Projects in the field of information technology implemented on the basis of Scrum are quite often carried out under the influence of sharply changing circumstances both in the project itself and in the environment, which are characterized as risky. Therefore, the processes related to the situational project management, which is the object of this study, become important. For projects, it is necessary not only to identify the current situation but also to formally present it in order to evaluate and determine rational ways of achieving project goals under risky conditions, which is the task of this study.

Crisis situations in projects that arise under risky conditions are quite difficult to predict and take appropriate preventive measures in time. In difficult cases of establishing a cause-and-effect relationship between factors, we have unstructured data of various types and nature. Therefore, to solve this task, it is necessary to apply a combined approach, based on a complex combination of situational management methods, formalized, intelligent methods and expert methods, as well as ontological engineering. This will make it possible to build an adequate decision-making model under risky conditions, taking into account the influence of external and internal environmental factors.

An ontological model of situational project management based on Scrum is proposed, which will ensure the interconnection and consistency of decisions in accordance with the situation under risky conditions. The proposed model of the situation provides a formalized description and assessment of the situation under risky conditions in real time. The result of the application of this model is an increase in the efficiency of projects due to compliance with time limits, reduction of overspending of resources, as well as adaptation to rapidly changing circumstances and adequate response

Keywords: situation model, situational management, ontological model, risk conditions, flexible methodologies, Scrum

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DEVELOPMENT OF THE ONTOLOGICAL MODEL OF SITUATION MANAGEMENT OF PROJECTS BASED ON SCRUM UNDER RISKY CONDITIONS

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1. Introduction

Under today's dynamic conditions of uncertainty, project management in the field of information technology (IT projects) acquires the tendency of an integrated response to external and internal disturbances in real time. Projects are characterized by embeddedness, openness, close interaction of control elements, the need to control and concentrate all information in one element, the presence of feedback, unpredictability of behavior in some situations, etc. Under risky conditions caused by the uncertainty of the external environment and internal state, to ensure effective management processes, the primary requirement is to ensure the flexibility of software development and mobility, as well as the speed and adequacy of decision-making. Timely achievement of planned results must be ensured on the basis of high performance in accordance with the strategies of the external environment and internal dynamics.

In project management based on Agile software development methodology, in particular Scrum, the success of making correct and accurate operational decisions depends on available information. This will provide an opportunity to evaluate the likely potential results and will also help improve the productivity of developers. As stated in [1–3], the software development process based on Agile software development requires constant adjustment of the project cost with direct control of quality, terms, and duration within each iteration. Scrum provides opportunities for an innovative approach in the management system. However, for each iteration, it becomes necessary to study various situations that may arise and affect the dynamics of project implementation. Action analytics, the key elements of which are purposefulness and information analysis scenario, will provide an opportunity to develop information models. Such models will facilitate monitoring and analysis of results, timely warning of emerging changes that may have serious consequences under risky conditions. Therefore, there is an important scientific task of developing an ontological model of situation management in projects implemented on the basis of Scrum under risky conditions. This will provide opportunities for flexibility in the formalization and expansion of the factor space of the model and taking into account the heterogeneity of the environment and the project when determining the scenarios of project implementation in different situations. Also, during the description and implementation of complex formalized tasks in the modeling environment, it will contribute to the development of appropriate information technology. This substantiates the relevance of our studies.

2. Literature review and problem statement

In the process of Scrum-based project management under risky conditions, it is necessary to ensure the flexibility of software product development processes, adaptation to internal and external factors, based on the fact that both the external environment and the conditions of IT project implementation will change. However, in most cases it is quite difficult to predict how these changes will occur. Therefore, project management based on Scrum under risky conditions is a poorly structured problem characterized by the impossibility of using methods and models based on an accurate description of problem situations, as indicated in [4].

Thus, in work [5], a hybrid model of XP and Scrum, called XSHM, is proposed for flexible software development. This model is flexible and provides opportunities to adapt strong and useful features of both Scrum and Extreme programming models, and to skip or disable all irrelevant and less effective modules of both models. However, this approach comes down to only choosing a modeling technique in some agile development situations. At the same time, it does not take into account various situations, in particular crisis and risk situations, which may arise during the implementation of the project and lead to negative consequences.

