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Managing of Change Streams in Projects of Development Distributed Information Systems

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***Abstract*—The IT project models in the development of distributed information systems using cloud technologies are proposed for consideration. Concepts definitions, their relationship in the effects of turbulent dynamic changes are given. A process model has been proposed for a proactive approach for managing changes in IT projects.**

Index Terms — cloud technologies, distributed information systems, IT projects, proactive management

I. INTRODUCTION

Cloud technology is relatively new and one of the most promising directions in 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. It is considered as an effective tool to meet the contemporary tasks and challenges that emerge from trends of rapid development, globalization, the complicating of technology and the enhanced 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, while now it is 15%. This indicates an increase in the demand for cloud services and a change in the information policy paradigm in enterprises [2].

Along with cloud technologies, experts also mention other important aspects of the improvement and development of information technologies, for example, in the development of technologies in the field of analytics of large volumes of data and the integration of mobile devices and technologies of social networks 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 the various sectors of the information technology market in the near future [2].

II. ANALYSIS OF RESEARCH AND PUBLICATIONS

The issue of cloud technologies application in the creation of modern IT was considered in the works of M.S. Kosyakov [5], A. Alpatov [6] and other domestic scientists. Their generalized purpose-oriented application is to consider the processes of functioning of IT in organizations, that allow to significantly save finances by integrating the functions of various IT systems while achieving a spatially-temporal balancing of business processes in order to obtain a positive synergistic effect.

The problems of the project-oriented approach based on IT projects are reflected in the works of many domestic scientists. A lot of works by Ukrainian scientists are devoted to the problems of using the project approach to IT creation: S. Bushuev [7], A. Biloschickij [8], Yu. Teslia [9], I. Chumachenko [10], V. Morozov [11] et al. The issues of proactive project management are considered in: [12], N. Bushueva [13], et al. In their works, the methodology of project management (in particular IT projects) is evolving. Its aimed at mutually coordinated management of the full range of management processes in the space of the organizations themselves and their development projects with the goal of effectively implementing the entire portfolio of projects.

However, the possibility of proactive management in IT projects have not been sufficiently researched. Especially in the aspects that would allow to take into account the complex dynamic influences of the turbulent environment on the processes of product creation and project management.

The **purpose** of the article is to substantiate and develop a structural model of 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. It is also building a process model for management these changes in the development of modern IT.

The main tasks of this research include the following:

1. Identification of the control elements that make up the elements' basis of the processes of creating distributed information systems.

2. Design of conceptual model of projects of creating complex IT products.

3. Investigate the impact of changes at interaction with the turbulent environment of the project during its implementation.

4. Conduct a formal description of the elements and build a mathematical model of the process of creating complex IT products.

5. To research the obtained models with the help of special information technologies for project management.

III. MODELS OF PROJECT INTERACTION

The implementation of integrated solutions for the 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 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 the IT projects.

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

A *Distributed Information System* (DIS) is a set of interconnected autonomous computers or processors and a set of independent processes (system executable program components) interacting through the transmission of messages for data exchange and coordination of actions [19].

Cloud Technologies – the concept of providing upon request (application) the network access to distributed computer resources (computing networks, servers, data warehousing, software, network services, etc.), allocated regardless of the time of day, and the channel of access to the computer network [5].

To define the concept of "*distributed project*" and "*distributed project management*", [8] introduces the concept of a "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 its 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 information systems, regardless of the level of complexity and the range of the solved tasks for such system, 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.

Figure 1 shows the proposed platform for implementing distributed IT projects, which integrates existing technologies that synthesizes new solutions, allowing to achieve synergy when using proactive influence at the same time on product components and project elements.

