Розглядається комплексний підхід до управління складними проектами створення розподілених інформаційних систем, який заснований на аналізі взаємозв'язку процесів управління проектом, створення продукту, управління зацікавленими сторонами і зовнішнім оточенням. Проаналізовані особливості виконання проектів створення розподілених інформаційних систем, які полягають у врахуванні дії значної кількості складних впливів з боку турбулентного зовнішнього оточення та реакцій проекту на ці впливи. Для рішення виникаючих при цьому проблем запропоновано використання проактивного підходу.

В роботі були ідентифіковані та формалізовані основні структурні елементи моделі складних проектів створення розподілених інформаційних систем. Побудована концептуальна модель, за допомогою якої досліджені впливи турбулентного оточення проекту на всі елементи моделі. Визначені ключові галузі знань такого впливу. Розроблена структурна модель компонентів створення розподілених інформаційних систем з використанням хмарних технологій і проектного підходу, яка враховує реакції на динамічні зміни та турбулентності зовнішнього оточення.

Побудовано математичну модель процесу створення складного IT продукту, з урахуванням впливу турбулентного зовнішнього оточення проекту, виділені основні характеристики та визначено параметри. Виконано моделювання основних цільових функцій математичної моделі процесу створення складного IT-продукту.

Запропонований алгоритм управління змінами на основі проактивного підходу в проектах створення розподілених інформаційних систем, який враховує моніторинг середовища реалізації проекту та ідентифікацію трьох типів можливих подій.

В результаті досліджень була підтверджена ефективність використання проактивного підходу в проектах створення розподілених інформаційних систем, що дозволить в подальшому використовувати запропоновані моделі для управління складними IT-проектами

Ключові слова: хмарні технології, розподілені інформаційні системи, IT-проекти, проактивне управління

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DEVELOPMENT OF THE MODEL OF THE PROACTIVE APPROACH IN CREATION OF DISTRIBUTED INFORMATION SYSTEMS

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1. Introduction

Cloud technology is relatively new and one of the most promising directions in the development of modern information technologies. The rapid development of cloud computing, such as distributed data processing technologies, opens horizons and perspectives for creating new cloud-based service opportunities [1]. Recent trends in this area show that this information technology concept is both useful and relevant. This concept is considered as an effective tool to meet the contemporary tasks and challenges that emerge from trends of rapid development, globalization, technology complication and the increased turbulence of the external environment.

Today, large corporate workloads actively transit to cloud solutions. According to estimates, in the next five years, 40 % to 50 % of corporate loads will be concentrated in cloud services. Now this indicator is 15 %. This indicates an increase in the demand for cloud services and a change in the information policy paradigm in enterprises [2].

Together with cloud technology, experts point important aspects of the development of the IT sector: analytics of large amounts of data, as well as the integration of mobile devices and social networking technologies into the corporate environment [3].

International research and consulting company IDC combines all these directions into the concept of “third platform” [4]:

– first platform: mainframes and terminals are the backbone of thousands of applications and programs, and it involves thousands of users;

– second platform: traditional personal computers, Internet and Web technologies, client-server software architecture – hundreds of thousands of applications. It covers millions of users;

– third platform: large volumes of information, mobile devices, cloud computing, social technologies. Covers billions of users.

The development of the third platform is expected to lead to significant changes in business models in various sectors of the information technology market in the near future [2].

2. Literature review and problem statement

The issue of cloud technologies application in the creation of modern IT was considered in [5–7]. For example, [5] describes the roles and characteristics of distributed computing processes that are used in the creation of modern distributed information systems (DIS). However, the description of project processes is completely absent here. [6] shows 48 project management processes. However, it is unspecified, which of them and whether it should be implemented in full when using modern IT. [7] describes the features of the methods and technologies used in creating distributed IT projects. But the description of the design approach is also missing here. Herewith, it is noted that the target use of such technologies is to consider the processes of IT functioning in organizations. A substantial degree of financial savings is achieved through integrating the functions of various IT systems, which gives the spatio-temporal balance of business processes.

On the other hand, the problems of using a project-oriented approach to managing complex projects are reflected in [8–12]. Thus, [8, 9] consider the issues of resource management in distributed projects working on methods of identification of parameters and characteristics of projects based on the cluster analysis. The authors of [10, 11] consider the effect of the characteristics of IT projects on the success of their performance, goals achievement and obtaining desired products of IT projects. However, the consideration of the environmental factors impact on the processes of IT projects implementation is practically not shown. It is obvious that such effects, in some cases, are rather important, thus leading to frequent failures in project activities. Possible solutions to these problems were analyzed in [12], where it was proposed to use a proactive approach. However, in this publication there is no mathematical justification for the proposed solutions.

Several works were dedicated to the issues of using a proactive approach in project management. Thus, [13] discusses proactive problem solving when creating IT products. However, little attention has been paid to the project approach. [14] proposes several models for proactive project management, but it does not specify how it can be used for IT projects and especially for the development of modern distributed IT.

