Management of the IT project as a complex system *

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Abstract

The article analyzes IT project management as a complex system with an emphasis on the implementation of the task of increasing the efficiency of management of organizational processes in IT projects, taking into account the specific features of IT projects. The priorities and sequence of solving IT project tasks, difficulties in planning and standardizing the work of IT specialists, which have an impact on the quality and terms of project implementation, are determined. The technology for solving the task of IT project management based on evolutionary modeling is presented, which provides complex information processing and support for the adoption of management decisions. It has been proven that the use of an iterative approach to the development of the life cycle of projects with the dynamic formation of requirements and ensuring their implementation with the Agile methodology is the most promising and affects the performance indicators. Formulated principles of this methodology aimed at improving the quality of software products, a method of multi-level quality control by solving project problems is proposed.

1. Introduction

Project management in the field of IT is aimed at meeting the informational needs of business and creating new competitive advantages for it in the market. Project management is the process of organizing, planning, motivating the team and monitoring the progress of project implementation. One of the ways to improve the efficiency of management of organizational systems of educational institutions and enterprises is the implementation of IT projects. Successful implementation of IT projects depends on effective organization of software development processes.

According to modern software development methodologies, people and relationships are of decisive importance in IT projects. Therefore, the IT project can be considered as a complex system, and the task of increasing the efficiency of IT project management can be considered as the task of managing a complex system.

2. State of the problem research

A specific feature of IT project management nowadays is the frequent change in the conditions of the project's external environment. The change in the composition and structure of IT project tasks due to the change in the customer's requirements leads to the need for prompt decision-making regarding the change in the structure of the executive team and redistribution of their roles [1]. Focusing on managing IT projects as complex systems allows taking into account their internal complexity, interrelationships and the influence of external factors on the project's success [2-3]. Considering these aspects allows you to avoid problems related to changes in the development process, unexpected costs or unsuccessful risk management[4-5]. Thus, the study of IT project management as a complex system is important for developing effective strategies and methods to ensure the success and stability of IT projects in today's rapidly changing information environment [6-7]. Existing approaches consider only certain aspects of the task of increasing the efficiency of IT project management: assessment of personal qualities of developers; forming a team of performers; estimation of the labor intensity of the project; distribution of project resources[8-9]. The analysis of the existing approaches showed the lack of comprehensive approaches to increase the efficiency of management of organizational processes of IT projects, which provide complex information processing and support for the adoption of management decisions at the following stages of the project: during the selection of project participants, formation of executive teams, planning and quality control of project works [10-11].

Using evolutionary modeling is suggested for studying organizational processes in IT projects. This mathematical apparatus allows for solving multidimensional search problems with a large amount of space for searching.

3. IT project implementation

The project life cycle is a sequence of project phases necessary to achieve the result. The life cycle of an IT project begins with the emergence of an idea to develop software and the decision to implement it and ends after the software is completely decommissioned. The set of IT project management tasks that corresponds to the general theory of management of socio-economic systems is presented in Figure 1. Monitoring and analysis of processes that need to be automated determine the system's initial state, the efficiency of which is expected to be increased during the implementation of the IT project. Comparing the current state of the system with the state which should be after automation allows the customer or product owner to determine the effectiveness of the existing system.

The forecast of the results of automation of system processes allows concluding the dynamics of the system's behavior during the implementation of the IT project and how the

