Information and analytical collective decision-making support using intelligent technologies

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Abstract. The issues of organizing collective decision-making support for innovative project teams are considered. Research relevance is justified by the need to reduce the degree of uncertainty in decision-making during the projects set implementation, using accumulated corporate experience and knowledge. A synthesis of the subject area and information systems functionality ontological models is proposed. This will improve the efficiency of information system reengineering and the quality of made decisions, among them during the process of collective decision-making support system development.

Introduction

Currently innovative projects are the integral part of complex production and economic systems (PES) evolution process. This is especially true for the high-tech and science-intensive industries which need to use the latest technologies, equipment and materials to increase the competitiveness of Russian products. In Russian Federation statistical research results, that reflect a state of innovations in the country, regions, and individual industries, are regularly published. According to the research \cite{1, 2} more than 70\% of successful innovative projects are carried out within the existing PES, which is due to the availability in production facilities and formed team of executors. At the same time, if a number of organizations that implement technological innovations in the field of industrial manufacturing remains almost unchanged, the result number of innovative products in the form of manufactured goods, works and services, as well as the costs of technological innovations, has been steadily decreasing over the past years (Fig. 1). In the annual report "Global innovation index", published in September 2020, Russia ranks 47th position between 131 countries by the results of comparative analysis of innovation systems development. Data from this rating indicate a serious decline in innovation results over the past 5 years \cite{3}.

According to the results of manager’s surveys in industrial enterprises, the main reasons in this situation are problems with financing, as well as a decrease in goods, works and services demand, due to a general decline in living standard of a solvent population (Fig. 2).
These reasons are overlaid by the problems that arise in innovative projects management, due to the very nature of projects as a unique activity [4]:

- high degree of uncertainty in assessing the current situation and predicting the consequences of made decisions;
- tight deadlines for solving problems, set at a higher level;
- personnel shortage caused by the complexity of attracting a staff, that combines high professionalism, teamwork skills, and ability to set and solve tasks;
- high variability of external and internal environment of the project implementation;
-unavailability to access the information about the progress of related projects.

From the generalized list of problems, we can distinguish those that are related to the lack of qualified personnel at all levels of decision-making and the lack of information for assessing the current situation. To solve these problems, data mining and knowledge management methods are the best way to predict and guide the progress of current projects based on the accumulated experience of implementing successful and unsuccessful projects by a team of performers. Therefore, a purpose of
the research is to study a possibility of using intelligent knowledge management technologies to improve the efficiency of collective decision-making in the process of innovative projects implementation in complex industrial and economic systems.

1. A task of collective decision-making support in innovative projects implementation

Innovative project activity is characterized by a high degree of uncertainty when making decisions, related among other things to distribution of resources between individual teams of executors, working to achieve a common goal. Development and application of the intellectual decision-making support system (IDSS), which contains decision-making rules and cases, based on the knowledge about a subject area and manager’s experience in various situations, will reduce the degree of uncertainty within the innovative project management.

Despite the fact that knowledge management problems in project activities have been actively discussed in recent years, which has led, for example, to including the knowledge management processes in project management standards [4], in reality, a procedure of using PES accumulated intellectual assets is described only for individual projects. A lack of clear methods that allow to build such system on any economic object affects the effectiveness of the developed DSS – each time they need to be designed “from scratch”, pushing from the specific tasks of a specific project. At the same time, on the one hand, in the practice of information systems developing there are many standard solutions, which could be successfully implemented at the enterprise after a certain adaptation. On the other hand, publications [5-7] offer solutions related to the use of ontological analysis in software design.

The authors believe that it is possible to offer similar methods of typical design also within the development of intelligent DSS. Such IDSS, based on the use of accumulated experience and knowledge, will be able to rely on the best practices in the field of project management, redirected on the specific subject area of realizing innovative project. This requires combining of the ontological approach to the innovative project subject area specification, implemented within PES, and the object-oriented approach to the IDSS development. Proposed article describes the stages of organizing the information and analytical collective decision-making support for the innovative project teams. Originality of the approach lies in a synthesis of the subject area and the information systems functionality ontological models, that ensure the individual projects implementation, as a part of a comprehensive innovative project.

2. Organization of collective decision-making support for project teams

Analysis of the innovative projects realization in PES [8, 9] showed that the success of its preparation and implementation largely depends on:

1) the competent application of project management methods related to the specific situation in implementing project;

2) the use of modern information technologies, which are largely the basis for finding new technological solutions and increasing the economic efficiency of its application;

3) the project manager’s ability to make decisions based not only on his own experience and knowledge, but also on the use of joint experience of PES and best practices in industry as whole.

Large innovative projects usually have organization structures, the complexity of which depends not only on the number of its participants, but also on the nature of the tasks solved in the project. Thus, to get the final result, it may be needed to develop and deploy a project management system (software project), to build or modernize a manufacturing area (construction project), to develop complex schemes for attracting financing to a project (investment project), and so on (fig. 3).

