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МОДЕЛЬ УПРАВЛІННЯ РИЗИКАМИ ІТ-ПРОЕКТІВ НА ОСНОВІ ЗНАНЬ

KNOWLEDGE-BASED RISK MANAGEMENT MODEL FOR IT PROJECTS

АНОТАЦІЯ. У статті розглянуто шляхи розв'язання проблем, пов'язаних з використанням моделей, заснованих на знаннях, в управлінні ризиками ІТ-проектів. Розроблено модель управління ризиками ІТ-проекту, засновану на знаннях, яка на відміну від наявних дозволяє врахувати особливості різних методологій розроблення програмного забезпечення та надає механізм логічного виведення для бази знань.

КЛЮЧОВІ СЛОВА: Управління знаннями, база знань, управління ризиками, ІТ проект, модель управління ризиками.

АННОТАЦИЯ. В статье рассмотрены пути решения проблем, связанных с использованием моделей, основанных на знаниях, в управлении рисками ИТ-проектов. Разработана модель управления рисками ИТ-проекта, основанная на знаниях, которая в отличие от существующих позволяет учесть особенности различных методологий разработки программного обеспечения и предоставляет механизм логического вывода для базы знаний.

КЛЮЧЕВЫЕ СЛОВА: Управление знаниями, база знаний, управление рисками, ИТ проект, модель управления рисками.

ANNOTATION. In the article, the ways of solving the problems concerning the use of knowledge based models in IT project risk management are reviewed. A knowledge based IT project risk management model, which, in contrast to the existing ones, allows for peculiarities of different software development methodologies and provides an inference mechanism for the knowledge base.

KEYWORDS: Knowledge management, knowledge base, risk management, IT project, risk management model.

Problem statement. Because of rapid development of technologies, constant changes in requirements and immaterial deliverables, IT projects are implemented under conditions of uncertainty and are highly susceptible to risks. According to the current statistical data [1], only 39 % of all IT projects are successful, i. e. delivered with required features, on time and within budget. At the same time, the most common causes of IT projects' failures include changing priorities within organizations (in 40 % of cases), inaccurate requirements (38 %), changes in project objectives (35 %), undefined risks and opportunities (30 %), inadequate cost estimates (29 %), and inaccurate task time estimates (27 %) [2].

Uncertainty either positively or negatively affects achieving project objectives. In order to increase predictability of project outcomes, it is necessary to reduce the level of uncertainty in a project and develop response measures adequate to risk assumptions and estimates. According to ISO 31000:2009, uncertainty is "the state, even partial, of deficiency of information related to, understanding or knowledge of an event, its consequence, or likelihood" [3]. Proceeding from the aforementioned, reducing uncertainty requires obtaining and using relevant information, or knowledge, about events or processes that may have impact on achieving project goals. It is particularly important for IT projects which are knowledge intensive and imply high levels of complexity and risk.

The concepts and principles of effective knowledge use were embodied in knowledge management. Knowledge management is "a discipline that promotes an integrated approach to identifying, capturing, evaluating, retrieving, and sharing all of an enterprise's information assets" [4]. Statistics identifies that organizations applying knowledge transfer technologies increase the chances of project success by 20 % [2]. Moreover, the organizations transferring knowledge effectively meet original goals (82 %), complete projects on time (74 %) and within budget (75 %) more often than those that are less effective (62 %, 42 % and 48 % respectively).

Since it was established as an academic discipline in 1990, knowledge management with its ideas has merged with risk management techniques forming a knowledge risk management approach. In addition, knowledge management has started being embedded in project management domain. At the same time, there is little research on applying knowledge management tools to risk management in IT projects considering their particularities.

Moreover, the existing approaches and models don't allow for particularities of different software development methodologies as

well do not specify the principles of decision support systems. In order to improve the effectiveness of applying knowledge management techniques to IT project risk management, these issues require addressing and further research.