system is coming to the presentation of the customer or the product owner during process automation. Goal setting during the automation of system processes (implementation of an IT project) implies the formulation of general goals of system development in the process of automation, the determination of performance criteria that reflect the compliance of the system state before and after the implementation of the IT project with the goals of system development. The distribution of IT project tasks among team members involves the formation of the composition and structure of the project team, taking into account previous experience in solving project tasks, knowledge, abilities, skills, personal and psychological qualities of project team members and the appointment of executors for each project task [12]. During the implementation of each stage of solving the problems of the IT project, the successful implementation of the following stages requires an analysis of the effectiveness of automation. The analysis results are necessary for making strategic and tactical decisions on system automation.
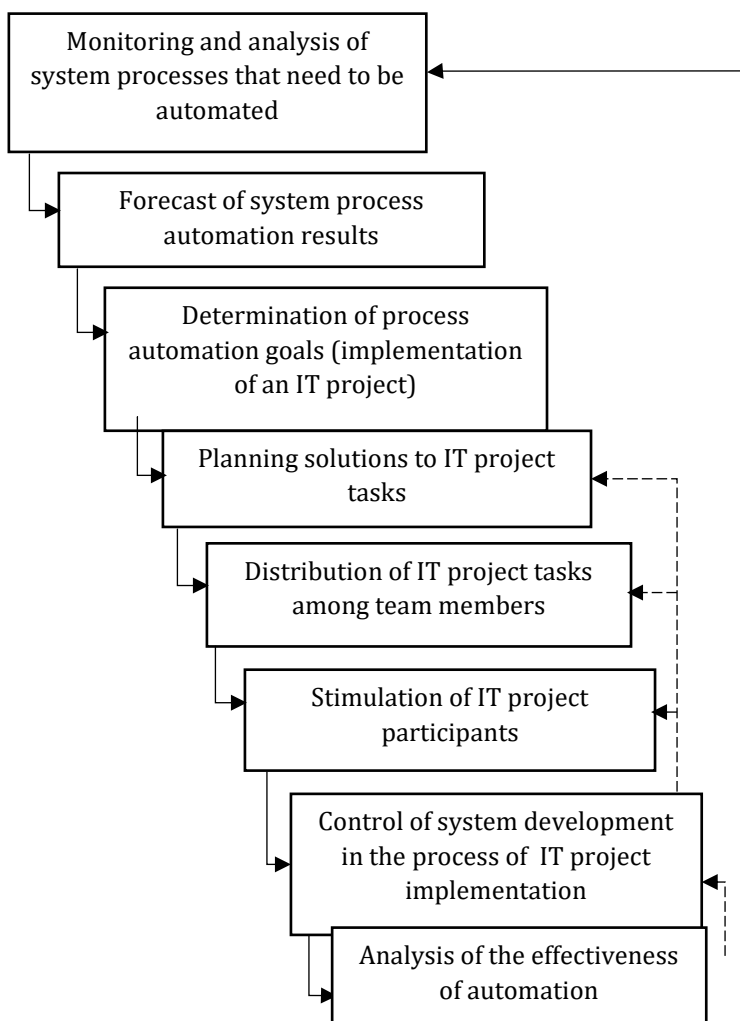
Figure 1: Complex of IT project management tasks.

IT project management includes a number of processes and consists of step-by-step (once a week, two weeks or a month - depending on the size of the sprint) planning of the

solution of project tasks, distribution of project team members to tasks, quality control of the solution of project tasks. According to the results of monitoring the quality of problem solving, knowledge about the work results of each member of the IT project team is accumulated. The object of management is the processes performed during the implementation of IT projects: selection of team members, formation of a list of tasks, assignment of participants to tasks, quality control of task solving [13,17].

Functional areas of IT project management include the composition and structure of teams, tasks, distribution of IT project participants on tasks [19]:

$$IT_{pr} = \langle Struct_{team}, Composition_{team}, Struct_{task}, Composition_{task}, \|Distr_{iJ}\| \rangle \quad (1)$$

where $Struct_{team}$ – the structure of the project team;
$Composition_{team}$ – the composition of the project team;
$Struct_{task}$ – the structure of the project tasks;
$Composition_{task}$, – the composition of the project tasks;
$Distr_{iJ}$ – the distribution of participants on project tasks.
The stages of the IT project management process include:

1. complex information processing of personal psychological qualities of project team members:

$$PP_{team} = \langle \{PPQ_{team}\}, \{Tech_{team}\} \rangle \quad (2)$$

where PPQ_{team} – set of parameters that characterize the personal psychological qualities of project participants;

2. complex processing of the results of each participant of the IT project:

$$LT = \frac{\sum_{i=1}^{NTasks} quality_i + \sum_{i=1}^{NTasks} speed_i}{NTasks} complexity \quad (3)$$

where $quality_i$ – the quality of the solution to the project's i-task;
$speed_i$ – the speed of solving the project task, which is calculated as the ratio of the planned deadline for solving the problem to the actual deadline for its solution;
$complexity$ – the difficulty of the task.
3. complex processing of information about the results of problem solving:

$$LT = \frac{\sum_{i=1}^{NTasks} quality_i + \sum_{i=1}^{NTasks} speed_i}{NTasks} complexity \quad (4)$$

$$quality_i = \frac{ConfirmedErrors}{FindErrors},$$

where $ConfirmedErrors$ – the number of confirmed errors;
$Find\ Errors$ – the number of errors found.

4. synthesis of the composition and structure of IT project teams:

$$Struct_{team} = \langle TotalNumber, \{TechNumber_i | TechNumber_i \in Tech_{it\ pr}\}\rangle, \quad (5)$$

where $TotalNumber$ – total number of project team members;
$TechNumber_i$ – the number of project team members who have i-technology
$Tech_{it\ pr}$ – set of technologies used to implement IT projects.

