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GENERAL PRINCIPLES OF BUILDING THE MODEL OF DEVELOPMENT AND OPERATION OF HETEROGENEOUS TEAMS FOR PROJECT MANAGEMENT

The subject of the research is the basic principles of making the model of managing the production of software and models of development and operation of heterogeneous teams for project management. **The objective of the research** is to develop the mathematical model representing the operation of heterogeneous teams for project management. The sociometry is used for psychodiagnostic procedures in the course of social and psychological analysis of group relations. This method is directed at determining the structure of interpersonal relations by identifying mutual feelings of frienliness and unfrienliness among the members of groups. The mathematical methods of processing data and information obtained during the sociometric survey lie in calculating mathematical indicators which can be subdivided into group and individual indexes. In the course of the research the following **tasks were solved**: the requirements for team building and development of models for software implementation were analyzed; the method for analyzing the cohesion of team members was selected; the options for developing the mathematical model representing the principles of building the team which works on the project were considered. Groups different in structure were compared with the help of mathematical processing of statistical data; and correlation procedures were conducted. Individual indexes were defined; among them are: the index of sociometric status which indicates the advantage of any member of the group over other participants; the indexes of positive and negative emotional expansivity; the index of group cohesion; the index of sociometric coherence. **The methods used are**: statistical and correlation analysis, sociological, Hungarian, mathematical. **As a result** of the conducted researches the basic principles of making the model of managing software development are shown, mathematical methods of development and operation of heterogeneous teams for project management are suggested. Thus, the goals and objectives of the research are carried out.

Keywords: software, the model of management, sociometry, individual indexes, Hungarian method.

Introduction

The key object of studying software engineering is the process of software development. However, nowadays, there is no universal software development process, that is a set of techniques, rules and regulations that are suitable for any software, for any company, for teams of any nationality. Each current development process, carried out by any team within a particular project, has a large number of features and individualities. Before starting a project, it would make sense to create a process template, for example, as in the Microsoft Visual Team System that is created or adapted (if a standard one is used) before developing. In VSTS, there are workpieces for specific processes based on CMMI, Scrum, and others.

These features of software development process require a model that would enable managing this process.

Problem analysis and task setting

Generally, the development of a model is considered as a process of purposeful "creation" of a special way of interaction among the people in a group (called team), which makes it possible to realize their professional, intellectual and creative potential efficiently according to the strategic objectives of this model of management (team). The model in this case is defined as a group of people who are mutually reinforcing and interchanging one another in the course of achieving the goals [1].

Nominally, four types of models (groups) that are often formed in the course of practical activities of enterprises and are classified in terms of their work can be determined.

1. Teams that create something new for the organization or do work that has been done earlier. Project teams fall into this group. They are temporary in nature, as the content of a project is determined as a temporary specific organizational form for achieving goals and solving unique tasks.

2. Teams (groups) that deal with problems, goals and tasks of the enterprise using analysis, control and recommendations, e.g. auditing and controlling teams, quality assessment teams.

3. Teams (groups) that are not special, but a permanent part of the organizational structure and which carry out the process of production and performance of repetitive work, e.g. production teams (groups), sales teams and service teams (brigades, groups).

4. Teams that are of multifunctional executive management nature. These teams are usually formed at higher levels of enterprise management and act as executive committees, management teams or top managers of the enterprise.

The following conditions determine the efficient work of a team:

- each member of a team should clearly understand their role, which enables performing their tasks without disturbing the work of others;

- project specification and schedule of work should be coordinated with all the members of a team;

- all the team members should interact with one another and respect the professional qualities of one another;

- all members of a team should clearly see the model of the process that is used during the project implementation;

- each member of a team should know all the aspects of the project plan.

The type and amount of work that should be done determine a number of model members; significant impact of the external environment is also very important.

There are common features that should be taken into account when determining the size of a team:

- the larger the group, the more invisible the pressure which leads to conformism of team members;

- the structure of the model affects the behaviour of its members – the more powerful the structure, the lower its tolerance towards employees who have special views, the more acute antagonism against any deviations from the norm;

- a great number of team members can leave any person without a conscious role and diminish the importance of a personality.