Publications analysis. Knowledge management (KM) in the context of project management is defined as "the systematic process of identifying, capturing, organizing, and disseminating/sharing explicit and tacit knowledge assets that add value to the project(s) and organizations" [6]. Explicit knowledge can be formally expressed and includes but is not limited to print publications, internal records, databases and data warehouses, best practices etc. Tacit knowledge, which is not codified, exists in the form of experience and expertise.

The effective use of knowledge often depends on its organization. This requires a certain knowledge management method and, more important, a form or manner, in which it will be organized. As mentioned above, the use of knowledge management techniques has proven its significance for project success. In order to identify the most widespread and effective knowledge management practices, the PMI conducted the specific study [5]. According to the findings of the study, the most popular KM techniques by knowledge life cycle profile are as follows:

1) Knowledge identification is done mainly through identification of crucial knowledge. Techniques that are used less often include industry benchmarks, identifying knowledge domains and current gaps in documented knowledge, performance statistics, expert judgment etc.

2) The most popular method of knowledge capture is documenting lessons learned for each project or programme. Other common ways of capturing knowledge include domain experts, the company intranet, knowledge transfer workshops etc.

3) The most common ways knowledge is shared include intranet search engine, informational networking, peer-review process, and post-implementation reviews.

4) Knowledge application is facilitated mainly with the use of knowledge assets inventories, searchable databases of lessons and stories, knowledge transfer-related software resources etc.

5) Knowledge assessment is generally done based on project success rates, quality of deliverables, and project efficiency.

Morales-Arroyo et al. [10] adduce the most widespread knowledge management tools which can be used corresponding to project management stages and KM processes (see table 1).

Table 1

SELECTING KM TOOLS FOR PROJECT MANAGEMENT. SOURCE: [10].

	Definition of Goals	Planning	Execution and Monitoring	Closing	Evaluation
Knowledge creation	Conceptual models Brainstor-ming Assumption busting	Conceptual models CATWOE			Lessons learned Best practices
Knowledge capture	Document managemen t systems (DMS)	DMS	DMS Information retrieval systems (IRS)	DMS IRS	DMS IRS
Knowledge transfer-sharing	Social network analysis (SNA) Groupware	Social network analysis Groupware and com-munication technolo-gies	Groupware and communicat ion technologie s		Groupware and commu-nication techno-logies
Knowledge reuse	Lessons learned Best practices	Knowledge repositories IRS Experts systems Business intelligence	Knowledge repositories IRS		

Besides the application of numerous KM methods (tools, practices), in order to merge the project management and knowledge management disciplines, several models were proposed. The model constructed by Yeong et al. [13] implies that knowledge management and project management are influenced by such common factors as culture, process and technology (see figure 1). Also, it is assumed that continuous feedback and alignment of PM and KM enhances project success.

Handzic et al. [7] developed the model allowing for intellectual capital of an organization (see figure 2). The components of KM include contextual contingencies, drivers of KM as well as knowledge management practices. The project management components include

are people (stakeholders) and process elements as critical intellectual capital dimensions, and project success as PM and KM outcome component. Concerning the relations, the model implies that various motivational forces and contextual contingencies affect the choice and application of knowledge management practices and thereby have a mediate impact on project success.

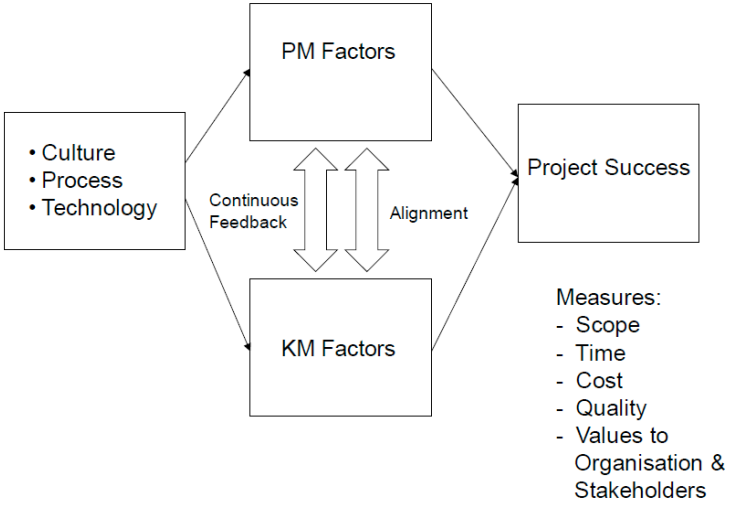

Figure 1. Integrated knowledge management and project management model. Source: [13]