Most often, such projects are carried out by different project teams, when each has its own principles of interaction, and can adopt its own managing and decision-making methods. A single management center is needed to achieve planned results of the complex project while respecting the interests of all its participants.

Sometimes such a center is an appointed project manager with more authority. In this case, a decision maker responsible area is clearly defined, decisions are made faster, but they can have
subjective and voluntary character, when there is an ambition to achieve the desired goals without taking into account objective circumstances and possible consequences. In another case, the so-called project committee can serve as a decision-making center, which slows down the decision-making process due to the need for its comprehensive consideration and coordination, but at the same time guarantees a balanced approach to the interests of all integrated project participants. In the case of collective decision-making interaction procedures become significantly more complex, which makes it necessary to use scientifically substantiated approaches to reach consensus as soon as possible.

Fig. 3. Complex innovative project management within the production and economic system

It should be also remembered that organizational structure of the project will overlay organizational structure of the production and economic system, which often leads to conflicts between its participants. Therefore, all components (both of the production and economic system and of the innovative project) should function in a unified information field that provides diverse groups of decision-makers with the up-to-date and reliable information about the PES production and economic activities progress and projects implementation (Fig. 4).

Studies devoted to the development of a comprehensive reference production ontology [10-12] have shown the effectiveness of its application to improve the quality of production and economic systems functioning in the case of regular business processes realization that have stable characteristics, including a clear sequence of operations. On the other hand, many methods adapt project management standards to real-world problems [13, 14]. The authors offer to use such approach to aggregate heterogeneous information on more complex, dynamically changing objects – innovative projects that are implemented in production and economic systems along with the current course of production activity. From the project management information system information about all parameters of a complex project and its subprojects – both planned and actual values of labor costs, resource costs, deadlines and priority of works, etc., can be obtained. Local project resources,
including information systems of various purposes, reflect data about business processes implementation, which are necessary to achieve project goals, and contain information about the projects subject areas. Comprehensive analysis of obtained data allows the groups of decision-makers to assess a probability of problem situations arising at various stages and in various areas of innovative project and severity of decision consequences.

Neither one innovative project can be successfully realized without using the software tools, methods and products to some extent. This position follows both from definition of an innovative project and transition to a digital economy in all spheres of human activity [15]. In this regard, the best position belongs to those enterprises whose organization structure includes relevant services that are well qualified with the specifics of PES business processes. At the project initiation stage this helps to avoid spending time on searching a partner, who can provide services of information technologies implementation and support, that will be used during the innovative project realization. Another variant is also known, when IT company has a long-term cooperation with a large customer, whose
innovative projects are supported by its information technologies. Most often such IT company has a status of system integrator, since it is necessary to solve the problems of various information systems joint use, which ensure implementation of the customer's business processes.

Thus, the main organization stages of the collective decision-making support can be represented as follows:

1. Ontological analysis of the projects, included to innovative project. Project ontology includes description of each project subject area essential aspects – source data, obtained results, main life cycle stages, composition of participants.

2. Ontological analysis of IT tools, that support each project subject area business processes implementation. IT ontology includes description of the software products functionality, composition of users, and a complex of technical tools and specialists that ensure its functioning.

3. Identification of interacting projects and prioritization in case of conflicts over allocated resources.

4. Development of the innovative project integrated ontology, taking into account projects classification and organization structure of the decision-makers group.

5. Development of the IDSS, which will be based on the project team member’s decision-making rules and decision-making cases, fixed in PMIS and based on the PES projects implementing experience.

Thus, the IDSS structure can be defined as a set of the following components (Fig. 5):

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\text{IDSS} = < \text{Onto, KB\{Rule, Case\}, M, S(M), Dec }>, \quad (1)
\]

where \text{Onto} – an integrated knowledge management ontology;
\text{KB\{Rule, Case\}} – a knowledge base with the modules of rules and cases;
\text{M} = \{M_1, M_2, \ldots, M_N\} – a set of analytical, simulation, formal, logical models, realizing the functions of modeling the decision-making process;
\text{S(M)} – a module, realizing a required model(s) choice for the considered problem;
\text{Dec} – a module of decisions forming, relying on the knowledge base and mathematical modeling.

An important moment when building a knowledge base is that in problem situations there exist rules and cases indicators to the project team participants, who performed the decision-makers functions in previous projects, or should realize proposed recommendations and take responsibility for its realization in current projects.

It is proposed to use the ontological model for describing both successful decision-making cases that include successful decisions and descriptions of its applications context, and those decision-making cases that contain descriptions of actions that are erroneous and ineffective, and which should be avoided later in project realization [16].

In order to use and share the knowledge effectively, it is needed to provide regular and repeatable work with the model and to ensure that the rules and cases are kept up to date.