Typically, the literary sources suggest the following classification of teams in the context of team members: a) small teams (less than 4 people); b) medium-sized teams (from 5 to 9 people); c) large teams (more than 10 people).

In the full-scale project of the ERP implementation of the Microsoft system there are specialists with different functional responsibilities. The following characteristic roles can be distinguished [2, 3].

The director (general manager) of the project who ensures making strategic decisions and interacting with the top management of the enterprise of a customer and / or a partner.

The project manager (manager) is the main responsible for its successful completion.

The project coordinator, who is appointed when the project manager is not a customer employee, and whose responsibility is to manage the resources and represent the interests of the customer while discussing project issues.

The architect of business solutions is primary responsible person for making business management decisions in large and complex projects.

The business analyst (consultant) is very important for ensuring the efficiency of solutions within the ERP system. Their responsibilities include: inspecting the enterprise, designing and optimizing business processes with the help of the system which is introduced.

The system (functional) analyst (consultant) is responsible for designing technical tasks within the selected ERP system of Microsoft Axapta or Microsoft Navision and whose main task is to implement business automation solutions into software design.

In practice, the roles of business and functional analysts are often combined, which is, in principle, quite feasible for small projects.

The development manager is responsible for the coordination and quality of work performed by a group of programmers. As a rule, they are experienced professional programmers with managerial skills and ability to manage resources.

The programmer (software designer) needs no introductions. It is only necessary to keep in mind that end customers might describe all IT specialists engaged in the project as "programmers".

The system administrator (DB), at the stage of introduction, is responsible for technical deployment of the solution on the server architecture and for the working efficiency of a client part at customers' computers. Initially, it is reasonable to assign this task to a customer specialist, since it will subsequently proceed from the the stage of implementation to the stage of technology operation of the ERP system.

The testor, whose responsibilities include: preparing a test plan, verifying the compliance of software design development as well as error checking in accordance with the plan of testing; they also carry out initial code testing.

The instructor (teacher) mainly teaches the users of future solution of a new functionality.

The technical editor prepares online help system for users.

The project administrator is a project assistant, whose routine responsibilities are carried out by the manager of a small project.

The expert plays a sporadic, but nevertheless, a very important role in a project. Experts are experienced managers and just key customer employees; they know the business of the enterprise at which they work. These people, especially at the stage of conceptual design, conduct formal or informal expert evaluation.

The key user is an experienced customer specialist, who is an agent distributing the future solution among other users.

Of course, one role can be performed by several specialists. But, on the other hand, one and the same man can combine different roles. There are some recommendations for possible and undesirable combinations in the context of performing different roles by one and the same person [4, 5, 6].

The developemt of a model begins at the early stages of a project from the moment of its start and can actively continue until its completion. This happens due to the fact that at different stages the necessity in different specialists varies. Due to the temporary nature, it is more efficiently to build the skeleton of a team grounding on the resources of the partner, as it is rather difficult to put a professional and cohesive team together at the customer side for a short period of time.

The model for developing a software product is a model that comprises the team of employees who are directly involved in the implementation of the project and are responsible to the project manager. This is the main element of its structure, because the correct construction of the model ensures the realization of the idea of the project.

The management model is an independent subject of activity, which can be considered in terms of properties, processes, parameters that are specific for a social group.

In order to develop a model of management, there exists a whole process of its development that comprises a task that requires high managerial competence. In the course of its implementation not only properly selected high-skilled professionals are necessary, but also people who want to work together witnin a team.

M. Bir and other authors singled out four approaches for developing a management model, they are goal-oriented, interpersonal, role-playing and the approach of management grid; all of them are detailed in [7, 8]. He considered the first three approaches to be the main ways of developing a management model.

When developing a management model, it should be taken in account that the efficient team can not be created "in general" for a project. The management model that is most appropriate for each specific project should be developed.