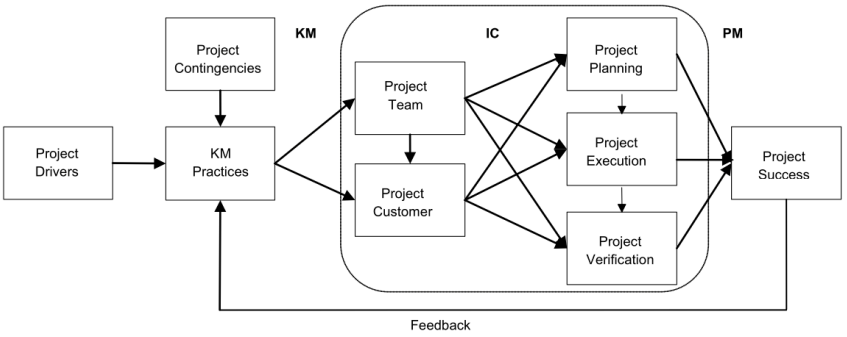

Figure 2. Proposed Merged Model of KM, IC and PM. Source: [7]

Another direction of applying knowledge management to reduce uncertainty is knowledge risk management. Massingham [14] examines how conventional approaches to risk management based on decision tree methods are ineffective and proposes an alternative knowledge risk management model. In the Unilever case study [12] four processes for knowledge risk management corresponding with knowledge life cycle were picked out:

1) Knowledge Discovery. New risks imply new measurement ways as well as new potential events and workflow that can be affected. The application of the existing risk knowledge facilitates understanding current or new risks.

2) Knowledge Capture. Risk management principles require that the captured risk knowledge should be "codified, stored, organized and indexed within the knowledge base" [12].

3) Knowledge Transfer. RM provides a holistic view that allows individuals and organizations learning and transferring risk knowledge to develop the capacity to manage them.

4) Knowledge Application. Adopting best practices and lessons learnt, risk knowledge is embedded into new product development and converted into competitive advantage.

Concerning the application of knowledge management tools to risk management in IT projects, there are few publications.

Vetrici and Cristian [17] propose to use a knowledge-based stochastic model to estimate duration of software projects. The model applies Monte Carlo simulation over the activity graph to the calculation of project deadlines based on information from the knowledge base including historical data on task durations from completed projects. Historical data is tracked and stored with the use of document management systems.

Neves et al. [19] analyse the integration of knowledge management techniques with risk management in software development projects. According to the results of the case study, it was identified that, in IT projects, knowledge management techniques contributed to risk management activities when those techniques were used to identify, analyse and prioritize risks. At the same time, Neves et al. note that, to achieve the desired effect, such activities should be structured allowing for to specific techniques used by each organization.

Alhawari et al. [18] developed a conceptual framework (Knowledge-Based Risk Management). The framework consists of components corresponding with knowledge risk management processes, mentioned above (knowledge-based risk capture,

knowledge-based risk discovery, knowledge-based risk examination, knowledge-based risk sharing, knowledge-based risk evaluation) as well as knowledge-based risk repository (see figure 3).

According to Alhawari et al., the aim of processes related to knowledge-based risk repository is to integrate knowledge management and risk databases as a collation of captured information (expertise, lessons learned, case studies, best practices and branch standards). Thus, knowledge application provides the stakeholders access to the latest information and updates to risk knowledge in the repository. In order to facilitate the access, using expert systems, decision support systems, and enterprise information portal is proposed.