Work [6] considers the Scrum+ model, which is developed on the basis of Scrum and defines a set of actions, tasks, roles, and criteria for supporting AGSD projects in a multi-model environment. This model is a combination of Scrum together with project management practices defined in several models such as: ISO/IEC 15504, ISO 9001, and CMMI-DEV. However, such a model lacks a description of the parameters of a specific situation and its dependence on various factors.

In [7], a multi-criteria decision-making model for evaluating the effectiveness of Scrum-based projects is proposed. The study is based on taking into account the importance of project management risk factors. WASPAS, COPRAS, and EDAS methods are used in the work. However, such studies should be based on precisely and clearly defined data that do not take into account the processes of sudden changes in the situation and the possibility of adaptation to external influences.

Research in work [8] is based on flexible software development projects with a fixed cost and a fixed schedule. It uses multi-group analysis (MGA) to perform repeated comparisons of parameters between groups of Scrum or Kanban methodologies based on structural equation modeling (SEM). At the same time, it is shown that risk management has a mediating effect between the scope of the project, resources, and the quality of the final product. But more attention in this study considers investigating the impact of project management constraints on fixed-cost Agile software development projects. However, no attention is paid to the processing of data of a qualitative nature, as well as to the solution of weakly structured and unstructured problems.

The definition and study of the most important features of the application of the Scrum framework from theoretical and practical aspects in the framework of projects in the IT sector are discussed in detail in [9]. However, there is no study of models and methods based on the analysis of situations in projects. Ontological engineering, which was applied in work [10], contributed to the development of information technology that would work equally with different subject areas.

Our review [4–10] showed that the existing models and methods of Scrum-based project management under risky conditions do not provide opportunities for describing the situation and generating management decisions appropriate to the current situation. Crisis situations in projects arising under conditions of uncertainty are quite difficult to predict and take appropriate preventive measures in time. In difficult cases of establishing a cause-and-effect relationship between factors, we have unstructured data of various types and nature. Therefore, to solve this task, it is necessary to apply a combined approach, based on a complex combination of situational management methods, formalized, intelligent methods and expert methods, as well as ontological engineering. This will make it possible to build an adequate decision-making model under risky conditions, taking into account the influence of external and internal environmental factors.

3. The aim and objectives of the study

The purpose of our work is to devise an ontological model of situational project management based on Scrum under risky conditions, characterized by the combined use of situational management methods, formalized and intelligent methods, expert methods, as well as ontological engineering. This will provide an opportunity under risky conditions to make dynamic management decisions in real time to increase development productivity, as well as the project as a whole.

To achieve the set goal, it was necessary to solve the following main tasks:

– to build and investigate a model of the situation in the project based on Scrum in the form of a set of fuzzy values of a fixed set of features, which will provide a formalized description and assessment of the situation under risk conditions in real time;

– to substantiate and build a meta-ontology of situational project management based on Scrum, which will contribute to the development and adoption of a management decision under risky conditions.

4. The study materials and methods

Risk is defined as a consequence of making a management decision under conditions of uncertainty, which is described by the totality of an event, the probability of this event, losses. Risks in projects implemented on the basis of Scrum affect the effectiveness of the project and are a condition for determining the direction of management actions [4]. Therefore, in the course of project implementation, the management of situations that are unpredictable in nature and require taking into account quite new and complex factors that determine the success of the project to varying degrees becomes important. Such conditions can be defined as risky. At the same time, the method of situational management is used, which will ensure the control of the implementation of the IT project under such conditions.

During the life cycle of an IT project, a significant number of events may occur that are difficult to predict and investigate using quantitative methods. Knowledge and skillful application of situational approaches to management will provide opportunities for the project manager to influence the situation, which will contribute to increasing the efficiency of the execution of processes and tasks, as well as a motivated approach to decision-making. The essence of this approach is that the same management functions are implemented differently in specific situations [11]. That is, the situational approach is based on the fact that the priority of decision-making is determined by

the situation [12]. Due to the fact that there are many factors both in the project and in the external environment, there is no single «best» solution. For each specific situation, the most effective solution is the one that most fully corresponds to its condition, which is the object of our study.