5. synthesis of the composition and structure of project tasks:

$$Task = \langle T_{task}, Type_{task}, Tech_{task}\rangle, \quad (6)$$

where T_{task} – the task completion time;
$Type_{task}$ – the type of task;
$Tech_{task}$ – the technology used.

6. complex support for decision-making on the distribution of IT project tasks among team members. IT project management includes a number of processes that iteratively repeat throughout the IT project life cycle[18]. At each iteration, information is processed to support decision-making regarding the composition and structure of tasks, the distribution of roles in the team, and project tasks among team members. Data on project team members are constantly updated as the quality of IT project problem solving is monitored.

4. Peculiarities of IT project management

The technology for solving the problem of IT project management can be presented in the form of a sequence of stages shown in Figure 2.
Key features characterizing IT project management processes:

- the iterative process of implementing the project life cycle, which involves conducting an analysis of work results at each iteration; the possibility of the appearance of new requirements of the customer of the product; adjustment of decisions obtained at previous stages of work;
- changing the requirements for the final software product during the entire cycle of its development. Depending on the change in the requirements of the software product by the customer, there is a change in the priorities, composition and structure of the project tasks, which makes it necessary to periodically change the distribution of tasks between the participants of the IT project;
- in the process of forming the composition of project teams, it is necessary to take into account not only the work experience and professional competences, but also the personal psychological qualities of the IT project participants;
- the hierarchical structure of IT project work (by processes, tasks, types of work, responsibilities of executors) determines the expediency of evaluating the decomposition of each project task into subtasks from the point of view of reducing the overall labor intensity and terms of implementation of the IT project;
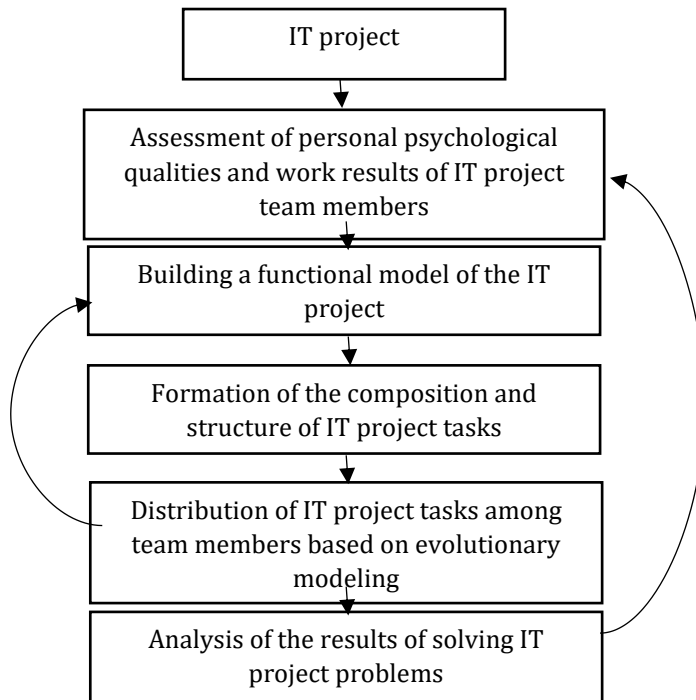
Figure 2: Technology for solving the problem of IT project management based on evolutionary modeling

- creating an effective system of motivation of IT project participants depending on the effectiveness of solving project tasks. The listed features of IT project management determine the need to automate the distribution of tasks among project team members in the process of forming the composition and structure of project teams and project tasks. [19]. Considering an IT project as a complex system, the main criteria for the effectiveness of managing such systems are the total time and effort involved in project implementation:

$$PM \rightarrow min, TDEV \rightarrow min \quad , \tag{7}$$

where PM – labor intensity of the project;
$TDEV$ – duration of the project;

5. Methodology for solving problems with improving the quality of IT project management

A complex system, such as an IT project, in the management process requires the implementation of the maximum number of priority tasks in the shortest possible time with minimum labor costs. Only this approach ensures an increase in the efficiency of IT project management.

The state of an IT project as a complex system depends on many factors that interact with each other [14-16]. Some of the key aspects that affect the health of an IT project include:

1. The purpose and scope of the project. A clearly defined goal and scope of the project determine its scope and effectiveness. Misunderstanding or lack of clarity about these aspects can lead to the termination of the project.