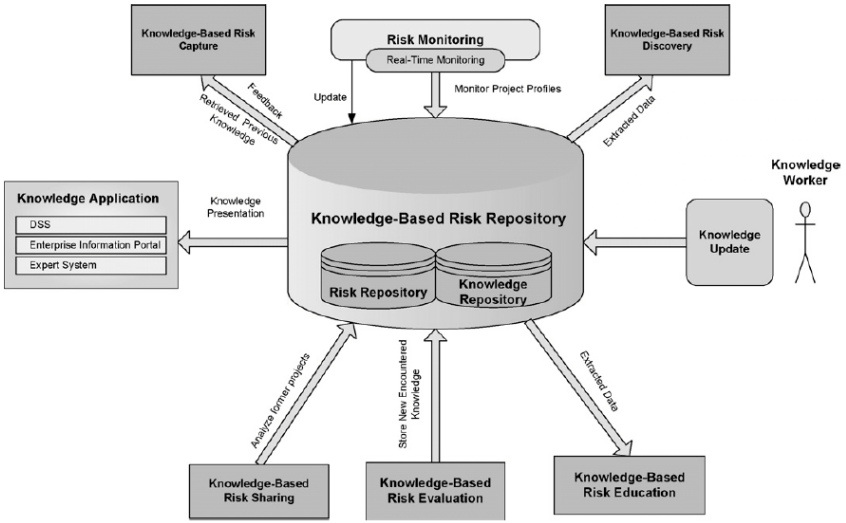

Figure 3. Knowledge-based risk repository. Source: [18]

*Unaddressed issues of the general problem***.** The analysis of publications has shown that, despite numerous propositions concerning the integration of knowledge management with project management, the area of risk management in IT projects with the use of knowledge is researched insufficiently.

The existing approaches and models don't allow for particularities of different software development methodologies, which is quite important. In order to model software development project deadlines, Alhawari [17] uses critical path method. At the same time, there is no

information concerning the application of knowledge management techniques to projects using critical chain project management (CCPM) or Scrum.

In the publications, the term "knowledge base" is frequently mentioned. However the term is used in different contexts and meanings. Knowledge base is an "organized repository of knowledge (in a computer system or an organization) consisting of concepts, data, objectives, requirements, rules, and specifications" [20]. The form of the knowledge base depends on whether it is to support retrieval based on expert system/artificial intelligence (data, design constructs, couplings, and linkages incorporated in a software) or human-based retrieval (physical documents and textual information).

In [18], the knowledge base comprises a knowledge-based risk repository, expert system, decision support system (DSS) and enterprise portal. At the same time, the logic of the expert and decision support system, which is quite important for solving specific risk management problems, is not specified.

Formulation of aims. Proceeding from the aforementioned issues, the aim of the article is to develop a knowledge-based risk management model for IT projects that allows for particularities of different software methodologies and provides a logical mechanism for knowledge-based systems.

The main material. Some scientists argue that, for the project's success, risk management techniques are necessary but not sufficient. According to Tesch et al., "critical to the success of projects and the professional project management is the ability to continually enhance the underlying knowledge base" [32]. Due to that, this article focuses on aspects of applying a knowledge-based system to improve risk management in IT projects.

In order to provide balance between the use of available and creation of knew knowledge concerning risks during an IT project's course, it is important that there should be an appropriate monitoring and control tool. This allows prioritizing knowledge management and project management processes.

At the initial stages of the project (i.e. the conceptual and planning phase), it is necessary to capture and analyse the available explicit and tacit knowledge for providing crucial risk estimates and assumptions. Thus, the initial project stages tend to be knowledge-intensive compared to the execution phase when the team is occupied with performing the main project tasks. Because the time is scarce, the project team needs to understand when the knowledge work is useful and when — superfluous.

The critical chain project management provides an effective monitoring and control tool using buffer management [21]. The depletion of the project's buffer, which is composed from safety time extracted from individual tasks compared, compared to the project's progress shows the overall level of project risk (see figure 4). Thereby, buffer management can be used to signalize that the current risk level requires obtaining additional information from stakeholders for further analysis and taking risk response measures. Consequently, when the overall level of project risk is not critical, the performers can concentrate on their current tasks. This is particularly relevant for organizations operating in a multi-project environment where the workload is rather high.