For Scrum-based projects, efficiency is ensured by a process framework that defines methods and roles. The basis of Scrum is Sprint [13], that is, a time interval lasting from one week to one month, during which the iteration of the IT project is implemented. The completion of the Sprint is the receipt of a new working version of the IT product. Every Sprint iteration starts with planning. Sprint Planning represents the initial situation when the content of the Product Backlog is evaluated, that is, a document containing a list of functional requirements for the product with an indication of priority. Based on this document, the Sprint Backlog is formed (those functional requirements from the Product Backlog that the Product owner chooses). All functional requirements are divided into tasks (Tasks), which must be completed, and which make up the Sprint. In addition, for Sprint, an important point is the formulation of the goal, which is a motivating factor and is achieved due to the implementation of Sprint Backlog tasks. Having a goal also helps the team to make an optimal decision when there are several alternative ways to solve the problem. Therefore, it is important to assess a specific situation under certain circumstances in order to develop and adopt an adequate management decision that justifies the application of a situational approach.

Situation management in Scrum-based projects should be based on the main provisions of the situational approach:

– management should provide for the analysis of what requirements the situation poses to the project and how the situation is described;

– an appropriate approach to the implementation of decision-making should be chosen, which would best meet the requirements put forward to the project by the situation;

– decision-making should provide the necessary flexibility to create the potential of the project, so that it is possible to move to a new management style that corresponds to the situation;

– decision-making should make appropriate changes that allow adaptation to the situation.

Thus, the situational approach provides research opportunities for projects based on Scrum problem situations and how the project reacts to risky conditions and specific circumstances. Therefore, it is important to establish a cause-and-effect relationship between situations, situational goals, decisions, as well as the final result.

As stated in [14], situational analysis represents complex technologies for preparation, adoption, and implementation of a management decision, based on the analysis of an individual management situation of an IT project implemented on the basis of Scrum. At the same time, the study of situations is carried out on the basis of the application of methods of fuzzy logic, logico-linguistic models, training procedures and generalization in the generation of management decisions according to the current situation, expert methods. Preparation for conducting a situational analysis involves, first of all, a clear formulation of the task and provision of the necessary information to experts and analysts who participate in its implementation. The analysis of information about the situation is carried out on the basis of the application of the method of expert assessments, and also involves the identification of the main factors of the external environment and the internal state of the IT project, which influence the development of the situation. In addition, information about the factors of the external environment and the internal state of the IT project is necessary for the development of scenarios of the most likely development of the situation. Next, an expert assessment of the management situation is carried out, processing of the data obtained during the examination and assessment of the results of the conducted expert assessment. The situational analysis ends with the preparation of analytical materials for the project manager, in which the results obtained during the situational analysis are presented.

Management of situations in IT projects implemented on the basis of Scrum under risky conditions is a poorly structured task that is quite difficult to describe based on the application of purely formalized methods and models. The construction of a semantic model of the IT project and the processes taking place in it is possible based on the representation of the situation in the form of a set of values of a fixed set of features, as well as the use of an artificial language for describing situations and relationships between objects. When solving certain problems, these methods can be combined, but it is necessary to take into account a number of features. The use of situational analysis in IT project management based on Scrum has a number of advantages that contribute to obtaining more accurate, reliable, and complete information for decision-making under risky conditions. For IT projects based on Scrum, it is necessary not only to identify the current situation and the set of management decisions corresponding to it but also to structure the relevant information, to highlight the concepts and connections that connect them. In addition, it is necessary to determine rational ways of achieving the goals of the functioning of the IT project management system, for which it is necessary to calculate the possible consequences of the sequence of management decisions several steps ahead. These tasks require the involvement of additional methods, in particular the use of ontologies.

In this regard, the combined use of the situational approach [11, 12], expert methods [15], and ontological engineering [16] is appropriate for the development of decisions during the situational management of an IT project based on Scrum under risky conditions. The development of an ontological model of situational IT project management under Scrum conditions is the essence of the scientific novelty of our study. This will help improve the effectiveness of the implementation of the IT project under risky conditions and could be used in the appropriate management system.