In order to manage any projects the models of development and operation of heterogeneous teams are of a great interest; these teams are the ones where all the members of the team perform various functions, and each member of the management model efficiently performs certain functions.

In [9], the following numerical indicators of a model are used: professional skills of an applicant, the professionalism of a team, average team qualification according to each function the team is carrying out, the heterogeneity of applicants' qualification, the heterogeneity of the team, "specialization" of the team.

Depending on the modelling apparatus used, several areas of researching are identified:

a) "assignment task" which uses the optimization apparatus in order to solve the problems of team development, the distribution of roles and work amount;

b) theoretic and gaming models that use the game theory for describing and studying the processes of team development and operation. Nowadays it is the most advanced direction of formal research of teams which includes such "branches" as:

1) Marshak – Radner model and its development;

2) the model of group stimulation;

3) models of reputation and norms of activity;

The term "assignment task" is conditional and comprises a wide class of optimization tasks, including the task of a model development, the task of assigning functions in heterogeneous teams, and the task of assigning the amount of work.

These three types of tasks are interrelated and solved as a "cycle". In this regard, let us successively consider the problem of assigning the amount of work, the problem of assigning functions and the problem of building the team which is developing a software product with the help of mathematical methods.

Assume that a fixed number of team members is a set of homogeneous (according to functions, which means that team members perform the same type of functions) applicants $N = \{1, 2, ..., n\}$, the total amount of work that should be done is known – R 0, and the types of employees are given – $\{r\}$ (characteristics that represent the efficiency of their activities). It is necessary to assign the amount of work to the applicants.

This task setting is too general and requires detailing. There may exist different options. First, it is necessary to distinguish discrete and continuous tasks.

In a discrete task, the amount of work $d_i \geq 0$, which may be performed by the i-th applicant, is fixed. If the type of an employee is interpreted as the cost of carrying out a unit of work, the discrete task of assigning the amount of work R to the applicants in order to minimize total expenditures is obtained:

$$\sum d_i r_i x_i \to \min , \qquad (1)$$

$$\sum_{i \in N} d_i x_i \geq R , \qquad (2)$$

where x_i equals 0 if the i-th applicant does not work and equals 1 if the applican works;

Tasks (1) and (2) belong to the class of rucksack problems [10, 11], and can be solved if:

$$\sum_{i \in N} d_i \geq R , \qquad (3)$$

that is, when the total amount of work does not exceed the "production capacity" of all applicants.

The general "disadvantage" of discrete tasks is that only a small part of them has effective (polynomial complexity) methods of solving. For NP-complex problems with their small dimension it is possible to use the method of full selection, and when their dimension is increasing, various heuristic or other methods of solution can be used [12].

Assume now that the i-th applicant can perform any amount of work that does not exceed d_i. Then, denoting x_i as the amount of work performed by the i-th applicant, a continuous task is obtained:

$$\sum_{i \in N} r_i x_i \to \min_{x_i \in [0;d]} , \qquad (4)$$

$$\sum_{i \in N} x_i \geq R , \qquad (5)$$

which has a simple solution under the condition (1): it is necessary to arrange all the employees in the order of cost increasing ri and consistently load them up to the maximum capacity until the total amount of work R is assigned.

Summarizing the model, assume that the known functions of the costs of agents $c_i(r_i, x_i)$ depend on the amount and the types of work.

The task of minimizing total costs is a typical task of conditional optimization under restriction (5) [13]:

$$\sum_{i \in N} c_i(r_i x_i) \to \min_{x_i \in [0;d]} , \qquad (6)$$

where c_i – is the function of agents (employees);

r_i – is the amount of work performed by an agent;

x_i – the type of work of the i-th agent.

Currently, the study of operations has accumulated considerable experience in formulating and solving various tasks of resource assignment, which should be used in analyzing the processes of efficient development and operation of the management model [14].

Assume that the solution of the task of assigning the amount of work is known, that is, if all working functions are assigned to all the members of the team, the amount of optimal "load" can be found out. Then the problem of function assigning can be considered.