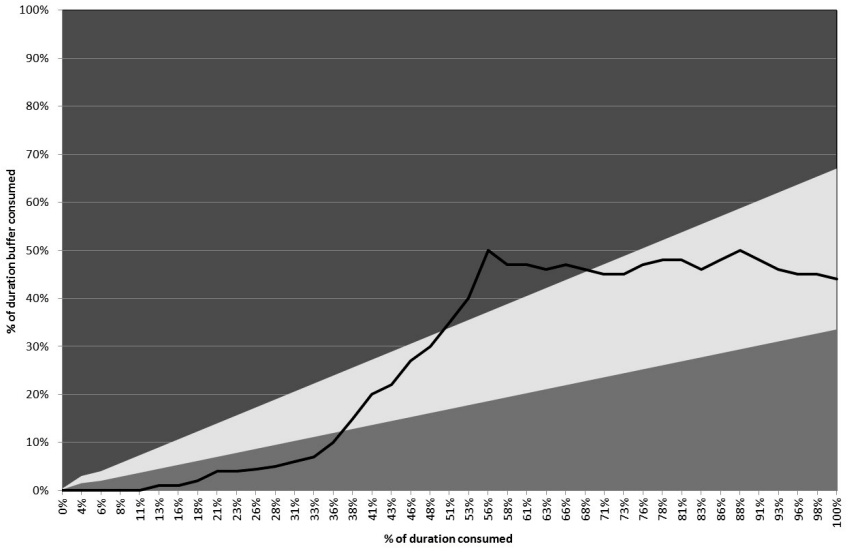

Figure 4. Fever chart. Source: [24]

The application of agile software development methodologies requires more autonomy for project teams [22]. Due to this, in order to implement knowledge management processes in agile organizations, it is even more important to provide a prioritizing tool. Disregarding significant distinctions between CCPM and Scrum, some researchers [23] argue that it is possible to use buffer management in agile projects. Thus, agile organizations can provide the necessary level of autonomy and take the advantages of knowledge management as well.

The knowledge-based risk management model for IT projects is shown in the figure 5.

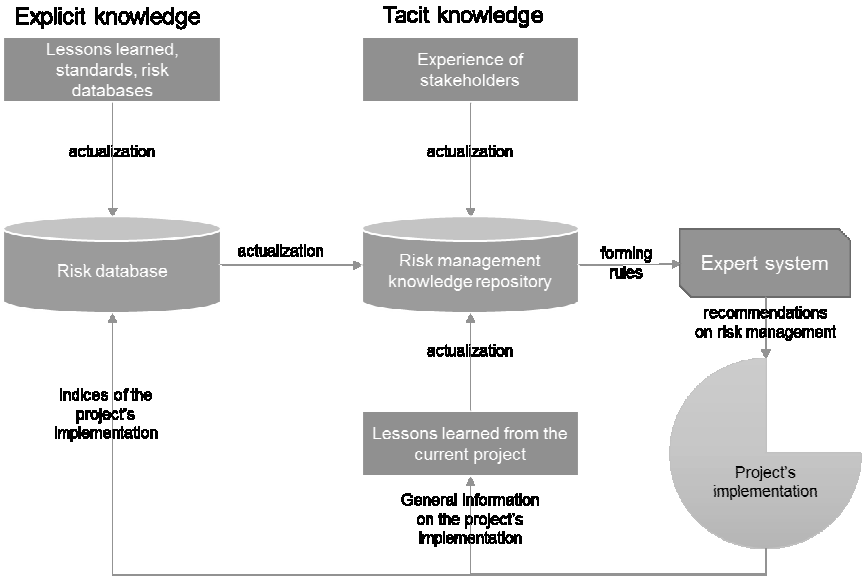

Figure 5. Risk management knowledge-based system.
Source: developed for this article

According to the model, applying risk management to the IT project is based on explicit and tacit knowledge:

1) The available explicit knowledge which includes lessons learned, databases, historical data etc. is actualized to be brought in the risk database. The risk database should contain quantitative and qualitative information on risk classification, severity and probability.