5. Results of investigating an integrated method of situational project risk management

5. 1. Model of the situation

In the course of the dynamic implementation of the IT project, management decision-making is implemented on the basis of a study of the extent to which the execution of the process ensures the achievement of the set goal. The real situation reflects the state of achieving the goal, which is described on the basis of knowledge, which will later become a guide to action. Knowledge management technology, which is an effective collection, analysis, and presentation of data about the situation, contributes to the adoption of management decisions in the project in real time based on the acquired knowledge.

In the process of project management based on Scrum, the formation and justification of the choice of the directions of achievement and support of the constant execution of the tasks that make up the Product backlog and Sprint backlog

become important. Therefore, a situational analysis is envisaged in order to assess the current situation in the process of Sprint Planning and then during each Daily Scrum.

The use of a situational approach allows one to ensure a reasonable selection, processing and evaluation of the necessary information when making decisions when managing a project under risky conditions. The flexibility of this approach makes it possible to use expert knowledge and reasoning mechanisms. Since projects belong to management objects characterized by such properties as uniqueness, dynamism, complexity, etc., it is necessary for them to take into account changes over time under the influence of external and internal factors.

Using the principles of situational management, it is possible to formalize the description of situations that arise in project management. This is an opportunity to visualize and visually examine the risk factors that affect the implementation of the project at various levels and timely identify critical situations that may lead to negative consequences. Taking into account the modern interpretation of situational management, the main concepts are the situation, classification, and transformation of the situation. The current situation is considered as a combination of the current state of the project and the external environment, characterized by parameters and goals corresponding to the situation. A situational goal is represented in the form of some target situation to which the current situation can be brought, using management decisions in a specific situation. The problem of choosing management solutions comes down to an adequate assessment of the state of the project and the external environment.

In the course of situational IT project management, the process of identifying the current situation and developing a management decision in accordance with the situation becomes important. The main parameters of the situation (the value of factors, the degree of influence of some factors on others) – after they are selected, are not quantitative, but qualitative. That is, we do not have numbers but intervals that characterize the accuracy of the assessment, or fuzzy values, or verbal (linguistic) assessments that form a linearly ordered scale.

The following model of the S_i IT project situation is proposed in the form of a set of fuzzy values of a fixed set of features:

$$S_i = \langle E,F,V,T,Z,C,SA \rangle, \tag{1}$$

where $E = \{e_1,e_2,..,e_k\}$ – a set of performance indicators of an IT project, characterized by threes:

$$e_k = (y_k,\tau_k,P_k), k \in [1,0],\ \tau_k \in [0,\mathrm{T}],$$

where y_k is the value of the project efficiency indicator at the moment of time τ_k; τ_k is the moment of time to which the value of the efficiency indicator y_k refers; P_k is the fuzzy probability of the value y_k at time τ_k. Time is considered as a discrete value ranging from zero to some given value T, with a discretization step $\Delta\tau$.

Performance indicators of an IT project based on Scrum should take into account both organizational and project-technological components of the IT project, i.e., Productivity of the IT project team, Labor intensity of the IT project, Velocity, Definition of readiness. It should be emphasized that performance indicators are interconnected and interdependent. Each efficiency indicator has its own weight, which is determined by an expert method in accordance with [17].

The process of investigating the situation should take into account the use of resources in the IT project, in particular human resources, in order to determine the amount of time spent on tasks during the implementation of the project. Therefore, it is important to study the influence of resources on the time of implementation of tasks in order to increase the productivity and efficiency of the IT project. This makes it possible to outline the long-term direction of the implementation of the IT project, determine the terms of completion of the project development, as well as determine the final result of the IT project.

Therefore, the next component parameter in the situation description model is $F=\{f_1, f_2, ..., f_n\}$ – a set of situational factors influencing resources on tasks (Tasks) that make up the Product backlog, Sprint backlog. This parameter directly affects the efficiency indicator and is characterized by the resource-object of influence pair (task of the IT project):

$$f_n = \left((v_1,t_1),...,(v_j,t_j),...,(v_n,t_n)\right), \tag{2}$$
$$n \in [1,N_n],\ j = \overline{1,N}_n,$$
$$v_j \in V,\ t_j \in T,$$

where $T=\{t_1, t_2, ..., t_q\}$ is a set of objects, i.e., IT project tasks (Tasks that make up Product backlog, Sprint backlog).