A number of works of foreign scientists have been devoted to the issues of project-oriented management of projects in companies. Thus, [15, 16] develop a methodology for project management (specifically IT projects), which aims for mutually agreed management of the complete range of management processes. These processes are considered within the space of organizations themselves and development projects, in order to effectively implement the entire portfolio of projects. Such a control can serve as a basis for the development of models of proactive management of complex IT projects. [17, 18] discuss the use of intelligent methods and tools for managing complex projects. Since this problem belongs to the class of weakly formalized problems, the use of such methods for proactive management would be appropriate.

Analysis of information sources [5–18] allows concluding that there are really no integrated models and methods for managing complex projects of DIS development, which allow responding to the turbulent impacts of the external and internal environment of the project with the least expenses. This significantly reduces the opportunities for effective project management. In turn, the possibilities for proactive management in IT projects, which would allow taking into account the complex dynamic impact of the turbulent environment on the processes of product development and project management, are not sufficiently researched.

3. The aim and objectives of the study

The aim of this work is to substantiate and develop a structural model of project components for the creation of distributed information systems using cloud technologies and design approach that would take into account responses to dynamic changes and turbulence. This will provide an opportunity to improve the quality of such projects management and reduce the loss of time and cost overruns on the project.

To achieve the aim, the following objectives were defined:

– to identify the controls that constitute the elemental basis of the processes of development of distributed information systems;

– to build a conceptual model of the projects for the creation of complex IT products;

– to investigate the impact of changes in the interaction with the turbulent environment of the project during its implementation;

– to conduct a formal description of the elements and build a mathematical model of the process of complex IT products development and explore the model obtained with the help of special information technology project management.

4. Consideration of models of the interaction of the main components of IT project under external influences

The implementation of integrated solutions development for different types of cloud environments (private, public, hybrid) and other third-platform directions involve the implementation of high-complexity IT projects.

Increased complexity is determined by the complexity of hardware, software, methodologies and tools, technologies, and the specificity of distributed projects on information systems creation.

Considering the pace and directions of information technologies development, which is determined by the trends in science, technology, society and so on, it is necessary to consider change management issues from a proactive perspective. This approach is imposed by many changes that occur in both the external and internal environment of the IT project. This will allow us to focus on ways to minimize problems, errors, and incidents in the provided solutions performance and improve the quality of IT projects.

In the context of the objective, it is reasonable to identify the main influences on the backbone elements in the building of models of proactive approaches. To build these models, the basic concepts including the "distributed information system", "cloud technology" and "distributed project" should be defined.

The concept of "distributed information system" (DIS) is presented in [19], "cloud technologies" – in [5].

To define the concept of "distributed project" and "distributed project management", [8] introduces the concept of "distributed system". The understanding of the above terms is formed through the principles of the system approach. The "distributed system" means a system for which the relation of the element positions is significant in terms of functioning, analysis and synthesis. However, the concept of a geographically distributed computing environment is present (for example, the Internet, a banking network with subsidiaries in different countries or a corporate network). It represents a system with geographically distributed elements. The emphasis on the physical location of the elements of such a system is somewhat blurred by the focus on transparency of information systems.

Based on the above, we understand that a distributed IT project is a system/set of interrelated distributed (over time, territory, function, etc.) processes and distributed resources that function in a dynamic turbulent environment. For such projects, all the properties and patterns of regular projects remain relevant and existing management methodologies are applicable [6, 7].

Because cloud services are a combination of existing information technology solutions that are mutually integrated and have a spatially distributed infrastructure, they can be treated as DIS. Therefore, the activities related to the development of cloud-based DIS, regardless of the level of complexity and the range of the solved tasks, involve the implementation of projects and are determined by characteristics of the project approach. Thus, the integration of the problems and challenges of the technological aspects of the subject area and the project management is inevitable.

Fig. 1 shows the proposed platform for implementing distributed IT projects, which integrates existing technologies, synthesizes new solutions, thus allowing to achieve synergy when using a proactive impact on product components and project elements simultaneously.

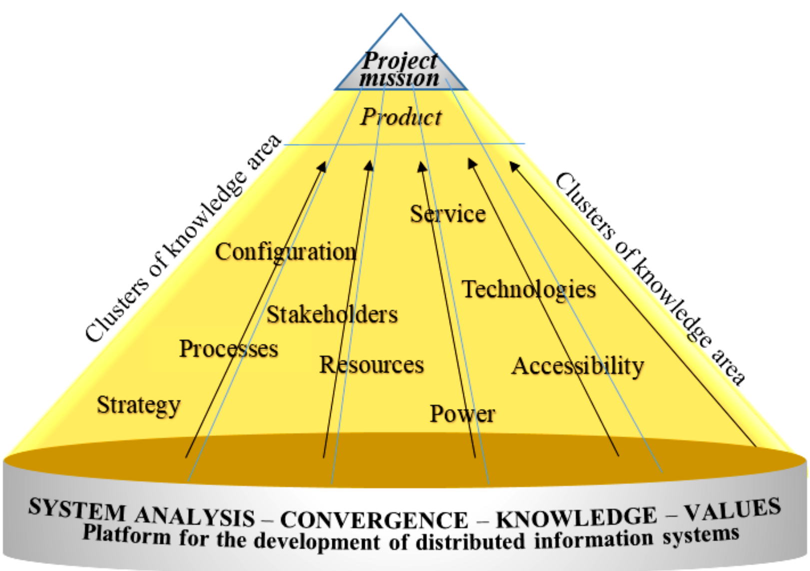

Fig. 1. "Cone" model for IT projects for distributed information systems development

Let us consider the components of the proposed model. The base of the cone is a platform that contains the basic components that define the principles of functioning of the management model for the IT project.

