relations as given in equation (5). In this case, the initial conditions are described below (K_1 and K_2 $\alpha_{1,2}$ and $\alpha_{2,1}$). Therefore, the stability was not determined because the solution had

been reduced to the linear equation for the special case of equilibrium.

In these equations, K_1 and K_2 are dominating factors (the sum of the values of prevailing command roles in the range of 6 to 10 standardized points) and $\alpha_{1,2}$ and $\alpha_{2,1}$ are dispersive factors (the sum of the values of command roles, which have a minimum intensity, i. e. in the range of 1 to 5 standardized points); n_1 and n_2 are the intensity of conservative and changing tendency accordingly; r_1 is psychological characteristics of species. $\alpha_{1,2}$ and $\alpha_{2,1}$ can not be changed in an unpredictable way.

Sign «±» to n_1 and n_2 reflects the interaction of conservative and changing tendencies of self-developing biological systems, such as “cooperation” and “competition” accordingly.

The K_1 and K_2 values correspond to the bearing of the dominating roles at the absence of one of the tendencies. With the presence of both tendencies, each member of the team reduces the dominating factors of a certain role. The impact of one tendency on another is considered in the system of Lotka, Volterra and Gause’s differential equations by introducing an additional term with a negative sign $-\alpha_{ij}n_j$, reducing the dominating role factors for each tendency [10].

With the joint solution of a system of differential equations (3) and (4), the relation for the calculation of tendencies is determined – the conservative and changing ability being in project relationships between team participants. To analyze the relationship of interspecific competition, a special case of the system state is considered when the state of quasi-equilibrium is achieved between the one participant’s abilities and the project team. In this case, the coordinates of the equilibrium point ($n_1; n_2$) remain practically constant, i. e. derivatives on the left side of equations (3) and (4) are zero.

$$\begin{aligned} K_1 \pm n_1 - \alpha_{1,2}n_2 &= 0, \\ K_2 \pm n_2 - \alpha_{2,1}n_1 &= 0. \end{aligned} \tag{5}$$

The system of differential equations is written for each team member, considering the type of interaction of his team roles. By means of the system of equations, “equilibrium point” is analytically calculated, which in a Cartesian coordinate system is the intersection of the two tangents (appropriate to the conservative and changing tendencies). It is a stationary solution of the system of equations. “Equilibrium point” is the point, in which the development of conservative and changing tendencies is characterized by a maximum uncertainty and maximum sensitivity for effects [14].

4. 2. The model of ratio, which is determined by means of expert evaluations based on the diagnostic data of team roles differentiation

During modeling team roles differentiation of project team members, the equilibrium point ($n_1; n_2$) is calculated analytically on the basis of models of “cooperation” and “competition” (Table 2). At the first phase, the testing was held according to the Belbin’s questionnaire and the role points obtained by project team members were transferred to the standardized points. Then the dominant roles were identified, the values of which are equal to or more than 6 standardized points, and the roles, the values of which are below 6 standardized points. Role positions interact with each other. It affects the efficiency of the project.

The solution of the system of equations (5) is the solution (6):

$$n_1 = K_1 - \alpha_{1,2}n_2, \quad n_2 = K_2 - \alpha_{2,1}n_1. \tag{6}$$

The features of this model can be investigated by determining isoclines.

The isocline of the horizontal tangent ($n_2=0$) is found by the formula (7):

$$n_1 = \frac{\alpha_{1,2}}{K_1}. \tag{7}$$

The isocline of the vertical tangent ($n_1=0$) is found by the formula (8):

$$n_2 = \frac{K_2}{\alpha_{2,1}n_1}. \tag{8}$$

So, we can see that the team members A, B and C are characterized by the presence of equilibrium points with minimal changing tendency: on the basis of the “cooperation” model $0,5 < n_2 < 1,3$ and on the basis of the “competition” model $0,3 < n_2 < 0,5$. They have a more expressed conservative tendency: on the basis of the “cooperation” and “competition” model $1 < n_2 < 4,5$. The results of applying the “competition” model have shown the ability to reduce the severity of some of the team members’ conservative tendency and changing tendency through the internal personal role conflict. The situation of the internal role conflict can occur when a project team member is forced to take a psychological role under the pressure of external circumstances, as well as in a situation where one and the same role is produced with conflicting expectations of different participants or groups which are not possible to be satisfied simultaneously. These team members are conservative managers, who are the least effective in the conditions of the introduction of innovations.