$V=\{v_1, v_2, ..., v_l\}$ is a set of resources. At the same time, the main resource of an IT project based on Scrum is human resources, that is, the development team (Scrum Team) and the project manager (Scrum master), who makes decisions:

$$V = \bigcup_{v=1}^{U} V^u, V^u = \left\{v_1^u, v_2^u, ..., v_l^u\right\}. \tag{3}$$

When implementing tasks (Tasks) of varying degrees of complexity and duration, the direct dependence of the situation on the task-resource pair is of decisive importance since there is a clear division of roles in the team. The influence of situational factors on project performance indicators leads to the correction of the situation, which requires the implementation of appropriate management decisions.

The result of the work of each member of the project team in accordance with the task performed by him/her is described by a linguistic set of pairs result – fuzzy assessment, where consequences are the results of the task:

$$v_g^u = \left\{(P_e,U_e)\right\} e = \overline{1,N_g}.$$

The result of the task corresponds to the performance indicator and is described as follows:

$$v_d : E^a = \left\{\left(P_m^a, U_m^a\right)\right\} \in E,$$
$$v \in \left[1,N_{ag}\right].$$

Each specific pair of results, i.e., fuzzy values of estimates, in turn determines one of the consequences of the task, i.e., the corresponding value of the performance indicator:

$$m = \overline{1,N_E}, \tag{4}$$
$$\left(P_m^a,U_m^a\right): e_k = (y_k,\tau_k,p_k) \to e_h = (y_h,\tau_h,p_h),$$
$$v \in \left[1,N_{ag}\right],\ m = \overline{1,N_E},$$
$$k,h \in [1,N_w],\ t_k \in [0,T_G - 1],\ t_h = t_k + 1.$$

The correspondence of the situation to the management decision is established on the basis of determining the degree z of achieving the goal c when implementing the corresponding decision as a result of the occurrence of the situational factor.

$S=\bigcup_{r=1}^{n} S^z$, $S^z=\{s_1^z, s_2^z, ..., s_n^z\}$, where the whole set of situations is divided into a set of basic situations S_{osn}^z and a set of alternative situations S_{dop}^z, divided into groups in accordance with the value of the degree z of the achievement of the goal c: $S=\bigcup_{z=1}^{V} S_{osn}^z \cup \bigcup_{z=1}^{L} S_{dop}^z$. Each main group of situations corresponds to the value of the degree z of the achievement of the goal c in accordance with the indicator of the used resources, which will contribute to the increase of the corresponding efficiency indicator , and development of a control decision:

$$S_{osn}^z \leftrightarrow V,\ z\in[1,Z],\ S_{osn,q}^z \leftrightarrow V_q^z \in V^z,\ z\in[1,Z],\ q\in[1,N_{sv}].$$

The set of goals C of an IT project is set by developing a goal tree, as described in [18], and consists of the following goals (Table 1).

Table 1

Table of IT project goals

Designation	Name
C0	Increasing the efficiency of the IT project
C1	Maximizing the productivity of the IT project team
C2	Minimizing the duration of IT project implementation

SA – a technique of adapting an IT project to a change in the situation – ensures compliance with the situational goal according to the current performance indicators of the IT project and, as a result, forms a set of admissible estimates for the given situation, which will ensure the formation of an appropriate management decision:

$$SA:(C,u_k)\rightarrow R'\in R. \quad (5)$$

After setting the initial conditions, the construction of the graph is carried out cyclically – the current node related to the analyzed moment of time is selected, the corresponding situation is identified, and the corresponding control decision is formed.

The adequacy of this model is proven by establishing the qualitative and quantitative influence of situational factors F on performance indicators E based on the method of multivariate regression analysis [19]. The relationship between the performance indicators e_i, i=1, ..., k of the IT project and the situational factors will be described based on the determination of the degree of influence of the arguments on the function:

$$E=f(v_1,v_2,...,v_n), \quad (6)$$

where $V=\{v_1, v_2, ..., v_l\}$ is a set of resources.

The dependence of IT project efficiency indicators on resources will be described on the basis of the construction and evaluation of a multivariate regression equation that has a power-law relationship [19]:

$$E=A_0 v_1^{a_1}\cdot v_2^{a_2}\cdot ...\cdot v_n^{a_n}, \quad (7)$$

where A_0 is a constant coefficient of the regression equation; a_i – regression coefficient reflecting the degree of influence of arguments on the function; E is a function corresponding to the IT project efficiency indicator; v_i is an argument that corresponds to the indicator of the involvement of IT resources in the project to perform a certain task.