The task of group building is formally set. Formally, to solve the task of building a team means to determine a number of its members N^* which would have the maximum efficiency:

$$N^* = \arg \max_{N \subseteq N_0} F(N) . \qquad (7)$$

where N_0 – is a number of employees who apply for work in the team, $|N_0| = N_0$;

N – is the number of team members (a variant of solving the task of team building), $|N| = N \leq N_0$;

$F(N)$ – is the functional of efficiency that matches each possible number of team members $N \subseteq N_0$ to a real number.

Task (10) is a task of discrete optimization. The requirements of mandatory integration of different applicants into the team as well as prohibition of such integration can be imposed on building the team.

From a theoretical point of view, the task of determining the optimal model of management is reduced to searching all possible models.

However, this general task may have no solution, or its search can be extremely laborious. Such problems are typical for the tasks of developing a model and structure of organizational systems.

Thus, the "assignment tasks" take into account such characteristics of the model as: the identity of purpose, joint activity, specialization and complementarity of roles. On the other hand, this class of models almost does not take into account such properties of a team as: the consistency of the interests of its members and the autonomy of the team, which can be considered with the help of sociometry.

Sociometry is one of the most frequently used psychodiagnostic procedures in the social and psychological analysis of group relationships. This method is aimed at revealing the structure of interpersonal relationships by identifying mutual feelings of frienliness and unfrienliness among the members of groups [15–17].

Sociometric cards are often used to collect information in a sociometric survey, they are given to all the members of a group to be filled in. The sociometric card comprises questions to respondents (some space for their answers is left). Written application is placed on the card, but it can be given orally.

The sociometric matrix enables calculating selections, and immediately suggests an idea as for ranking the members of a group according to their advantages and disadvantages. Considering the results of sociometry, microgroups can be identified.

Sociometric matrix data determine certain status positions of group members, such as: stars, desirable for employment, accepted for employment, isolated ones.

The task of status determination can be solved according to the following formula. First, the number m (the average number of selections) should be determined:

$$ m = \frac{R}{N'} , \qquad (8) $$

where R – is the total number of positive selections made;

N – is a number of group members;

m – is the average number of selections.

A particular group is formed on the basis of sociometric matrix. The sociometric status (St) in this case corresponds to the number of selections received.

Mathematical methods of data processing comprise the calculation of mathematical indicators, which can be subdivided into group and individual indices. The most widely used indicators are the index of sociometric status and the index of group cohesion.

Mathematical processing enables comparing different groups according to a number of their members, conducting correlation procedures, carrying out the statistical analysis of data. Let us consider the individual indexes.

The index of sociometric status is an indicator of the advantage of any member of the group over the other members of the group. The position of a subject in the system of interpersonal relations which defines their rights, duties and privileges is referred to as status in social psychology.

The index of sociometric status of the i-th member of the group is determined by the formula:

$$ S_i^+ = \frac{\sum (R_i^+)}{N-1} , \qquad (9) $$

where R_i^+ is positive sections received by the the i-th member of the group, Σ is the sign of the algebraic summation of the number of selections received by the i-th member of the group, and N is a number of members of the group.

The index of rejection of the i-th member of the group is determined by the formula:

$$ S_i^- = \frac{\sum (R_i^-)}{N-1} , \qquad (10) $$

where R_i^- is all negative selections received by the i-th memberof the group.

There is also the following option for calculating the index of sociometric status, it takes into account both positive and negative selections.

$$ S_i = \frac{\sum (R_i^+ - R_i^-)}{N-1} , \qquad (11) $$

If sociometry does not take into account the selections ranking, their exact calculation, sociometric status varies from zero (no selections) to one (all members of the group give their preferences to the applicant).

Another type of personal indexes is emotional expansiveness, which is expressed in a number of all selections done by any subject of the group, both positive and negative. From the psychological point of view, the indicator of expansiveness explains if a person needs communication, however, this index loses its diagnostic value in case of the parametric procedure of sociometric study.