Table 2

Modeling of the equilibrium point based on the models “cooperation” and “competition”

Team participant	Standardized points								Modeling of the equilibrium point							
	Changing ability				Conservative ability				Changing tendency		Conservative tendency		Model “cooperation”		Model “competition”	
	Shaper	Plant	Resource Investigator	Team worker	Coordinator	Monitor Evaluator	Complete Finisher	Implementer	K_1	$\alpha_{1,2}$	K_2	$\alpha_{2,1}$	n_1	n_2	n_1	n_2
A	6	4	5	3	4	7	10	5	6	12	17	9	0,66	1,96	0,35	1,8
B	4	4	8	5	7	5	8	3	8	13	15	8	1,24	2,03	0,48	1,81
C	2	4	5	8	5	6	7	7	8	11	20	5	1,11	4,22	0,37	3,93
D	6	7	7	5	5	5	5	5	20	5	0	20	4,04	0,2	4,04	0,2

Due to the fourth member of the team, the average changing tendency is increased ($0,5 < n_1 < 4,5$) and the average conservative tendency is reduced ($0,2 < n_2 < 4,5$) according to the “cooperation” and “competition” models. This indicates the absence of the internal personal role conflict at this stage.

Thus, the average team conservative tendency ($n_{2av.}=2,1$ on the basis of the “cooperation” model; $n_{2av.}=1,9$ on the basis of the “competition” model) and the average team changing tendency ($n_{1av.}=1,8$ on the basis of the “cooperation” model; $n_{2av.}=1,3$ on the basis of the “competition” model) are characterized by a small permissible variation.

According to this analysis, it can be concluded that the role differentiation of the effective team does not always depend on the number of participants. Each participant may combine the multiple roles that can lead to the balance of conservative and changing tendencies on the basis of the model of “cooperation” and “competition”.

5. Analysis of the results of applying the role differentiation method for forming the project team

The research presented in this paper allowed to offer new effective and non-traditional method of formation of the project team on the basis of role differentiation, considering team members' activity tendencies.

The advantage of this method is that it does not require preliminary preparation of project team members and the project manager, and you can involve a large number of participants simultaneously at the stage of teambuilding. By means of this method, an attempt is made to prevent conflicts at the interaction of participants. Tools for the diagnosis of the group role structure and the quality of participants' role execution are developed.

The disadvantage of this method is that the team members change their roles in different situations. Experience, regulations and value have an additional influence. Harsh role distribution stops the development of the group, leading to the dominance of personal goals over collective ones, every employee works to achieve the effectiveness on the basis of his role.

The results indicate that project management has at its disposal a new cognitive – making search tool in the project team forming.

By means of developed mathematical modeling methods of the project team resources conditions of formation of differentiated curriculum for team participants can be detected, thereby increasing the efficiency of management consulting and optimization of the project team costs provided training innovation.

However, in this paper the relation of participants' competence level and the interaction level of the team roles is not investigated that defines perspective directions of further research.

Role interaction management in projects is advisable to be distinguished in a separate management function and formalize the appropriate field of knowledge in the system of knowledge in project management.

6. Conclusion

1. By means of the Belbin's model, each team participant's role structure is determined. On the basis of project operation and development, team roles are distributed on the basis of their characteristics relevant to the changing and conservative ability of the system functioning parameters. According to the diagnostic of managers' activity in teamwork “Coordinator”, “Monitor Evaluator”, “Implementer” and “Completer Finisher” have the conservative tendency. “Plant”, “Resource Investigator”, “Shaper” and “Team worker” have the changing tendency. The results of participants' testing were converted into standardized points by means of which changing and conservative tendencies were determined.

2. On the basis of the system of Lotka, Volterra and Gause's equations, each team participant's conservative and changing abilities of the system functioning parameters are identified considering the types of interaction such as “cooperation” and “competition”.

3. As a result of building up team roles differentiation model, the equilibrium point is calculated analytically, which is characterized by a minimally expressed changing activity tendency and more expressed conservative activity tendency of the parameters of the system functioning. On this basis, it was found that the formation of the new project team role structure should pass through the dispersion stage of role differentiation or roles distribution and functions among all team members.

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