System analysis is used as a tool for investigation of the DIS as a complex adaptive system.

Convergence is now a trend in the IT sphere. It is implemented through the sharing of known and new technologies. Using convergence allows getting unexpected solutions, creating new prospects and so-called "blue oceans" in IT business, creating new niches in the marketplace. Any "cloud" service is a converged service. It combines the technologies of telecommunications (Internet access, network infrastructure, billing, etc.) and IT (implementation of functionality of the applications supporting the service technology of data centers, Internet protocols, etc. on the server).

Knowledge is subjective models of action that are constantly constructed (recalled and/or generated) by a human adequately to a certain situation of life as a result of cognitive activity.

Values are the properties of products/services/phenomena demonstrated through their relevance, usefulness, or importance. The values are characterized by temporal factors and subjectivity.

As Fig. 1 shows, the primary objective (mission) of such IT projects is to obtain the necessary product properties (DIS), which form the value of the product. The project mission can be achieved by identifying the directions and trajectory of the mission within the limited clusters of the knowledge areas of the project space realization.

The *strategy* means the directions and methods of the system management by running the project and the product creation system, taking into account the interaction with other available components of the "cone" model. Project strategy can be represented through the interests of its environment,

$$G=\left\{G^L,G^D\right\},$$

where G^L – the set of goals and tasks of the immediate environment of the project, G^D – the set of goals and objectives of the project's long-range environment. Thus,

$$G^L=\left\{g_1^L,g_2^L,\dots g_n^L\right\},$$

n is the number of the goals and objectives of the near environment;

$$G^D=\left\{g_1^D,g_2^D,\dots g_m^D\right\},$$

m – the number of goals and objectives of the long-range environment.

Processes in the "cone" model are the processes of product development and management processes of the IT project management. $P=\left\{P^P,P^S\right\}$, where P^P – the set of project management processes, P^S – the set of processes of product development. Herewith, $P^P=\left\{p_1^P,p_2^P,\dots,p_i^P\right\}$, i is the number of processes associated with the management of the IT project; $P^S=\left\{p_1^S,p_2^S,\dots,p_j^S\right\}$, j – the number of processes associated with the IT product development.

The set of *resources* in the "cone" model includes the material, software, labor and information resources existing and outsourced (purchased) within the project. All the resources materialize in the final product and form a new desired value in the form of IT project product (DIS).

$$R=\left\{R^M,R^H,R^P,R^I\right\},$$

where R^M is the set of material resources involved in the project, R^H is the set of human resources involved in the project, R^P – the set of software resources used in the project, R^I – the set of information resources involved in the project. Thus,

$$R^M=\left\{r_1^M,r_2^M,...,r_l^M\right\},$$

l is the number of types of material resources required for the project;

$$R^H=\left\{r_1^H,r_2^H,...,r_k^M\right\},$$

k – the number of human resources types involved in the project;

$$R^P=\left\{r_1^P,r_2^P,...,r_s^P\right\},$$

s is the number of types of the software resources involved in the project;

$$R^I=\left\{r_1^I,r_2^I,...,r_z^I\right\},$$

z is the number of types of information resources involved in the project.

Interested parties [6], which have a direct influence not only on the functionality of the future product of the project, but also on the success of the whole project, significantly impact the success of the IT project. Interested parties may include representatives of the client or customer, users of the IT product, designers, developers, management teams, etc.

$$O=\left\{O^L,O^D\right\},$$

where O^L is the set of the project participants (near environment of the project) O^D – a set of interested parties (long-range environment). Herewith,

$$O^L=\left\{o_1^L,o_2^L,...,o_f^L\right\},$$

f – the number of the project participants that comprise its near environment;

$$O^D=\left\{o_1^D,o_2^D,...,o_h^D\right\},$$

h is the number of interested parties that relate to the long-range environment of the project.

For IT projects, the development of complex IT products is characterized by the presence of a *service component*, which suggests the presence of service strategy, service design, transitions, operations and continuous improvement [21].

$$S=\left\{S\ \ ,S^B,S^{US}\right\},$$

where S^I is the set of services supporting the IT infrastructure, S^B – the set of services that provide support for business applications, S^{US} – the set of services that provide user support. Thus,

$$S^I=\left\{s_1^I,s_2^I,...,s_q^I\right\},$$

q is the number of services to support the IT infrastructure;

$$S^B=\left\{s_1^B,s_2^B,...,s_w^B\right\},$$

w is the number of services to support business applications;

$$S^{US}=\left\{s_1^{US},s_2^{US},...,s_v^{US}\right\},$$

v is the number of services to support users.