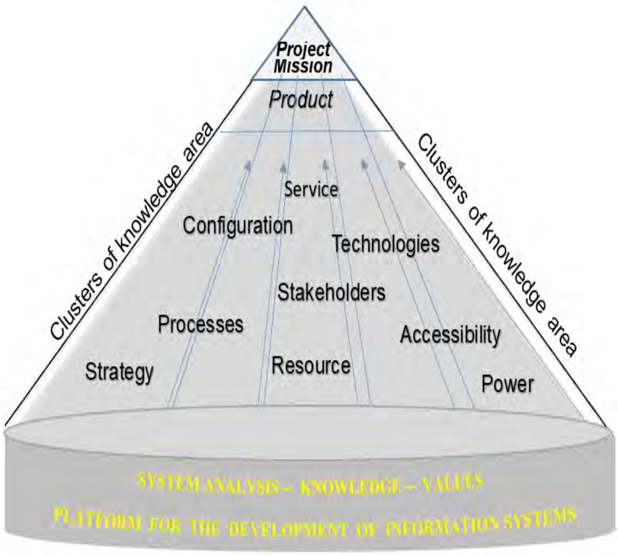

Fig. 1. "Cone" model for distributed information systems IT projects

Let us consider the components of the proposed model.

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 to get unexpected solutions, create new prospects and so-called "blue oceans" in IT business, creating new niches in the marketplace. Any "cloud" service is a convergent service that integrates telecommunication technologies (Internet access, network infrastructure, billing, etc.) and IT (implementation on the server of application functional, supporting service technologies of data centers, Internet protocols, etc.).

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 Figure 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.

The product creation and IT project management processes are presented as the *processes* in the "cone" model.

A lot of *resources* in the "cone" model include existing and attracted (purchased) within the project framework material, software, labour, and information resources, which materialize in the final product and form the new desired value in the form of the IT project product (DIS).

Stakeholders [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 influence on the success of the IT project. This can include representatives of the client or customer, IT product users, vendors, developers, management commands, etc.

For IT projects, creating complex IT products is characterized by a service component that requires a strategy service, development services, transitions, operations, and continuous improvements [14].

We've already talked about using *technologies* to create an IT product. Additionally, this group also includes technologies for development, management, testing, operating, and maintaining the IT project product.

Components of IT product *configuration* [14, 15] are related to determining of the elements, their parameters and relationship to the developed information system. The same is relevant to project elements (Fig. 1) and the project environment.

Reviewing the project environment influence on its elements and success factors shows that it is the influence (or ignoring this influence) very often is the main threat of the project failure. The influence 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. At this, issues of proactive influence on the distributed information systems functioning remain relevant. This can be addressed by means of proactive approaches in projects on building such systems.

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

A lot of resources in the "cone" model include existing and attracted (purchased) within the project framework material, software, labour, and information resources, which materialize in the final product and form the new desired value in the form of the 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, $R^M=\left\{r_1^M, r_2^M, ..., r_l^M\right\}$, here l – is the number of kinds of material resources required in the project; R^H – is the set of human resources involved in the project, $R^H=\left\{r_1^H, r_2^H, ..., r_k^H\right\}$, here k – is the number of kinds of human resources involved in the project; R^P – is the set of program resources used in the project, $R^P=\left\{r_1^P, r_2^P, ..., r_S^P\right\}$, here s – is the number of kinds of program resources involved in the project; R^I – is the set of information resources in the project, $R^I=\left\{r_1^I, r_2^I, ..., r_z^I\right\}$, here z – is the number of kinds of information resources involved in the project.

Stakeholders [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 influence on the success of the IT project. This can include representatives of the client or customer, IT product users, vendors, developers, management commands, etc. $O^L=\left\{O^L, O^D\right\}$, where O^L – is the set of project participants (close environment of the project), $O^L=\left\{o_1^L, o_2^L, ..., o_f^L\right\}$, here f – is the number of participants who are part of its close environment; O^D – is the set of stakeholders (long-range environment of the project), $O^D=\left\{o_1^D, o_2^D, ..., o_h^D\right\}$, here h – is the number of stakeholders that relate to the long-range environment of the project.

For IT projects, creating complex IT products is characterized by a service component that requires a strategy service, development services, transitions, operations, and continuous improvements [21]. $S=\left\{S^I, S^B, S^{US}\right\}$, where

S^I – is the set of services supporting the IT infrastructure, $S^I=\{s_1^I,s_2^I,...,s_q^I\}$, here q – the number of services to support the IT infrastructure; S^B – is the set of services supporting the business application, $S^B=\{s_1^B,s_2^B,...,s_w^B\}$, here w – is the number of services to support business applications; S^{US} – is the set of services that provide user support, $S^{US}=\{s_1^{US},s_2^{US},...,s_v^{US}\}$, here v – is the number of services to support users.