2) The actualized information from the risk database along with tacit knowledge (experience and expertise of the project's stakeholders, the regularities of the knowledge domain etc.) are used to obtain conclusions and regularities reflecting the key risk management policies, estimates and assumptions.

3) Based on the conclusions and regularities, the rules for the expert system, which helps the user identify the issues and address them through a series of questions and answers, are formulated.

4) The recommendations provided by the expert system can be applied to risk management in the project.

5) Since the project's start, based on the performance information (explicit knowledge, including buffer data) and feedback from the stakeholders (tacit knowledge), the knowledge-based risk management system receives new information and the cycle repeats itself.

The expert system's logic is based on the project's transitions between certain states depending on the buffer consumption rate compared to the project's progress. From the previous work [24], in terms of buffer consumption rate, the project at a certain moment of time can be in one of three states: w1, w2 or w3. The expert system's logic is described in the figure 6.

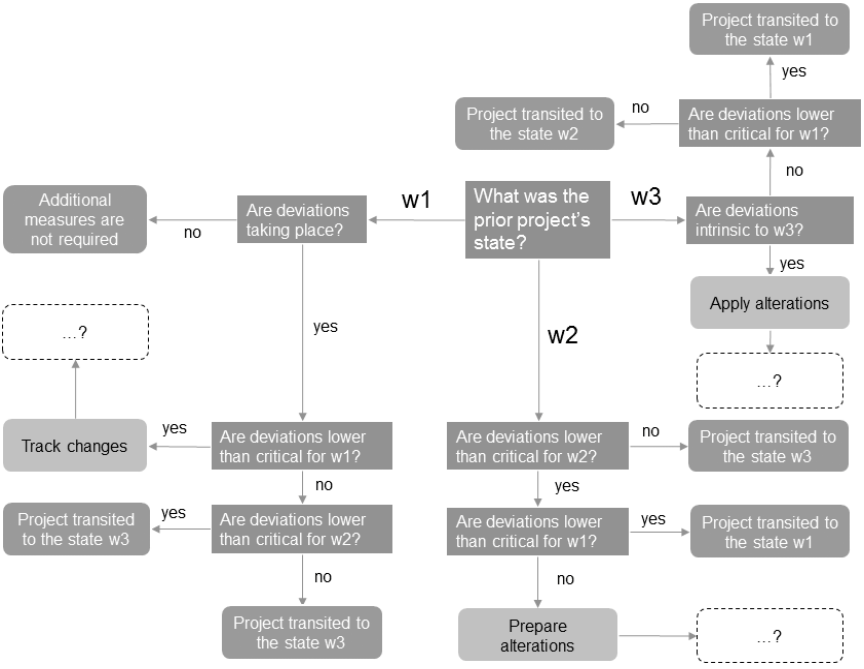

Figure 6. Expert system's logic. Source: developed for this article

According to the division into states, the following rules can be formulated.

1. In the state w1, negative deviations either don't occur or don't exceed the critical level for w1.

1.1. If deviations don't take place, additional measures are not envisaged.

1.2. If deviations in the state w1 take place but do not exceed the critical level, it is necessary to track the consequent changes in the project.

1.3. If deviations exceed threshold values for w1, the project has transited from the state w1 to w2 or w3 since the last observation.

2. In the state w2, deviations that may affect the project's success negatively take place.

2.1. The project's being in the state w2 requires planning new or complementing measures stipulated by the plan with respect to minimization of deviations and returning the project to the state w1.

2.2. If deviations are lower than immanent to the state w2, the project has transited to the state w1.

2.3. If deviations are higher than critical for the state w2, the project has transited to the state w3 since the last observation.

3. In the state w3, deviations negatively affecting the project's success are present.

3.1. The project's being in the state w3 requires taking measures concerning minimization of deviations and returning the project to the state w2 or w1.

3.2. If the deviations are lower than immanent to w3, the project has transited to the state w2 or w1.

Deriving from the rules, to solve the problem for the expert system, we may adduce the following entities:

1) To solve the problem, the expert system needs to "know" in which state the project was according to the last observation. Three possible states are w1, w2 and w3.