For the creation of an IT product, we use different *technologies:* development, management, testing, operation and maintenance of the IT project product.

$$Z=\left\{Z^C,Z^M,Z^I\right\},$$

where Z^C is the set of technologies for the development and testing of the project product, Z^M is the set of technologies of project management, Z^I – the set of technologies for the implementation and maintenance of the project product. Herewith,

$$Z^C=\left\{z_1^C,z_2^C,...,z_c^C\right\},$$

c is the number of technologies used to create the product of the project;

$$Z^M=\left\{z_1^M,z_2^M,...,z_u^M\right\},$$

u is the number of technologies used to manage the project;

$$Z^I=\left\{z_1^I,z_2^I,...,z_y^I\right\},$$

y – the number of technologies used for the implementation and maintenance of the project product.

Components of the IT product *configuration* [19, 22] are related to determining the elements, parameters and relationships with respect to the developed information system. The same applies to the elements of the project (Fig. 1) and the project environment.

$$K=\left\{K^P,K^S,K^E,K^{DP},K^{DS}\right\},$$

where K^P is the set of project parameters, K^S – the set of parameters of the project product, K^E – the set of parameters of the external environment of the project, K^{DP} – the set of requirements to the project, K^{DS} – the set of requirements to the project product. Thus,

$$K^P=\left\{k_1^P,k_2^P,...,k_r^P\right\},$$

r is the number of project parameters;

$$K^S=\left\{k_1^S,k_2^S,...,k_d^S\right\},$$

d is the number of parameters of the project product;

$$K^E=\left\{k_1^E,k_2^E,...,k_\gamma^E\right\},$$

γ is the number of parameters of the external environment of the project;

$$K^{DP}=\left\{k_1^{DP},k_2^{DP},...,k_o^{DP}\right\},$$

o is the number of requirements (conditions, opportunities and limitations), which must be met by the project;

$$K^{DS}=\left\{k_1^{DS},k_2^{DS},...,k_p^{DS}\right\},$$

p is the number of requirements (conditions, opportunities and limitations), which must be met by the project product.

The *power* means the set of

$$L=\left\{L^S,L^P,L^E\right\},$$

where L^S – the set of values of the capacities of the product components, L^P is the set of values of the capacity of the project elements, L^E – the set of values of the impact (degree of impact) of the external environment of the project. Herewith,

$$L^S=\left\{l_1^S,l_2^S,...,l_\mu^S\right\},$$

μ is the number of throughput capabilities of all the product components;

$$L^P=\left\{l_1^P,l_2^P,...,l_\varphi^P\right\},$$

φ is the number of throughput capabilities of all the project elements (product creation control processes and project management processes);

$$L^E=\left\{l_1^E,l_2^E,...,l_x^E\right\},$$

x is the number of values of the impact of the near and long-range environment of the project, as well as the parameters of the project environment.

Accessibility is determined by many estimates of the level of functions and requirements in the creation of the product (reliability, maintainability, serviceability, performance, security).

$$A=\left\{A^R,A^N,A^O,A^P,A^S\right\},$$

where A^R is the number of assessments related to security, A^N – the set of assessments of the level of maintainability, A^O – the set of assessments of maintainability, A^P – the set of performance assessments, A^S – the set of security assessments.

In this case,

$$A^R=\left\{a_1^R,a_2^R,...,a_\omega^R\right\},$$

ω is the number of security assessments;

$$A^N=\left\{a_1^N,a_2^N,...,a_\sigma^N\right\},$$

σ is the number of assessments of maintainability;

$$A^O=\left\{a_1^O,a_2^O,...,a_\varsigma^O\right\},$$

ς is the number of serviceability assessments;

$$A^P=\left\{a_1^P,a_2^P,...,a_\delta^P\right\},$$

δ is the number of performance assessments;

$$A^S=\left\{a_1^S,a_2^S,...,a_\vartheta^S\right\},$$

ϑ is the number of security assessments.

On this basis, the mathematical description of the proposed "cone" model can be represented as follows:

$$M_1=\left\{X,Y,H\right\}, \quad (1)$$

where $X=\left\{G, P, R, O, S, Z, K, L, A\right\}$ is the set of the input parameters of the model; $Y=\left\{C_p,T_p,\mathrm{Q}\right\}$ – the set of output parameters based on which we determine the effectiveness of the management processes of IT projects, where C_p is the planned cost of creating the elements of the project, T_p – the planned duration of the project life cycle (preset) [6], Q – the design quality determined by the quality of the final product and quality processes of the project; H – the set of relationships between model elements of IT projects management.

$$H=\left\{h_1,h_2,...,h_\varepsilon\right\},$$

ε is the number of direct links between all elements of the model and

$$\overline{H}=\left\{\overline{h}_1,\overline{h}_2,...,\overline{h}_\varepsilon\right\},$$

ε is the number of backward links between all elements of the model.

