UDC / JEL 004:005.8]-047.44

[0000-0002-6204-0708] **T. O. Prokopenko,** *Dr. Tech. Sc., Professor,*
e-mail: t.prokopenko@chdtu.edu.ua
[0000-0001-5722-4863] **O. I. Pidkuiko**
e-mail: o.i.pidkuiko.fitis20@chdtu.edu.ua
Черкаський державний технологічний університет
б-р Шевченка, 460, м. Черкаси, 18006, Україна

DEVISING A GRAPH-ANALYTICAL MODEL FOR SITUATION PROJECT MANAGEMENT OF SCRUM-BASED PROJECTS IN THE FIELD OF INFORMATION TECHNOLOGY

A graph-analytical model for situational project management in the field of information technology, which can ensure effective management decision-making, has been proposed. All features inherent in the implementation of the Scrum methodology used in the management of information technology projects have been taken into consideration. Ambiguous situations that constantly arise during the implementation of projects affect their effectiveness. Therefore, constant monitoring of the project efficiency will enable the project manager to make management decisions, which can contribute to improving the efficiency of the project. The impact of changing situational factors on the situation, which provides real-time monitoring of the situation for the project in Scrum conditions, has been studied. The model of situational management is built on the basis of the complex application of graph theory, situational analysis and expert methods, which ensure obtaining more accurate and reliable information for decision-making in conditions of rapidly changing circumstances.

Ключові слова: *Scrum, Sprin, factors, situation, graph.*

Introduction The trend of globalization and digitization of the modern world activates the development of innovative technologies, particularly in the management system. The best experience of applying such innovations, especially by companies in the field of information technology (IT), provides increased efficiency due to dual management in current and strategic activities. Therefore, it is important to implement the set tasks by applying the project approach, which is based on the Agile software development. In particular, Scrum is a framework that helps to increase the productivity of developers. However, ambiguous situations arise quite often. They are unpredictable in nature and affect the effectiveness of the project. As stated in [1-3], the basis of Agile software development is a short cycle that provides a minimum increase in the software product, i.e. iteration. Paper [4] indicates that the software development process requires constant adjustment of the project cost with direct control of quality, timing and duration. The use of Scrum provides opportunities for an innovative approach to the management system. However, within the framework of the iteration, the study of various situations that may arise and affect the course of the project is very important. According to Scrum [1-3], the dynamics of the implementation of an IT project requires a clear statement of tasks, a clear formulation of requirements, the distribution of processes between performers, a clear coordination of actions and decisions, and adaptation to the style of teamwork.

In the process of IT project management, it is necessary to ensure the flexibility of the software product development processes, adaptation to internal and external factors, based on the fact that both the environment and the conditions for the implementation of the IT project will change. However, in most cases it is difficult to predict how these changes will occur. Therefore, most IT companies during the implementation of projects choose to use the flexible Scrum methodology, which ensures both product quality control and the quality of the processes themselves.

In paper [5], the authors consider an IT project as a complex organizational and technological system, which is characterized by integrated management approaches, as well as strict standards and principles. The peculiarities of using the Scrum methodology in the IT project management system require taking into account the possibilities of various situations that can lead to negative consequences and affect the effectiveness of the IT project.

DOI: 10.24025/2306-4412.2.2022.261704

Situational management of complex organizational and technological objects focuses on the fact that the need for different management methods is determined by a specific situation. Situational analysis represents complex technologies of preparation, adoption and implementation of management decisions, which are based on the analysis of a separate management situation. In the course of situational management, methods of fuzzy logic [6], logic-linguistic models [7], training and generalization procedures are used in the generation of management decisions according to the current situation [8].

There are a number of methods that implement different ways of the situational approach. Paper [9] considers methods focused on the formation of an artificial language for describing situations and relations between objects. However, the construction of a semantic model of the IT project and the processes occurring in it is not always justified and is cumbersome when describing situations in the Scrum management system. The process of creating a language is quite time-consuming and does not always lead to a positive result.

Paper [10] reports the results of situation research based on a group of methods based on the representation of the situation in the form of a set of values of a fixed set of features. When solving certain problems, these methods can be combined, but it is necessary to take into account a number of significant differences.

Our review of works [4-10] has shown that the existing models and methods do not fully describe situations in Scrum and provide complete and accurate information for making management decisions in real time.