Based on statistical data for such performance indicators as e_1 – productivity of the IT project team, e_2 – labor intensity of the IT project, e_3 – Velocity, the following multiple regression equations were constructed:

$$e_1=57.6v_1^{0.87}\cdot v_2^{0.36}\cdot v_3^{-0.16}\cdot v_4^{0.02}\cdot v_5^{0.58}, \quad (8)$$

$$e_2=87.5v_1^{0.75}\cdot v_2^{0.34}\cdot v_3^{-0.408}\cdot v_4^{-0.417}\cdot v_5^{0.45},$$

$$e_3=1.78v_1^{0.81}\cdot v_2^{0.67}\cdot v_3^{-0.3}\cdot v_4^{-0.384}\cdot v_5^{0.788}.$$

Correlation coefficients of multiple regression for dependences (8) are 0.905, respectively; 0.975; 0.853, and reliability coefficients – 25.98; 6.17; and 2.75. The obtained values indicate that there is a relationship between the performance indicators (Productivity of the IT project team, Labor intensity of the IT project, Velocity) and the resources involved in the execution of the Product backlog and Sprint backlog tasks.

Evaluation of the qualitative and quantitative impact of each factor on performance indicators was performed on the basis of conditional calculations. At the same time, the argument under consideration changed by 1 % from the average value with the fixed value of other arguments in each specific situation at the moment of time τ_k.

The proposed model of the situation provides the possibility of researching the current state of the IT project based on the monitoring of the performance indicators of the IT project in real time by determining the deviation from the situation that «should be». At the same time, situational factors affecting project performance indicators are taken into account, and management decisions are made in a timely manner in order to avoid possible losses and overspending of project resources.

5. 2. Meta-ontology of situational project management based on Scrum

When constructing the ontological space of knowledge, by which we understand the system of ontologies describing the concept of the analyzed IT project, a fractal approach is used [20]. Within the framework of this approach, the introduction of meta-levels and the transition from meta-ontologies to detailed, separate concepts of meta-ontologies are envisaged. Fig. 1 shows the meta-ontology of situational management, which reflects the basic concepts related to the concept of «Situational Management», such as «Situation» and «Situational Decision», as well as other basic interrelated concepts. Fig. 1 demonstrates that the project manager (PM) chooses, using situational management methods, the necessary solution for the implementation of the IT project, taking into account the analysis of the situation and the influence of the external environment.

Situational analysis and situation modeling are considered as the main method of situational management. The task of the ontology of the situational analysis is to identify the parameters and essential factors that determine the situation, the relationships between the factors and the degree of their mutual influence. In the process of situational analysis, indicators of the effectiveness of the IT project, situational factors, which are characterized by the resource-object of influence pair (the task of the IT project), as well as factors of the external environment from the point of view of their connection with the IT project, are studied.

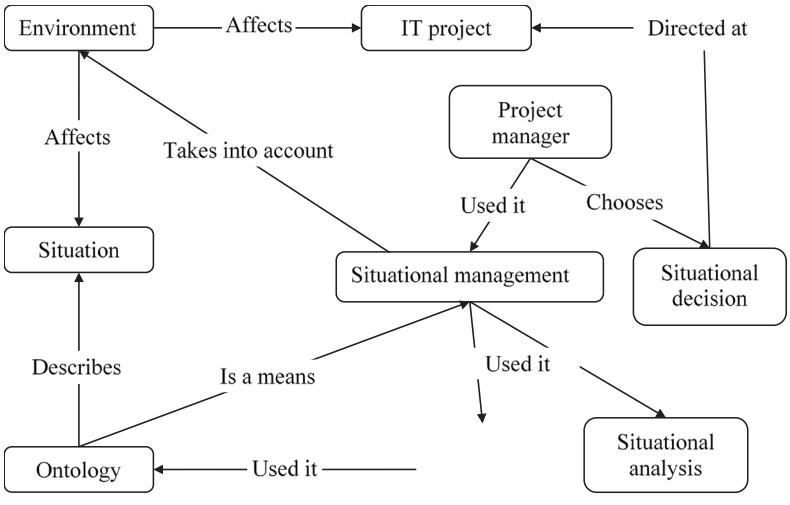

Fig. 1. The concept of meta-ontology of situational IT project management

According to this concept, the central element of situational management is the situation. According to [4], the current situation is considered as a collection of all data about the structure of the object and its functioning at the present time. We believe that the task of situational analysis is to identify parameters and essential factors or circumstances that determine the situation, relationships between factors and the degree of their mutual influence.