Thus, the set of input parameters of the project model can also be represented in the form of

$$X=\left\{x_{i_1}\mid i_1=1,2,...,N_1\right\},$$

where N_1 is the number of fields of knowledge models: M_1. Then the planned cost of the project will be:

$$C_p=\sum_{i_1=1}^{N_1}\sum_{j_1=1}^{T_p}\sum_{i_2=1}^{\varepsilon}(\mathrm{C}_1(x_{i_1},t_{j_1})+C_2(h_{i_2})), \quad (2)$$

with

$$\forall(x_{i_1}\in X)\cup(q_{i_2}\in Q)\exists t_{j_1}\in T_p,$$

$$T_p\geq 0 \text{ and } C_p\leq C_b,\ C_b\geq 0,$$

where C_1 is the cost function of elements development of the input parameters of $\left\{X\right\}$ at the time $t_{j_1}\in T_p$, C_2 – the cost function of channels of communication between the model elements of $\left\{X\right\}$, C_b – the budget cost of the project (investments).

Considering the project environment impact on its elements and success factors, we see that very often it is the impact (or ignoring this impact) that carries the main threat of the project failure. The impact of the project's environment often leads to dynamic changes. The selective accounting of these changes results in changes to the parameters and characteristics of virtually all elements within the "cone" model. In addition, the issues of proactive impact on the distributed information systems functioning remain relevant. This can be addressed by means of proactive approaches in projects on building such systems.

The current conditions in which complex IT projects have to be developed and implemented are characterized by downturns, intermittent funding, turnover of core personnel, changes in technologies, customers' preferences, market conditions, etc. All this requires frequent changes not only in the "cone" model "base", but also in the knowledge clusters. Therefore, the influence of environment turbulence must be introduced in the "cone" model. After the "cone+" model receiving, the influence of this environment should be studied through the subsequent changes influence on all elements and characteristics of complex IT projects. For the successful project completion, all these changes need to be managed. Otherwise, frequent changes result in chaotic abnormal inconsistencies in the system elements resulting in its failure. Fig. 2 shows the proposed change management model for IT projects.

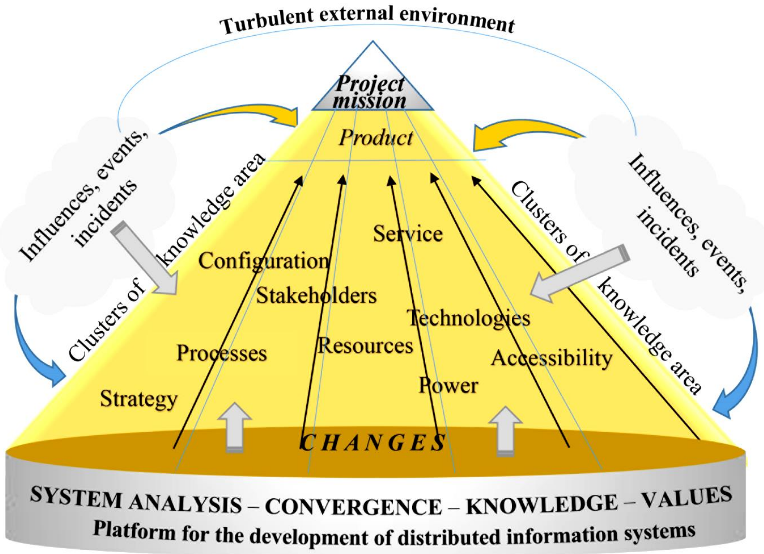

Fig. 2. "Cone+" model for investigation of the changes impact

A feature of the proposed model is a reviewing of the interaction of the product creation system and the necessary project (changes) management system under conditions of complex intersecting impacts of the turbulent environment. These impacts generate changes in individual model components resulting in changing the process of creating distributed information systems.

These changes can lead to problems and incidents at different stages of project implementation and product performance. A possible solution for avoiding problems or minimizing the impact of problems may be early detection of specific signals of these problems occurrence.

The presence of the impact of the turbulent environment of the project requires the introduction of the proposed "cone" model parameters of this impact and response to it as a governing influence, which ensure stabilization of the model when deviations occur.

Then the modified model of the project will be as follows:

$$M_2 = \{X, Y, \text{H}, I, U, V\}, \tag{3}$$

where $I = \{I^E, I^S\}$ is the set of impacts on the project, consisting of I^E – the set of impacts of environmental factors and I^O – the set of impacts of project interested parties. At the same time,

$$I^E = \{i_1^E, i_2^E, ..., i_e^E\},$$

e is the number of possible impacts from the external project environment (political, economic, social, legal, environmental, technological aspects);

$$I^O = \{i_1^O, i_2^O, ..., i_b^O\},$$

b is the number of possible impacts from the near and long-range environment of the project (secondary and primary interested parties). U is the set of states of the IT project,

$$U = \{u_1, u_2, ..., u_\beta\},$$

β is the number of possible states of the model resulting from the effects of the environment and project interested parties. V is the set of responses of the project to external impacts,

$$V = \{v_1, v_2, ..., v_a\},$$

a is the number of managing actions aimed at stabilizing the model in the case of deviations of its parameters from specified values.