Proposed approach to the knowledge base inductive learning includes the intellectual analysis of cases and adding them to the rule base, which can be described as follows:

- search for the cases, that are similar to occurred problem situation;
- applying them for problem solving;
- evaluating the effectiveness of obtained decision-making results;
- saving a new case in the knowledge base, intended to the occurred problem;
- considering the question of converting the cases into the decision-making rules, if these cases were used successfully for the defined problem situations several times;
- realizing the intellectual case analysis and adding new rules to the knowledge base.

Knowledge base checking by systematically monitoring the system under implementation conditions allows detection and correction of errors related to the incompleteness of the knowledge base, and elimination of contradictory and useless rules, which increases the accuracy and speed of the system.
Information search based on ontology

Decisions output based on rules

Decisions output based on cases

Making recommendations

Evaluating the decisions effectiveness

Providing recommendations for decision-making

Creating queries to the knowledge base

Integrated knowledge management ontology Onto

Onto

OWL DL + SWRL

Logical output algorithm

Problem situation cases

Case module Case

Inductive learning

Cases intellectual analysis

Decision-making rules

Rule module Rule

Learning new knowledge

Decision-making support models and methods M

Evaluating the decisions effectiveness

Making recommendations

Adapting the decisions

Optimization module

Fig. 5. A structure of IDSS components interaction

**Conclusion**

Combination of heterogeneous projects that are the parts of the innovative project complicates its management system, since each subproject has its own approaches to managing and allocating resources, source data formats and different ways to present results. A key factor for the innovative project success is the purposeful coordinated joint activity of various project participating teams. To achieve this goal, it is proposed to develop and implement an IDSS that accumulates knowledge and experience in project management, subject area and information systems functionality, ensuring the project’s realization. In future, authors plan to continue the research in order to evaluate the effectiveness of IDSS basing on simulation modelling of the problems, solved during the process of innovative project management.
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References

[1] Project Management Institute 2019 Pulse of the Profession®: The Future of Work: Leading the Way with PMTQ (Pennsylvania: PMI Publications)

[2] Gokhberg L, Ditkovskiy K, Kuznetsova I et al. 2019 Indicators of Innovation in the Russian Federation: 2019 (Moscow: National Research University Higher School of Economics) p 376

[3] Dutta S, Lanvin B and Wunsch-Vincent S 2020 The Global Innovation Index 2020: Who Will Finance Innovation? (Geneva, New Delhi: Cornell University, INSEAD, and the World Intellectual Property Organization) p 448

[4] Project Management Institute 2017 A Guide to the Project Management Body of Knowledge (PMBoK Guide): Sixth Edition (Pennsylvania: PMI Publications) p 762

[5] Khoroshevsky V 2019 Designing of software systems under ontology control: models, methods, implementations Design ontology 4(34) 9 429–48.

[6] Zagorulko G 2019 Model of the integrated support to the intelligent DSS developing Design ontology 4(34) 9 462–79

[7] Gavrilova T A, Kudryavtsev D V and Muromtsev D I 2016 Knowledge Engineering. Models and Methods (Saint Petersburg: PS Lan) p 324

[8] Nikulina N, Malakhova A and Ivanova I 2019 Application of intelligent technologies in solving the innovative projects problems 21st Int. Conf. Complex Systems: Control and Modeling Problems (CSCMP) (Russia, Samara) (IEEE Xplore Digital Library) pp 777–82

[9] Chernyakhovskaya L, Nikulina N and Malakhova A 2020 Studying the problem of innovative projects management in strategic planning and progress processes of production and economic systems Information technologies 4 26 239–51

[10] Chungoora N, Gunendran G, Young R, Usman Z, Anjum N, Palmer C, Harding J, Case K and Cutting-Decelle A 2012 Extending product lifecycle management for manufacturing knowledge sharing Journal of Engineering Manufacture A12 226 2047–63

[11] Palmer C, Usman Z, Cancigliero O, Malucelli A and Young R 2017 Interoperable manufacturing knowledge systems International journal of production research 8 56 2733–52

[12] Borgo S and Leitão P 2007 Foundations for a core ontology of manufacturing Integrated series in Information Systems 14 751–75

[13] Pavlov A N 2019 Effective Project Management based on the PMI PMBOK 6th Edition Standard (Moscow: Knowledge Laboratory) p 270

[14] Kheldman K trans. from Eng. Shavrina A V 2016 Professional project management: 7th ed. (Moscow: Knowledge Laboratory) p 760

[15] Lubyanskaya E and Anisimov YU 2019 Features of the innovative projects strategic management system in the cases of digital economy Production organizer 2 27 81–93

[16] Chernyakhovskaya L, Nikulina N and Malakhova A 2019 Principles of the knowledge base formation as a part of intellectual decision support system in innovative projects management Atlantis Highlights in Computer Sciences: Proc. of 21st Int. Workshop on Computer Science and Information Technologies (CSIT 2019) (Austria, Vienna) vol 3, ed N Yusupova, T Sauter et al (Amsterdam: Atlantis Press) pp 125–30