We've already talked about using technologies to create an IT product. Additionally, this group also includes technologies for development, management, testing, operating, and maintaining the IT project product. $Z=\{Z\ \ ,Z^M,Z^I\}$, where Z^C – is the set of technologies for developing and testing a project product, $Z^C=\{z_1^C,z_2^C,...,z_c^C\}$, here c – is the number of technologies used to create the project product; Z^M – is the set of project management technologies, $Z^M=\{z_1^M,z_2^M,...,z_u^M\}$, here u – is the number of technologies used to manage the project; Z^I – a set of technologies for implementing and maintaining a project product. $Z^I=\{z_1^I,z_2^I,...,z_y^I\}$, here y – is the number of technologies used to implement and maintain the project product.

Components of IT product configuration [19, 22] are related to determining of the elements, their parameters and relationship to the developed information system. The same is relevant to project elements (Fig. 1) and the project environment. $K=\{K^P,K^S,K^E,K^{DP},K^S\}$, where K^P – is the set of project parameters, $K^P=\{k_1^P,k_2^P,...,k_r^P\}$, here r – is the number of project parameters; K^S – is the set of project product parameters, $K^S=\{k_1^S,k_2^S,...,k_d^S\}$, here d – is the number of project product parameters; K^E – is the set of parameters of the external environment of the project, $K^E=\{k_1^E,k_2^E,...,k_\gamma^E\}$, here γ – is the number of parameters of the external environment of the project; K^{DP} – is the set of requirements for the project, $K^{DP}=\{k_1^{DP},k_2^{DP},...,k_o^{DP}\}$, here o – is the number of requirements (conditions, opportunities and constraints) that the project must meet; K^{DS} – is the set of requirements to the project product, $K^{DS}=\{k_1^{DS},k_2^{DS},...,k_p^{DS}\}$, here p – is the number of requirements (conditions, opportunities and constraints) that the project product must meet.

By power we mean the set $L=\{L^S,L^P,L^E\}$, where $L^S=\{l_1^S,l_{2,...,}^S l_\mu^S\}$ – set of values of throughputs of product components, μ – the number of throughput capabilities of all components of the product; $L^P=\{l_1^P,l_{2,...,}^P l_\varphi^P\}$ – is the set of values of throughputs of project elements, φ – is the number of throughput capabilities of all project elements (product creation management processes and project management processes); $L^E=\{l_1^E,l_{2,...,}^E l_x^E\}$ – is the set of influence values (influence degrees) of the project's external environment, x – is the number of values of the influence of the project's close and long-range environment, as well as the parameters of the project's external environment.

Accessibility (when creating a product) is determined by a set of evaluations of the level of performance of functions and requirements (reliability, supportability, serviceability, performance, security) $A=\{A^R,A^N,A^O,A^P,A^S\}$, where $A^R=\{a_1^R,a_2^R,...,a_\omega^R\}$ – is the set of estimates related to reliability, ω – is the number of reliability estimates; $A^N=\{a_1^N,a_2^N,...,a_\sigma^N\}$ – is the set of support level estimates, σ – is the number of supportability estimates; $A^O=\{a_1^O,a_2^O,...,a_\partial^O\}$ – is the set of estimates of serviceability, ∂ – is the number of serviceability estimates; $A^P=\{a_1^P,a_2^P,...,a_\delta^P\}$ – is the set of performance estimates, δ – is the number of performance estimates; $A^S=\{a_1^S,a_2^S,...,a_\vartheta^S\}$ – is the set of security estimates, ϑ – is the number of security estimates.

Based on this, the mathematical description of the proposed "Cone" model can be represented as follows: $M=\{X,Y,H\}$, where $X=\{G,P,R,O,S,Z,K,L,A\}$ – is the set of input parameters of the model; $Y=\{C_p,\mathrm{T}_p,Q\}$ – is the set of output parameters, on its basis we will determine the efficiency of IT project management processes, where C_p – is the planned cost of creating project elements, T_p – is the planned duration of the project life cycle (given) [6], O – is the quality of the project, determined by the quality of the final product and the quality of the project implementation processes; H – is the set of relation-channels between the elements of the IT project management model communication channels. $H=\{h_1,h_2,...,h_\varepsilon\}$, ε – is the number of direct links between all model elements and $\overline{H}=\{\overline{h}_1,\overline{h}_2,...,\overline{h}_\varepsilon\},\varepsilon-$ is the number of feedbacks between all elements of the model.