The use of situational analysis in IT project management under Scrum conditions has a number of advantages that contribute to obtaining more accurate, reliable and complete information for decision-making in a changing environment. Therefore, the development of a model for situational management of an IT project in the context of the Scrum methodology is an urgent scientific task. At the same time, for complex organizational and technical systems, it is necessary not only to identify the current situation and the set of management decisions corresponding to it, but also 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 for several steps forward. These tasks require the involvement of additional methods. The development of a graph-analytical model of IT project situational management under Scrum conditions is the essence of the scientific novelty of this study, which will contribute to increasing the efficiency of IT project implementation and can be used in the relevant management system.

The purpose of the original work is to devise a model of situational IT project management in Scrum conditions based on the graph-analytical method. This would provide an opportunity to make effective decisions, taking into account the influence of external and internal environmental factors at various stages of the implementation of the IT project.

To achieve the set aim, the following tasks have been solved:

- to investigate the factors of the external and internal environment that shape the situation;
- to build graph-analytical model for situational project management of Scrum-based project in the field of information technology.

The study materials. According to Scrum [11], the effectiveness of an IT project is ensured by a process framework that defines methods and roles.

The foundation of Scrum is Sprint [12]. This is a time interval, the duration of which is from one week to one month and during which an iteration of the IT project is being implemented. The completion of Sprint is the obtaining a new working version of the IT product. Every iteration of Sprint starts with planning. Sprint Planning is the starting situation for evaluating the content of Product Backlog. Product Backlog is a document that lists the functional requirements for a product and prioritizes it. Sprint Backlog is the functional requirements from Product Backlog that the Product owner selects. All functional requirements are distributed by tasks. Sprint is made up of tasks that need to be completed. In addition, for Sprint, an important point is the formulation of the goal. The goal is the motivating factor. The implementation of Sprint Backlog tasks is aimed at achieving the goal. Having a goal also helps the team to make the optimal decision when there are several alternative ways to solve the problem.

Since the situational management of an IT project is expedient to be carried out on the basis of Scrums, the basic procedure for the implementation of an IT project in the conditions of scrums is as follows (Figure 1):

DOI: 10.24025/2306-4412.2.2022.261704

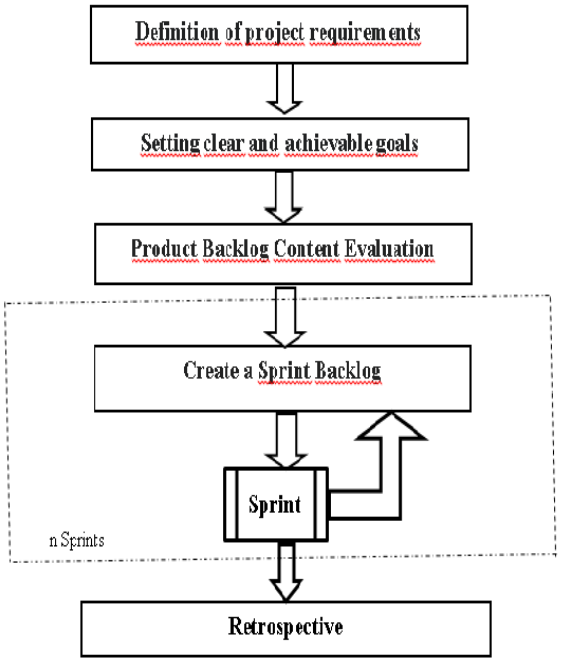

Figure 1 – Scheme for the implementation of an IT project based on the flexible Scrum methodology

During the life cycle of a project, a large number of events can occur that are difficult to foresee and study quantitatively. Therefore, it is important to establish a causal relationship between situations, situational goals, tasks, as well as the end result. Information about the factors of the external environment and the internal state of the IT project can be obtained using the method of expert assessments.

Therefore, a combined combination of intellectual and expert methods is effective. This would provide more accurate and high quality results. The reliability of the examination is ensured by a reasonable number of proposed factors, which allows not to go beyond the psychological capabilities of experts. However, the information obtained depends on the competence of experts, which is a limitation of this method [13].