The proposed modified model of the project (3) allows considering more than the input, output parameters and their relationship, which are of great practical importance in the development of DIS in real conditions the impact of the external environment of the projects. This takes into account possible impacts on the project, changes in the state of the project under the impact of such effects and the response of the project to any changes. In this case, an objective pattern of the real state of the project at a specific point of time can be obtained and, accordingly, administrative actions adequate to the current state of the project can be proposed.

Given the impact of the external environment and interested parties of the project, which lead to changes and deviations from the preset parameters of the project, we can determine the actual cost of the project upon its completion (C_f) and the actual completion time of the project (T_f):

$$T_f = T_p \pm (f_1(I) + f_2(U) + f_3(V)), \tag{4}$$

$$C_f = C_p \pm (C_3(I) + C_4(U) + C_5(V)), \tag{5}$$

where C_3, C_4, C_5 is the change because of the many impacts on the project, monitoring the set of states of the IT project and the set of performed control actions, respectively; f_1, f_2, f_3 – measurement functions of time intervals of the multiple impacts on the project, monitoring the set of states of IT projects and the set of performed control actions, respectively.

In this case, the target functions of the model of IT project management can be represented as follows:

$$C_f - C_p = \pm\Delta C \to \min, \tag{6}$$

$$T_f - T_p = \pm\Delta T \to \min, \tag{7}$$

where ΔC, ΔT – accordingly, the actual deviations in cost and time of project implementation, taking into account changes due to a variety of environmental impacts.

Fig. 3 shows a diagram of the algorithm representing the sequence of basic stages of change management in projects based on a proactive approach. To build models of proactive impact on the specified systems (Fig. 3), the term of "event" should be specially emphasized. As the process of proactive impact consists of trends analysis, forecasting and planning of preventive actions, it is important to identify weak signals (events) that could potentially become a source of future problems.

Considering the multi-objective optimization problem (3), it should be noted that it belongs to the class of semi-structured. Hence, it can be solved using methods of artificial intelligence using knowledge bases developed by the authors of adaptive systems, neural networks, etc.

The degree of importance for the selection of the criterion (6) or (7) is determined based on the project customer's preferences. However, the criterion (6) is more integrated and its assessment in different periods of time can be obtained by a known method of mastered volumes in terms of value, widely used in standard information systems of project management, e.g. Microsoft Project.

5. Results of research of the proposed "cone" model in IT projects

The results of the reviewed studies were the basis for the projects on the development of new IT based on cloud technologies. Fig. 4 shows the used DIS example. Thus, along with the formation of the office for project management, portfolio and program management, the distributed e-learning system was developed and used. Its more detailed description is given in [12, 19].

Along with this, data regarding the estimated (planned) cost of the IT project were obtained. They are shown in Fig. 5 in the form of bar charts. The initial data for the cost calculation are determined on the basis of the cost and quantity of necessary resources for this project. Thus, using IT for the project management (here, a licensed software product Microsoft Project was used), we managed to build a cumulative curve of the base cost of the project.