In this case, the set of output parameters of the project model can also be presented in the form $X=\{x_{i_1}\,|\,i_1=1,2,...N_1\}$, were N_1 – is the number of knowledge areas of model M_1. Then the planned cost of the project will look like:

$$C_p = \sum_{i_1=1}^{N_1}\sum_{j_1=1}^{T_p}\sum_{i_2=1}^{\varepsilon}(C_1(x_{i_1}, t_{j_1}) + C_2(h_{i_2})), \quad (1)$$

on condition $\forall(x_{i_1} \in X)\bigcup(q_{i_1} \in Q)\exists t_{j_1} \in T_p$, $T_p \geq 0$ and $C_p \leq C_b$, $C_b \geq 0$, where C_b – is the budget cost of the project (investments), C_1 – is the cost function of creating input parameter elements from $\{X\}$ at time $t_{j_1} \in T_p$, C_2 – is the cost function of communication channels between the elements of the model from $\{X\}$.

Reviewing the project environment influence on its elements and success factors shows that it is the influence (or ignoring this influence) very often is the main threat of the project failure. The influence 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. At this, issues of proactive influence 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, changes in customers' preferences, changing in market conditions, consumers, users, 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. At 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 influence

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 influences of the turbulent environment. The data of influence generates 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 their influence may be early detection of specific signals of their occurrence.

The presence of the project's turbulent environment influence suggests: adding parameters of this influence into the proposed "cone" model and the reaction to it as control actions that ensure the stabilization of the model with the arising deviations.

Then the modified model of the project will have the following form: $M_2 = \{X, Y, Q, I, U, V\}$, where $I = \{I^E, I^O\}$ – is the set of influences on the project, I^E – is the set of environmental factors' influences, $I^E = \{i_1^E, i_2^E, ..., i_e^E\}$, e – is the number of possible influences from the external environment of the project (political, economic, social, legal, environmental, technological aspects); I^O – is the set of influences of the project stakeholders, $I^O = \{i_1^O, i_2^O, ..., i_b^O\}$, b – the number of possible influences from the long-range and close environment of the project (secondary and primary stakeholders); 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 due to the environmental impact and stakeholders of the project; V – is the set of reactions of the project to external influences, $V = \{v_1, v_2, ..., v_a\}$, a – is the number of control actions, oriented on model's stabilization in the case of deviations of its parameters from given values.

Taking into account the influence of the external environment and stakeholders of the project, which lead to changes and deviations from the specified project parameters, it's possible to determine the actual cost of the project upon completion (C_f) and the actual completion time of the project (T_f):

$$T_f = T_p \pm (f_1(I) + f_2(U) + f_3(V)), \quad (2)$$

$$C_f = C_p \pm (C_2(I) + C_4(U) + C_5(V)) \quad (3)$$

where C_3, C_4, C_5 – are the actual costs of making changes due to the set of influences on the project, the monitoring of the set of IT project's states and the set of executable control actions, respectively; f_1, f_2, f_3 – functions for measuring the time intervals of the action of the set of influences on the project, the monitoring of the set of IT project's states and the set of executable control actions, respectively.

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

$$C_f - C_p = \pm\Delta C \rightarrow \min, \quad (4)$$

$$T_f - T_p = \pm\Delta T \rightarrow \min, \quad (5)$$

where $\Delta C, \Delta T$ – actual deviations in the cost and time of project execution, taking into account changes adding due to the set of influences and impacts of the environment.

IV. CONCLUSION

The proposed proactive approach for changes management in distributed information systems projects has allowed creating models displaying the key elements, which experience a constant impact of dynamic changes of turbulent environment.

For these changes management, the proposed structure of the IT project management processes based on the taken should be used. In addition, information exchange model of proactive management components should be proposed. Such processes in these systems should be further explored and elaborated with the construction of the appropriate mathematical apparatus.

The proposed change management technology has led to the construction of an algorithm that defines the response to their influence based on the identification of emerging events. Also, the changes consequences are accepted from studying the requests for changes.

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