2) The criterion of the project's being in a certain state is the rate of deviations, i.e. the buffer consumption rate compared to the project's progress in time. Deviations can be lower or higher than threshold values for a certain state.

To represent the knowledge in the knowledge base, it is proposed to use the CLIPS language. CLIPS, though being simple, provides comprehensive toolset including procedural, rule-based and object-oriented components. The ordered facts for the expert system are as follows.

1) The group of facts describing the project's state since the last observation are made up with the "prior-project-state" entity and it's attributes (w1, w2, w3). For instance, the fact "prior-project-state w1" means that the project was in the state w1.

2) The group of facts describing deviations for w1 (e.g. "deviations-w1 lower").

3) The group of facts describing deviations for w2 (e.g. "deviations-w2 higher").

4) The group of facts describing deviations for w3 (e.g. “deviations-w3 match”).

5) The group of facts describing recommendations for solving risk management problems (e.g. “solution “no additional action required”).

6) The group of facts describing transitions between states (e.g. “solution “see state w1”).

Such elements of the logic structure of the expert system as “track the changes”, “prepare alterations”, and “apply alterations” are not final. The system has the property of subadditivity, i.e. it can be complemented with new rules if necessary. Based on specific information about the causes, factors and conditions of risk occurrence the chains of questions and responses continue till the specific recommendations are provided.

Thus, the use of the knowledge-based risk management system provides a highly adaptive mechanism of identifying and responding risks occurring in a dynamic IT project environment. With the use of knowledge management techniques, the level of uncertainty in the project is reduced within an iterative process involving the feedback from stakeholders (tacit knowledge) and performance indicators based on project execution.

At the same time, another important issue is forming an integrated approach to developing the knowledge-based system in terms of the knowledge use. Handzic et al. [7] pick out four generations of knowledge management models:

1) Technocratic. Technocratic models concentrate on formalised knowledge bases emphasising on information and communication technologies. The issues of the approach include balancing knowledge exploration and exploitation, choosing accurate content and therefore making substantial effort along with providing evolutionary development, flexibility and user acceptance.

2) Oriented towards people and organizations. Such KM systems view knowledge as a competitive advantage determining the firm’s strategy.

3) Context-oriented. As a departure from the earlier approaches, the application of these systems implies that the effectiveness of knowledge management practices is determined with the context in which the knowledge is used.

4) Integrated. Within integrated models recognizing the evolutionary and contextual nature of knowledge management, it is considered as both a social and technological concept.

The proposed model integrates technocratic aspects (knowledge base), regarding knowledge as a competitive advantage and

orientation towards context (risk management). In order to transform tacit knowledge into explicit knowledge that can be stored and exploited, the formalized knowledge base involving the expert system is used. The application of knowledge management practices allows reducing the level of uncertainty in the project so that deliverables could be marketable and competitive in terms of due dates, budget and functionality. Finally, taking into consideration the high accessibility of information nowadays, the model provides not only the possibility to aggregate information but also to extract the relevant knowledge in terms of the specific context, i.e. IT project risk management.

Conclusions and prospects for further research. Resulting from the research, a knowledge-based risk management model for IT projects that allows for particularities of different software methodologies and provides a logical mechanism for knowledge-based systems was developed. According to the model, applying risk management to the IT project is based on explicit and tacit knowledge and includes the risk database and expert system, which helps the user identify the issues and address them through a series of questions and answers.

The expert system's logic is based on the project's transitions between certain states depending on the buffer consumption rate compared to the project's progress. The system has the property of subadditivity, i.e. it can be complemented with new rules if necessary. Thus, the use of the knowledge-based risk management system provides a highly adaptive mechanism of identifying and responding risks occurring in a dynamic IT project environment.

The proposed model integrates technocratic aspects (knowledge base), regarding knowledge as a competitive advantage and orientation towards context (risk management). In order to transform tacit knowledge into explicit knowledge that can be stored and exploited, the formalized knowledge base involving the expert system is used. The application of knowledge management practices allows reducing the level of uncertainty in the project so that deliverables could be marketable and competitive in terms of due dates, budget and functionality.

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