2. Project management. Effective project management, including planning, execution, monitoring, and control, is essential to achieving the objectives and ensuring the successful completion of the project.

3. Communications and cooperation. High-quality communication between project participants, including the project team, the client and stakeholders, helps to resolve conflicts, determine priorities and ensure mutual understanding.

4. Technical difficulties. The level of technical complexity, such as software flaws, technical integration, and interoperability issues, can affect the speed and quality of the software product being developed.

5. Risk management. Appropriate risk management, including the identification, assessment, control, and minimization of risks, helps to avoid negative consequences and ensures the stability of the project.

6. Stakeholder engagement. The support and involvement of stakeholders such as customers, users and other stakeholders is essential for the success of an IT project.

These factors, along with many others, jointly determine the state and effectiveness of an IT project as a complex system.

From the point of view of the project manager, the state of the managed system at the stage of forming requirements for the software product depends on several key aspects:

1. Understanding the needs of the client. This is the main point of departure when formulating requirements for a software product. The ability to clearly understand and document the client's needs and expectations is an important component of a successful project implementation process.

2. Determination of the purpose and scope of the project. It is important to define a clear goal and scope of the project at the stage of requirements formation to avoid misunderstandings and inconsistencies in the future.

3. Effective communication process. Mutual understanding between all interested parties is key to successfully formulating requirements for a software product. The project manager must ensure effective communication between the client, the project team and other stakeholders.

4. Change management. At the requirements generation stage, it is important to have change management mechanisms in place to take into account changes in customer needs or project conditions and adapt requirements accordingly.

5. Use of appropriate tools and methods. The use of modern tools and methods, such as requirements engineering, business process analysis, prototyping, etc., helps the project manager to effectively manage the formation of requirements and ensure the quality of the result.

In general, the state of the managed system at the stage of forming requirements for the software product depends on the ability of the project manager to effectively manage the

process of interaction with the client, manage changes and ensure mutual understanding between all parties of the IT project. From the side of the managed system of the IT project, the state depends on the actions of the project manager, who determines the structure of the project team at the stage of forming requirements for the software product; actions of project team members who, at the planning stage of the implementation process, perform the selection of tasks in the sprint, determination of the time to solve each task, selection of executors for each task, selection of the method of task implementation. The task of the governing body consists of: planning project work, organizing the development process, stimulating project team members, monitoring the quality of problem solving, taking into account the needs of users, the wishes of the customer and the capabilities and needs of the developer, the quality of the developed software, the degree of compliance of the results of the implementation of the software product with the expectations of the customer , ensuring the solution of the maximum number of customer tasks in the shortest possible time with minimum labor costs, depending on the state of the managed system. Agile is currently the most promising and widespread IT project management methodology focused on the use of an iterative approach to project development, dynamic formation and change of requirements, and ensuring their implementation. This methodology involves the use of the following basic principles during the implementation of IT projects:

Principle 1: People and interactions are more important than processes and tools.

The existing structure of the organization for which software product development is carried out, in some cases does not ensure the effective functioning and development of the organization, does not allow to increase the efficiency of processes due to the implementation of IT projects. According to the Agile methodology, the needs of interaction in the implementation of IT projects are primary, processes and tools should facilitate effective implementation and introduction, and not interfere with them. IT project teams must be able to change some processes but must also follow them. This principle of the methodology does not take into account the personal and psychological qualities of IT project participants.

Principle 2. Cooperation with the customer is more important than agreement on the terms of the contract.

The IT project should ensure an increase in the efficiency of the client's or customer's work. In the Agile methodology, the main focus is on cooperation with the client or customer. The terms of the contract should ensure effective interaction with the customer, and not interfere with this process. Accordingly, developers must be ready to change the terms of the contract when the needs of customers or the customer change.

Principle 3. Being ready for change is more important than following the original plan.

Flexible approaches to the implementation of IT projects were created to work in conditions of uncertainty and frequent changes in customer requirements. According to the Agile methodology, when the needs of customers or the customer change, the composition and structure of tasks in the IT project must change. It is proposed to use evolutionary modeling in the formation of project teams, the synthesis of the composition and structure of project tasks, and the distribution of project team members on tasks. This ensures an increase in the efficiency of IT project management due to operational changes in the

composition of teams and work plans when customer requirements change in accordance with the principles of the Agile methodology.

Principle 4: A working product is more important than comprehensive documentation.

According to the Agile methodology, the quality of the developed software product is of primary importance. In the process of implementing an IT project, only working documentation is created, which is necessary for the effective work of teams on the project.