A situation is understood as a set of circumstances that determine the internal state of an object or system, and circumstances that determine the state of the environment in accordance with a given object or system. The first circumstances are described by parameters characterizing the state of the system, the second by environmental conditions or significant factors that affect the development of the system.

In the most general form, the description of the situation can be considered as a description of the main parameters of the management object, in relation to which the situation is considered, as well as external and internal factors that affect the object. The environment and the object have properties, the values of which determine their state, and the states, in turn, determine a specific situation. Ontology in Fig. 2 reflects this definition and demonstrates the relationships that must be taken into account when assessing the situation and choosing management decisions, in particular when making decisions in Scrum-based project management.

The general scheme of situational IT project management research consists in assessing the current state of the IT project, selecting appropriate management decisions (preventive, operational or liquidation measures) to support or transition to a reference (target) situation in accordance with the situational goal.

The knowledge needed to solve the problems of situational IT project management is grouped in the form of a space of components united by common tasks and goals of development, formally described by some system of ontologies. The knowledge space of situational IT project management is understood as a set of necessary formalized knowledge about the situation of the IT project, its properties, or characteristics. In addition, the factors (external and internal) affecting the implementation of the IT project are taken into account, as well as the relationships between the factors and the governing influences necessary for decision-making in the management of the IT project.

The proposed ontological model of situational project management implemented on the basis of Scrum can be used as an integrated application to support managerial decision-making in project management systems. This will allow expanding the intelligent capabilities of these systems, as well as increasing the efficiency of management processes during project implementation.