Situational analysis is intended to assess the current situation during the Sprint Planning process and then during each Daily Scrum. The following procedure is proposed, which should be implemented using expert methods:

1. Examination of project situation:
• situational goals are determined;
• situational factors are determined;
• dynamics of influence of situational factors is being investigated;
• the situation is being formed and evaluated.

2. Development of a graph-analytical model of situational management for Sprint:
• establishing a connection between situations and situational goals;
• formation of alternative solutions aimed at achieving goals.

3. The procedure for choosing a decision aimed at achieving a situational goal.

4. Analysis of the obtained results and formation of the next situation.

To study the factors of the external and internal environment, we will apply the graph-analytical method [14, 15], which would provide the possibility of constructing a graph of the dynamics of the formation of the situation. Let the situation be characterized by internal factors f_i, i = 1, ..., n (Productivity of the IT project team, Labor intensity of the IT project, Velocity, Definition of readiness). Each factor is assigned a variable x_i, which is a function of continuous time τ and characterizes the factor:

$$x_i(\tau) = a_{i0} + a_{i1}\tau + ... + a_{ik}\tau^k, \qquad (1)$$

where a_{il} are constants, $l = 1,....,k$.

Over time, all situational internal factors change. Moreover, factors f_j, j = 1, ..., n, $i \neq j$ characterizing the events of the external environment can influence the factors f_i. Therefore, the internal situational factor at the moment will be expressed by the formula:

$$f_i(\tau) = x_i(\tau) + \sum_j b_{ji} \times x_j(\tau), \qquad (2)$$

where b_{ji} is the coefficient determining the impact of f_j on f_i. The values a_{il}, b_{ji} can be both positive and negative.

In the graph of the dynamics of the influence of situational factors, the vertices correspond to situational factors f_i, edges (f_{i1}, f_{i2}), i_1, i_2 = 1, ..., n, $i_1 \neq i_1$ correspond to the influence of f_{i1} on f_{i2} having coefficients $b_{i1,i2}$. An example of the graph of the dynamics of the influence of situational factors is given in Figure 2.

DOI: 10.24025/2306-4412.2.2022.261704

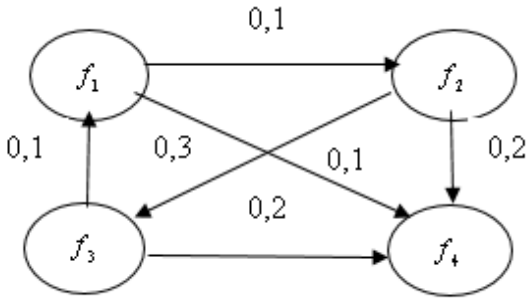

Figure 2 – Example of a graph of the dynamics of the influence of situational factors

According to (1), the functions characterizing situational factors are linear (k = 1). Therefore, let's express them as:

$$\begin{aligned} x_1(\tau) &= 3 + 0{,}4\tau \\ x_2(\tau) &= 3 - 0{,}4\tau \\ x_3(\tau) &= 5 + 0{,}2\tau \\ x_4(\tau) &= 5 - 0{,}2\tau\,. \end{aligned} \qquad (3)$$

Applying relations (1), (3) to the graph in Figure 2, we obtain:

$$k_1(\tau) = 3 + 0{,}4\tau + 0{,}2(3 - 0{,}4\tau) = 3{,}6 + 0{,}32\tau$$

$$k_2(\tau) = 3 - 0{,}4\tau + 0{,}1(3 + 0{,}4\tau) = 2{,}3 - 0{,}36\tau$$

$$k_3(\tau) = 5 + 0{,}2\tau + 0{,}1(5 + 0{,}2\tau) + 0{,}1(5 - 0{,}2\tau) = 6 + 0{,}2\tau$$

$$k_4(\tau) = 5 - 0{,}2\tau + 0{,}1(2 + 0{,}5\tau) + 0{,}1(2 - 0{,}5\tau) = 6 - 0{,}2\tau$$

If the necessary information is available, the values of the situational factors are given by numerical variables with a certain range of values. If there is not enough relevant information, then linguistic variables with qualitative values such as "very low", "low", "medium", "high", "very high" level are entered. Qualitative values are evaluated by the number of points on a special scale (for example, a five- or ten-point scale). In this way, linguistic variables are transformed into numerical ones with a standard scope of definition. Since it is rather difficult to measure the values of the factors in the real system, we would use the single linguistic point scale presented in Table 1 for them.