A method of multi-level quality control by solving project tasks is proposed to improve the quality of software products created as part of IT projects based on the principles of the Agile methodology. Improving the quality of solving project problems ensures a working product in accordance with the fourth principle of the Agile methodology and improves cooperation with clients and customers in accordance with the second principle of the methodology.

Using flexible software product development methodologies allows the customer or product owner to change the requirements, list and priorities of tasks with a certain frequency (once a week, two weeks, a month) depending on the results of solving project tasks in previous periods and achieving automation goals.

Contradictory the need for constant changes to IT project requirements and the list of tasks, considering the basic principles of flexible software product development methodologies, necessitate the constant operational processing of information to support management [20].

Specialists of various profiles participate in the IT project management process: customer or product owner, business analyst, project manager or SCRUM master, project team, quality specialist, data analyst.

Each specialist makes a management decision within the framework of his tasks and is responsible for the effectiveness of management decisions within the framework of his functional duties.

Project management systems offer advantages in calculating the project's duration and tasks, constructing Gantt charts, distributing tasks between project participants, and controlling terms, risks, and finances.

Disadvantages of project management systems include the risk of complicating simple projects, the high cost of programs with low performance, and spending a lot of time on making plans instead of actual actions [21].

The information technology market offers many software products for project management. All of them have a basic set of functions, such as a description of the logical structure of the project with an indication of the hierarchy of works, calculation of the critical path, project control, resource planning, risk analysis, means of creating reports, and support for multi-projects. However, in reality, there are a small number of programs on the market, among which are Microsoft Project, Open Plan Professional, Spider Project, Primavera Project, Artemis Views.

Existing universal project management systems do not take into account such features of IT projects:

- the need to take into account the personal characteristics and psychological qualities of participants for the formation of development teams;

- hierarchical structure of tasks in the project, which necessitates multi-level work planning and quality control of task solving;
- the use of flexible software development management methodologies leads to changes in the requirements for the software product throughout the entire development cycle. A change in the requirements for a software product leads to the need for an operational change in the composition and structure of project tasks, which necessitates a change in the composition and structure of project teams and redistribution of tasks between project participants.

The analysis of existing approaches to IT project management made it possible to identify the following problems of improving the effectiveness of IT project management. When planning project works:

- the difficulty of determining the duration of project work is due to a large number of factors that affect the duration and complexity of solving each task and the IT project as a whole;
- the complexity of modifying the project work plan when the customer's requirements change is due to the need to process a large amount of information about the project tasks.

When organizing the development process:

- the complexity of synthesizing the rational composition and structure of project teams at each change in customer requirements is due to the need to take into account personal and psychological qualities and the effectiveness of previous work in the project;
- The complexity of the rational redistribution of tasks between the project team members when the customer's requirements change is due to the need to process a large amount of information about the IT project participants and tasks.

When controlling the quality of project works:

- the difficulty of controlling the quality of solving project problems is due to the lack of a formalized methodology that ensures the minimization of errors in solving IT project problems.

The effectiveness of IT project management depends on the effectiveness of the work of the project team, the formation of the composition and structure of tasks, the distribution of tasks among project participants, and quality control of task solving [22].

Existing approaches consider only certain aspects of improving the efficiency of IT project management: assessment of developers' personal qualities; formation of the project team; estimation of the project's labor intensity; and distribution of project resources.

The analysis of existing approaches showed the lack of complex system approaches to increase the efficiency of IT project management, which provide complex information processing and support for management decision-making at all stages of the project: during

the selection of project participants, the formation of project project teams, planning and quality control of project work.

In this regard, an urgent task is to create a concept, method, software, and technology for improving the efficiency of IT project management through the rational selection of project team members, the distribution of tasks between team members, and multi-level quality control of project task solutions.

6. Conclusions

Understanding an IT project as a system allows for a better examination of the relationships between its component parts and promotes more effective management. Managing IT projects is a challenging task due to the large number of interconnected elements, heterogeneity, and rapid technological changes. It is important to use a systemic approach to project management, considering it as a holistic system of interacting components. Managing IT projects requires a comprehensive approach, as projects impact various aspects of the organization and interact with different stakeholders.

Due to rapid changes in technology and client requirements, risks in IT projects can be unpredictable. Therefore, it is necessary to actively manage risks, develop mitigation strategies, and create plans to respond to negative events. Managing IT projects requires flexibility and the ability to adapt to changes to accommodate new requirements and technological trends. The project team plays a key role in ensuring success. Facilitating effective communication and collaboration among team members is an important aspect of project management.

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