The index of positive emotional expansiveness is calculated by the formula:

$$ E_i^+ = \frac{\sum (x_i^+)}{N-1} , \qquad (12) $$

where x_i^+ – is a number of positive selections done.

The index of negative emotional expansiveness is calculated by the formula:

$$E_i^- = \frac{\sum(x_i^-)}{N-1} \, , \qquad (13)$$

where x_i^- – is a number of negative selections done.

The index of group cohesion expresses the degree of interconnection among the group members, the strength of their emotional bonds. The psychological content of this index lies in the presence or absence of reciprocity during the selection process in the group. The more mutuality in the group while selecting, the greater the quantity of group members who like one another, the higher its cohesion.

The index of group cohesion (psychological reciprocity) is calculated by the following formula:

$$I_{gr} = \left[(PS - NS)/(N \cdot (N-1)) \right], \qquad (14)$$

where PS – is a number of mutually positive selections in the group;

NS – is a number of mutually negative selections in the group;

N – is a number of group members who participated in the survey.

Group cohesion is high when there are 1-0,76 points (the team is united, everyone appreciates and respects the identity of each member of the group, individuals do not only carry out active significant activities within the group, but also have a positive impact on the others).

Group cohesion is on the average level when there are 0.75–0.46 points (the group is not united, there are only some groups with mutual likes and interests).

Group cohesion is low when there are 0,45-0,30 points (group members are separeted, there are only individual leaders who suppress the personality of others, group events are held from time to time and have no significant impact on the members of the group as well as on those around).

The critical level of group cohesion is below 0.30 points (the work is unorganized and almost unmanageable, there are no leaders among the group members and the management have no real authority).

The analysis of the level of group cohesion according to the selected criterion should be made using the sociometric coherence index. This index can be calculated as the ratio of a number of given (or received) selections to the total number of all possible selections:

$$I_{coh} = K_o \left(or \ K_n \right)/(N \cdot (N-1)), \qquad (15)$$

where K_o – is the number of selections given by the members of the group;

K_n – is the number of selections received by the members of the group.

The cohesion of the group can be calculated using the reciprocal index (I_r). The cohesion of the group manifests itself, first of all, as a number of mutual positive relations, therefore the cohesion index is calculated by the formula:

$$I_r = PS/(N \cdot (N-1)). \qquad (16)$$

Sociometric indices are a powerful tool for analyzing the information collected, since they enable using the quantitative methods of mathematical statistics for information processing, however, these endeces should be interpreted very carefully as in the process of calculation the illusion of getting accurate objective knowledge might occur.

The task of assigning functions can be solved with the help of the Hungarian method. According to the Hungarian method the matrix reduction process continues until all the units subjected to assigning come in a graph of zero value [18]. This means that the final value of the given target function is zero.

Sociometric method can identify interpersonal relations in the group, namely:

- the index of sociometric status;
- the index of emotional expansiveness;
- the index of group cohesion.

The sociometric status is selected as a constraint on the selection of applicants in the group; the group cohesion index enables determining the efficiency of group members work.

The suggested method, based on mathematical models, enables determining a number of group members and assigning functional roles to the applicants.

Practical verification of the suggested method of calculation while developing a software product for LTD "Ukraine" enabled solving the problem of team building according to the criterion of maximum competence. For several sets of applicants, the task of building a team according to the criterion of maximum competence under different constraints has been solved. The analysis of the results justified their validity.

Conclusions

The conducted research work showed the basic principles of developing the model of management of software production, mathematical methods of processing experimental data in the process of development and operation of heterogeneous teams for project management are suggested. The described procedure was tested when building a team to develop a software product for LTD "Ukraine" and showed its efficiency.

The results of the work can be used in any sphere where it is necessary to build the most efficient group for solving project problems.

The use of criteria of maximum competence, minimum time spent by an employee to do work, minimum financial expenses are the prospects for further researching.