The change in the value of situational factors reflects the nature of their change and corresponds to numbers from the closed interval [0, 1] with the sign "+" if the indicator increases, and the sign "-" if it decreases. The stability of the indicator is represented by the number 0. The rate of change (growth or decline) is estimated with the help of limit points on the closed interval [0, 1]: 0.1 – very weak; 0.3 – moderate; 0.5 – significant; 0.7 – strong; 1.0 – very strong indicator change.

Table 1 – **Linguistic-scoring value of assessment of situational factors**

Linguistic assessment of meaning	Point assessment
Very low	$2 > f_i \geq 0$
Low	$4 > f_i \geq 2$
Average	$6 > f_i \geq 4$
High	$9 > f_i \geq 7$
Very high	$12 > f_i \geq 10$
Super high	$f_i \geq 12$

Thus, each situation is characterized by a certain set of factors of the internal environment with the corresponding influence of factors of the external environment (Table 2).

Table 2 – **Assessment of the situation through external and internal factors**

factor	f_1	f_2	f_3	f_4
S_1	+0,5	+0,7	+0,3	+0,1
S_2	+0,2	+0,1	+0,2	+0,5
S_3	+0,2	+0,2	+0,2	+0,3

The graph-analytical model of situational IT project management in Scrum conditions should demonstrate cause-and-effect relationships between situations formed as a result of certain factors and decisions that should contribute to the achievement of certain goals. Depending on the obtained values of external and internal environmental factors characterizing the situation, one or another alternative solution is proposed.

The graph-analytical model of situational IT project management in Scrum conditions is a graph whose vertices correspond to situations, and arcs – to decisions aimed at achieving the set goal (Figure 3). Situations are represented by rectangles, to the upper sides of which arrows fit, according to the set goals. The root of the tree represents the starting (initial) situation.

DOI: 10.24025/2306-4412.2.2022.261704

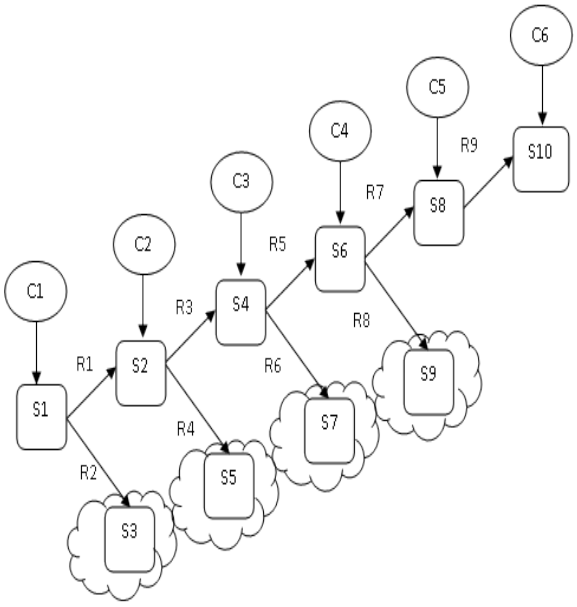

Figure 3 – Example of a graph of situations of one Sprint IT project in Scrum conditions

We would demonstrate the choice of a solution from a given alternative for a fragment of a tree using an example situation. S_1. We form Table 3, where for each alternative solution $\{r_1\}$ we match the value of factors f_i obtained on the basis of (2). In the second column of Table 3 "weights" (priorities) of factors on a scale from 0 to 1, assessed by experts, are specified.

Table 3 – **Predicted states of system indicators**

factor	weight	$\{r_1\}$	$\{r_2\}$
f_1	0,28	+0,6	-0,6
f_2	0,29	+0,2	-0,2
f_3	0,20	+0,3	-0,4
f_4	0,23	+0,2	+0,1
efficiency index $W(S_1)$		0,332	-0,283

For each column of factors f_i the decision efficiency index $W(S_1)$ for the situation S_1 is calculated in the form of the sum of the values of the indicators entered in the column by their "weights":

$$W(S_1) = \sum_{i=1}^{n} \alpha_i f_i, \qquad (4)$$

where α_i is the "weight" of the factor I_i; n is the number of factors. Next, the graph (decision) whose efficiency index satisfies the accepted criterion is selected. For example, if such a criterion is considered to be the maximum of the index, then a decision $\{r_1\}$ is selected on this interval and a controlling influence is formed. The procedure is repeated for the following situations.