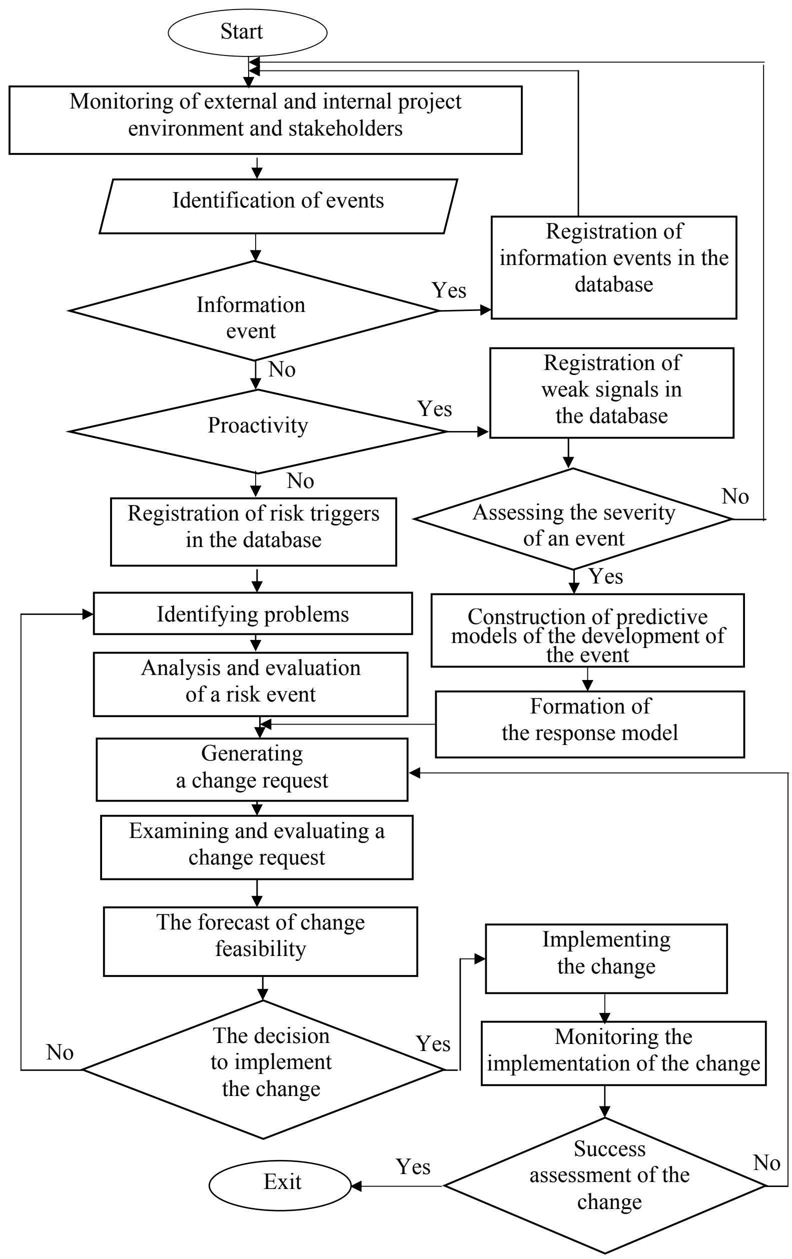

Fig. 3. Change management algorithm based on the proactive approach in distributed information systems projects

In fact, the collected data showed a relatively significant deviation in cost as a result of the impact of factors of the external environment, especially in the design phase of a project product.

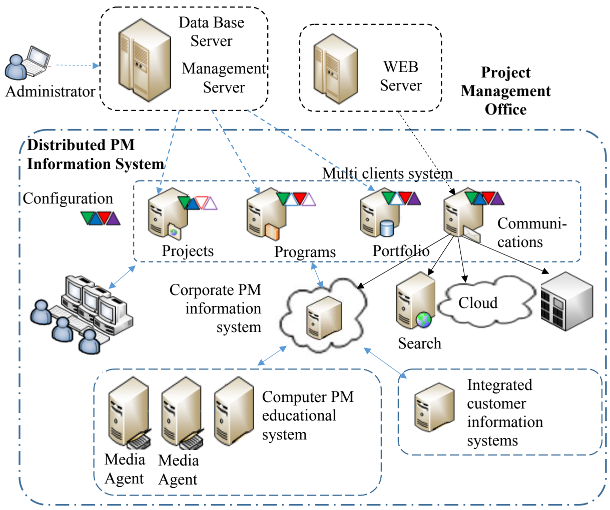

Fig. 4. An example of the developed DIS scheme

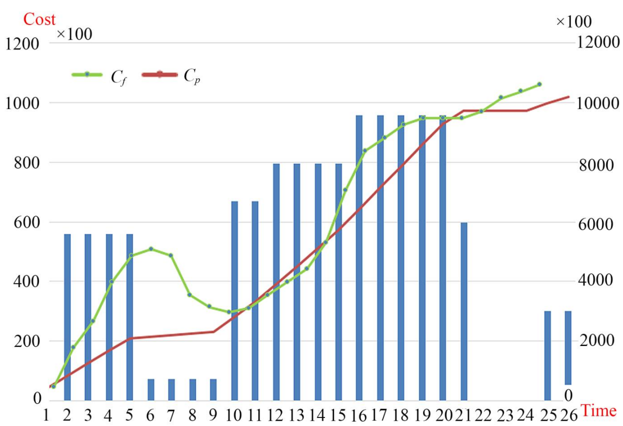

Fig. 5. Project cost diagram without a proactive approach

Using the tools of proactive management, it was possible to significantly reduce the deviation in cost, as shown in Fig. 6. We used the following methods of proactive management: search and identification of weak signals that can impact the implementation of the project, forecasting the development of the situation in the case of amplification of weak signals and making decisions on the use of pre-emptive impact, with the aim of avoiding unwanted changes.

Analysis of the obtained results showed the efficiency of the developed models of response to the impact of changes in the turbulent environment of projects of development of distributed information systems. Thus, we managed to reduce the additional costs of project management associated with changes in project parameters and additional predictive modeling of possible future states of the project. Turbulent environment leads to deviations in the parameters of the project. Using the proposed models reduces the time deviation (loss) and, as a result, provides a reduction of losses (cost overruns) of the project cost when it is executed.

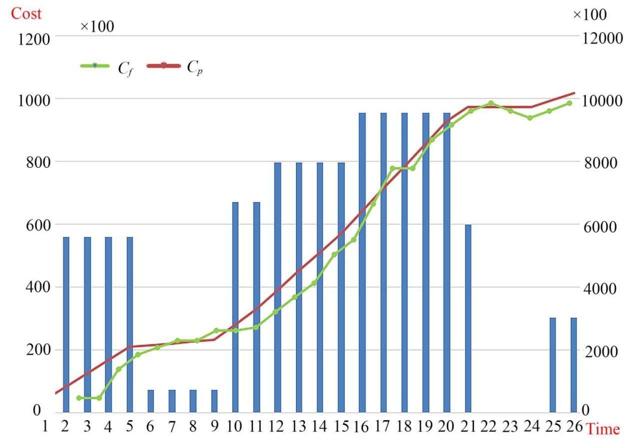

Fig. 6. Project costing scheme using a proactive approach

This approach on the basis of proactive management will allow forming sets of management processes, detailing their interactions and forming a hybrid methodology for managing the development of these systems based on the analysis of methodologies of IT project management.