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ЗАГАЛЬНІ ПРИНЦИПИ ПОБУДОВИ МОДЕЛІ ФОРМУВАННЯ І ФУНКЦІОНУВАННЯ НЕОДНОРІДНИХ КОМАНД ДЛЯ УПРАВЛІННЯ ПРОЕКТАМИ

Предметом дослідження є основні принципи формування моделі управління виробництвом програмного продукту і моделі формування і функціонування неоднорідних команд для управління проектами. **Метою** дослідження є побудова математичної моделі, що відбиває функціонування неоднорідних команд для управління проектами. З цією метою для психодіагностичних процедур в соціально-психологічному аналізі групових відносин використовується соціометрія. Це - метод, спрямований на виявлення структури міжособистісних відносин шляхом фіксації взаємних почуттів симпатії і неприязні серед членів груп. Наступні математичні методи обробки даних, отриманої інформації при социометрическом опитуванні, полягають в підрахунку математичних показників, які можна розділити на індекси групові та індивідуальні. У процесі дослідження **вирішено такі завдання**: проведено аналіз вимог до формування команд і моделей для реалізації програмного продукту; обраний метод аналізу сумісності членів команди; розглянуті варіанти побудови математичної моделі, що відбиває принципи формування команди, яка працює над проектом. Порівняння різних за складом груп шляхом математичної обробки статистичних даних і проведення кореляційних процедур. Визначено індивідуальні індекси: індекс соціометричного статусу, який є показником переваги будь-якого члена групи з боку інших її учасників; індекси - позитивної і негативної емоційної експансивності; індекс групової згуртованості; індекс соціометричною когерентності. У роботі використані **методи:** статистичний і кореляційний аналіз, соціологічний, угорський, математичний. В **результаті** проведених досліджень показано основні принципи формування моделі управління виробництвом програмного продукту, запропоновані математичні методи формування і функціонування неоднорідних команд для управління проектами. Таким чином, виконані поставлені завдання і мета дослідницької роботи.

Ключові слова: програмне забезпечення, модель управління, соціометрія, індивідуальні індекси, угорський метод.

ОБЩИЕ ПРИНЦИПЫ ПОСТРОЕНИЯ МОДЕЛИ ФОРМИРОВАНИЯ И ФУНКЦИОНИРОВАНИЯ НЕОДНОРОДНЫХ КОМАНД ДЛЯ УПРАВЛЕНИЯ ПРОЕКТАМИ

Предметом исследования являются основные принципы формирования модели управления созданием программного продукта и модели формирования и функционирования неоднородных команд для управления проектами. **Целью** исследования является построение математической модели, отражающей функционирование неоднородных команд для управления проектами. С этой целью для психодиагностических процедур в социально-психологическом анализе групповых отношений используется социометрия. Это – метод, направленный на выявление структуры межличностных отношений путем фиксации взаимных чувств симпатии и неприязни среди членов групп. Последующие математические методы обработки данных, полученной информации при социометрическом опросе, заключаются в подсчете математических показателей, которые можно разделить на индексы групповые и индивидуальные. В процессе исследования **решены следующие задачи:** проведен анализ требований к формированию команд и моделей для реализации программного продукта; выбран метод анализа совместимости членов команды; рассмотрены варианты построения математической модели, отражающей принципы формирования команды, работающей над проектом. Сравнение различных по составу групп путем математической обработки статистических данных и проведение корреляционных процедур. Определены индивидуальные индексы: индекс социометрического статуса, который является показателем преимущества какого-либо члена группы со стороны других ее участников; индексы – положительной и негативной эмоциональной экспансивности; индекс групповой сплоченности; индекс социометрической когерентности. В работе использованы **методы:** статистический и корреляционный анализ, социологический, венгерский, математический. В **результате** проведенных исследований показаны основные принципы формирования модели управления созданием программного продукта, предложены математические методы формирования и функционирования неоднородных команд для управления проектами. Таким образом, выполнены поставленные задачи и цель исследовательской работы.

Ключевые слова: программное обеспечение, модель управления, социометрия, индивидуальные индексы, венгерский метод.

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