Research results. As a result of the conducted research, the following theoretical scientific results have been obtained:

- cause-and-effect relationships between the current situation, situational goals and decisions are established. This provides opportunities to assess the situation and make an effective management decision for the IT project in Scrum conditions;

- the effects of changing situational factors on the situation, which provides real-time monitoring of the situation for the IT project under Scrum conditions, are investigated;

- an efficiency index is built for the situation in order to ensure the adoption of effective management decisions.

Discussion of results. In terms of using Scrum for IT project management, situational assessment is important both for each Daily Scrum and Sprint Planning. This will ensure the ability to adequately and accurately assess the current situation and make appropriate effective decisions that will contribute to the achievement of situational goals, as well as the avoidance of future crisis situations. And this increases the flexibility of the IT project. In such a setting, the presented scientific problem is considered for the first time.

Assessing the qualitative and quantitative impact of the factors that shape the situation provides the opportunity to study the changes in these factors that affect financial indicators after a certain period of time and does not allow to quickly respond to a change in the situation for the studied IT project during the implementation of each task This makes it possible to make the necessary management decisions in the "real-time" mode, which allows to reduce possible costs.

The research is carried out on the basis of an academic example of project management in the field of information technologies, which provides an opportunity to illustrate situational IT project management in the context of Scrum. It is important to study the interdependent relationship between various situational factors and build an index of the situation's effectiveness. The re-

DOI: 10.24025/2306-4412.2.2022.261704

search uses the method of expert evaluations, which is a limitation of this study.

Conclusions As a result, in this paper, for the first time, the factors of the external and internal environment that shape situations are investigated. This provides opportunities to monitor changes in the situation in real time and its impact on the effectiveness of the IT project.

A graph-analytical model of situational IT project management in Scrum conditions, which provides the possibility of obtaining a cause-and-effect relationship between the exact situation, situational goals and decisions, is developed. An index of situational efficiency is proposed, which would simplify the procedure of selection and management decision-making in the process of situational management. In the perspective of further research, the obtained model can be applied in the construction of ontologies as the basis of an intelligent IT project management system. This would ensure an increase in the efficiency of the IT project due to the adoption of adequate management decisions.

References

[1] G. I. Smith, A. L. Kolesnik, K. Lavrischeva, and O. Slabospitsky, "Improving the process of drafting families of software systems elements of agile methodologies", *Programming problems*, no. 2-3, pp. 261-270, 2010.

[2] J. Sutherland, *Scrum: The Art of Doing Twice the Work in Half the Time* (1st ed.) Currency, 2014, p. 256. ISBN 9780385346450.

[3] H. Kniberg, *Scrum and XP from the Trenches (Enterprise Software Development).* C4Media, 2007, p. 140.

[4] D. Maximini, *The Scrum Culture: Introducing Agile Methods in Organizations. Management for Professionals*. Cham: Springer, 2015, p. 26.

[5] T. A. Prokopenko, and Ya. L. Zyelyk, "Complex method of strategic decision-making in management of technological complexes of continuous type", *Journal of Automation and Information Sciences*, vol. 49, pp. 71-79, 2017.

[6] L. A. Zadeh, "Knowledge representation in fuzzy logic", *IEEE Trans. Knowledge an Data Eng. March*, no. 1, pp. 89-100, 1989.

[7] A. K. Lohani, N. K. Goel, and K. K. S. Bhatia, "Comparative study of neural network, fuzzy logic and linear transfer function techniques in daily rainfall-runoff modelling under different input domains", *Hydrological Processe*s, vol. 25 (2), pp. 175-193, 2011.

[8] B. Schwenker, and T. Wulf, *Scenario-Based Strategic Planning: Developing Strategies in an Uncertain World.* Springer, 2013. ISBN: 3658028742.

[9] Wei Dong, "Using a system dynamics simulation model to explore the validity of dynamics of Agile software development", Graduate Theses and Dissertations, 18486, 2021. [Online]. Available: https://lib.dr.iastate.edu/etd/18486.