6. Discussion of the results of studies of IT project management based on a proactive approach

The ambiguity and complexity of decision-making in IT projects are caused by the effects of the turbulent external environment, a significant number of processes and parameters, and multiple intersecting complex impacts within the project. The peculiarity of the study lies in the consideration of the set of project management processes, processes of product development and management processes by interested parties and the external environment of the project. The research of the proposed models for managing complex IT projects has confirmed the effectiveness of using the proactive approach. This will enable further using of the proposed model for complex IT project management in project-oriented organizations.

The conducted studies have shown that special attention should be paid to the concept of "event" for modeling the proactive impact on the structural elements of models of complex projects of creation of distributed information systems. As the process of proactive impact consists of trends analysis, forecasting and planning of preventive actions, it is important to identify weak signals (events) that could potentially become a source of future problems. According to the ITIL version: the *event* is a detectable phenomenon that is relevant to the management of IT infrastructure or to the provision of IT services. Events are typically presented in the form of alerts generated by IT services, configuration items, or monitoring tools. In the context of project management, the "event" is any phenomenon that can be considered as information about a potential problem. In other words, it is the identification of information signals in the phase of latent development of project problems.

All events are divided into the following types:

– informational events (normal operations) are events that do not require any actions, such as completing a routine procedure or obtaining a planned intermediate result;

– deviations are events that can be considered as triggers to incidents, problems, and changes. In other words, they are risk event triggers;

– warnings (unusual events that are not deviations) are events that raise a red flag, some sequence (combination) of which can lead to deviations. For proactive management, this is the type of events that refers to the "weak signals" concept. These events can be used in forecasting and trend analysis.

The description of the process of complex project management of distributed information systems on the basis of a proactive approach takes into account the above classification of signals obtained from the turbulent environment of the project. This approach will gradually move from reactive to active management. In this case, change management can be transformed from the incident response mechanism into a space (environment) forming tool with the following characteristics:

– relevance – variability according to recent trends (market, technology);

– flexibility – quite easily adapts to the influence of changes;

– adequacy – corresponds to the current situation/condition of the environment;

– self-regulation (adaptivity) has the characteristics of self-development, and strives for self-organization and evolution.

The results obtained indicate the need for further in-depth study of the issues of proactive response to the impact of the environment of the project. As directions for further researches, it should be noted that there is a need to determine the types of processes involved in creating complex IT products, project management processes considering the ongoing change dynamics in the interaction with a turbulent environment and their mutual impact.

It should be noted that the limitations of this research is an area of research itself related to the focus on the consideration of IT projects alone, and only when developing distributed information systems. In addition, as can be seen from (2), the planned cost of the project (C_p) and the resulting implementation of the IT project (C_f) should not exceed the budget allocated for the project implementation (C_b). As for time limits, in practice, the possible overruns in project implementation are in the range of 10–15% of the specified directorial deadlines. Such limitations are prescribed in the project charter, and all such deviations must be within these limits.

7. Conclusions

1. The proposed model of project analysis for the establishment of DIS is based on an integrated approach to the consideration of management processes in such projects. A distinctive feature of this approach is the holistic view and analysis of the impact of the environment on the set of all elements with the intersecting relationships. Thus, we consider the project management processes, the processes of product development, interaction with the interested parties and the processes occurring in the external environment of the project. In addition, it was possible to identify control elements for the formalization of the processes of distributed information systems development.

2. The identified elements and relationships between them formed the basis for the proposed conceptual model, "cone" model for projects of complex IT products development. A qualitative characteristic of this model is the DIS development platform with synergy functions based on knowledge, values, system analysis and convergence. Clusters of knowledge areas form the shell of this model and determine the conditions, assumptions and limitations for the projects with project management methodology and specificity of the generated product.

3. At the same time, the consideration of the influence of the turbulent environment on the project model indicates the presence of various kinds of influences that lead to changes in the parameters of the model elements. As a result, the DIS development platform generates a response to external impacts and balances their parameters through links between the system elements. However, the projects analysis shows that such responses in most cases are delayed, which reduces the efficiency of the project. Therefore, it was proposed that proactive approach mechanisms would be included in the model to minimize potential deviations.

4. As a result, the "cone" model was transformed into the "cone+" model. The mathematical description of the "cone+" model allowed formalizing the processes in the implementation of projects based on a proactive approach and defining the target functions to further investigate the model behavior under the impact of the turbulent environment. The cost and time of the project implementation were taken as a basis, as the main parameters, which determine the effectiveness of the project.

5. On the basis of IT for the project management, curves were plotted for the planned parameters of the target functions. Thus, the actual figures pointed to significant deviations in the range of 10–50 % from the specified values under the impact of factors of external environment. Using proactive management tools, with repeated modeling, it became possible to significantly reduce deviations in costs, which do not exceed 10 % of the deviation from the planned values.

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