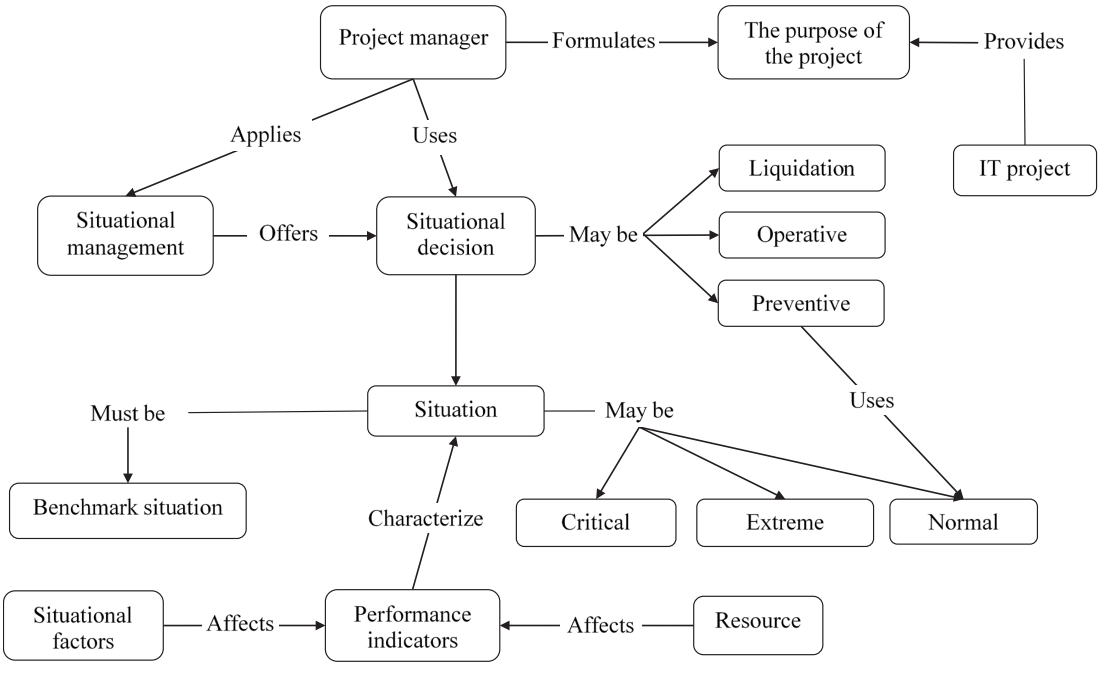

Fig. 2. Ontology of the project situation under Scrum conditions

6. Discussion of results of investigating an integrated method of situational project risk management

The use of situational analysis in Scrum-based IT project management has a number of advantages that contribute to obtaining more accurate, reliable, and complete information for decision-making under risky conditions. The constructed ontological model of situational management of the IT project (1) to (5) is based on the study of the situation. The S_i IT project situation (1) is represented as a set of fuzzy values of a fixed set of features. On the basis of (6) and (7), a study of the dependence of IT project efficiency indicators on resources was conducted, and on the basis of (8) conclusions were drawn about the adequacy of this model. The proposed mathematical model of the S_i IT project situation (1) is used in situational modeling. This will provide opportunities to comprehensively describe knowledge about the situation, to display cause-and-effect relationships between situational factors and their consequences, and to model the development of situations taking into account the events taking place.

The considered system of ontologies provides opportunities for the formal description of knowledge in the form of a space of components united by common tasks and development goals, which are necessary for solving the problems of situational management. Fig. 1, 2 show ontologies as a set of necessary formalized knowledge about the situation of the IT project, properties or characteristics of the IT project, factors (external and internal) affecting its implementation. In addition, the relationships between the factors and management decisions necessary for the effective management of an IT project based on Scrum in the «real-time» mode, which allows one to reduce possible costs, are shown.

The results of our study, in contrast to [6–10], are based on the combined application of situation management methods, formalized and expert methods, as well as ontological engineering for Scrum-based project management and are characterized by the following features:

– justified reduction of time for selection, processing and evaluation of necessary information when making decisions in each specific situation at the moment of time τ_k;

– the application of situation ontology and meta-ontology of situational management provide opportunities for understanding the main components of the formed knowledge space, the methods used, factors and other concepts;

– application of new methods and approaches to management based on case studies, which will ensure increased developer productivity in Scrum-based projects;

– the application of fundamentally new models of describing situations contributes to the development of promising and situation-adapted solutions that will contribute to increasing the efficiency of project management;

– development of intelligent technologies that will support management decision-making based on integrated information in a single space.

The basis of our study is an example of an academic project based on Scrum. Therefore, this study is characterized by limitations of resources and time of project implementation. In addition, the use of expert methods depends on the competence of experts and methods of expert survey, which is also a limitation of this study.

The ontological model of situational project management is focused on the formation of an artificial language for describing situations and relationships between objects. However, building a semantic model of IT project management processes is quite cumbersome when describing situations in the management system according to the Scrum methodology. The process of creating a language is quite time-consuming and does not always lead to a positive result, which is a possible drawback of this study. However, these circumstances can be avoided by enabling joint processing of knowledge based on a single semantic description of the knowledge space.

The proposed ontological model of situational project management based on Scrum under risky conditions can be the basis of project management information technology and the corresponding decision support system. Ontology-controlled project management system based on Scrum under risky conditions will provide opportunities for synchronous reproduction of the management decision in accordance with the situation. This direction is the subject of further research.

7. Conclusions

1. A model of the situation in the project based on Scrum was built in the form of a collection of fuzzy values of a fixed set of features, such as performance indicators, situational goals, situational influencing factors. This model provides opportunities for a formal description of the situation in real time and will ensure the interconnection and coherence of decisions in accordance with the situation under risky conditions.

2. The meta-ontology of situational project management and the ontology of the project situation under Scrum conditions have been built, which contributes to the development and adoption of an operational management decision for a situation under risky conditions. This model provides opportunities to identify parameters and essential factors that determine the situation, relationships between factors and the degree of their mutual influence. The result of the application of this research is a reduction in the time for making and adopting a management decision, which ensures an increase in the efficiency of the project due to the avoidance of overspending of resources.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

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Data availability

All data are available in the main text of the manuscript.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

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