[10] P. Serrador, and R. Turner, "The relationship between project success and project efficiency", *Project Management Journal*, vol. 46, no. 1, pp. 30-39, 2015.

[11] T. Prokopenko, O. Lavdanska, Y. Povolotskyi, B. Obodovskyi, and Y. Tarasenko, "Devising an integrated method for evaluating the efficiency of Scrum-based projects in the field of Information Technology", *Eastern-European Journal of Enterprise Technologies*, vol. 5, no. 3-113, pp. 46-53, 2021.

[12] M. Andrew, "Software development roles and responsibilities in outsourcing". [Online]. Available: https://qarea.com/blog/software-development-roles-andresponsibilities-in-outsourcing.

[13] S. L. Kendal, and M. Creen. *An Introduction to Knowledge Engineering.* London: Springer, 2007.

[14] A. Ladaniuk, T. Prokopenko, and V. Reshetiuk, "The model of strategic management of organizational and technical systems, taking into account risk-based cognitive approach", *Annals of Warsaw University of Life Sciences – SGGW Agriculture (Agricultural and Forest Enginweering)*, no. 63, pp. 97-104, 2014.

[15] A. Chochowski et al., *Innovative Energy-Saving Technologies in Biotechnological Objects Control.* Kyiv: Tsentr Uchbovoii Literatury, 2014.

DOI: 10.24025/2306-4412.2.2022.261704

Т. О. Прокопенко, *д-р техн. наук, професор,*
e-mail: t.prokopenko@chdtu.edu.ua
О. І. Підкуйко
e-mail: o.i.pidkuiko.fitis20@chdtu.edu.ua
Черкаський державний технологічний університет
б-р Шевченка, 460, м. Черкаси, 18006, Україна

РОЗРОБКА ГРАФОАНАЛІТИЧНОЇ МОДЕЛІ СИТУАЦЙНОГО УПРАВЛІННЯ ПРОЕКТОМ В УМОВАХ SCRUM У СФЕРІ ІНФОРМАЦІЙНИХ ТЕХНОЛОГІЙ

Запропоновано графоаналітичну модель ситуаційного управління проєктом в галузі інформаційних технологій, що забезпечить вироблення ефективних управлінських рішень. При цьому враховуються всі особливості реалізації методології Scrum, що застосовується в управлінні проєктами галузі інформаційних технологій. Неоднозначні ситуації, які постійно виникають у ході реалізації проєктів, впливають на їх ефективність. Тому постійний контроль ситуацій у проєкті забезпечить проєктному менеджеру можливості в оперативному прийнятті управлінських рішень, що сприяє підвищенню ефективності проєкту. Дослідження базується на застосуванні ситуаційного аналізу, що представляє комплекс технологій підготовки, прийняття та реалізації управлінського рішення на основі аналізу окремо взятої управлінської ситуації. Для кожного Sprint проєкту в умовах Scrum у ході Sprint Planning, а також у подальших Daily Scrum пропонується застосування процедури ситуаційного управління, що включає аналіз ситуаційних факторів та дослідження їх впливів, побудову графоаналітичної моделі ситуаційного управління, вибір рішення, що спрямоване на досягнення ситуативної цілі, аналіз отриманих результатів. Графоаналітична модель ситуаційного управління IT проєктом в умовах Scrum має демонструвати причинно-наслідкові зв'язки між сформованими внаслідок тих чи інших факторів ситуаціями та рішеннями, що мають сприяти досягненню визначених цілей. Встановлення причинно-наслідкових зв'язків між поточною ситуацією, ситуаційними цілями та рішеннями забезпечує можливості оцінки ситуації та прийняття ефективного управлінського рішення для IT проєкту в умовах Scrum. Дослідження впливів зміни ситуаційних факторів на ситуацію забезпечує моніторинг ситуації в режимі реального часу для IT проєкту в умовах Scrum. Запропонований індекс ефективності для ситуації дає можливість оцінки ситуації та прийняття відповідних управлінських рішень, що забезпечить підвищення ефективності проєкту.

Ключові слова: *Scrum, Sprin, фактори, ситуація, граф.*

Стаття надійшла 28.05.2022
Прийнято 14.06.2022

DOI: 10.24025/2306-4412.2.2022.261704