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Project Risk Management Based on Activity Progress Modeling in the Nuclear Power Industry

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ABSTRACT
The paper presents a risk-oriented approach to project management from the standpoint of events and risk factors. Risks for compliance with the time characteristics of the project are considered in more detail, as one of the most relevant ones in the implementation of the project. As the main tool for managing the time characteristics of the project, activity progress modeling with risk accounting was proposed. Methods for analysing the sequence of works, the composition of key risks associated with an increase in the development time of the project, and calculations of the probabilistic characteristics of project risks were carried out. The results of applying the proposed approach are generalized.

Keywords: *Project, Risk, Control, Activity progress chart, Probabilistic characteristic, Risk-oriented approach.*

1. INTRODUCTION

Nowadays, world development is characterized by economic crises on a local and international scale, changes in the social sphere, as well as expanded globalization and digital transformation in all areas [1].

The main theoretical prerequisites and methodology for risk management are documented in the domestic series of GOST standards (Russian State Standards). The main standard is GOST "Risk Management. Principles and Guidelines" (GOST R ISO 31000-2019 GOST), which defines the main approaches, terminology, as well as the procedure for integrating risk management infrastructure into organizational processes [2]. Related standard GOST "Risk Management. Terms and definitions" (GOST R 51897-2011/ISO Guide 73:2009) records the complete terminological apparatus of risk management as a management process [3]. Project management using risk management methods is fundamentally based on meeting the requirements of GOST R ISO/IEC 31010 – 2011 "Risk Management. Risk assessment methods" [4].

Due to the fact that the activities of organizations and industries are associated with a significant influence of various kinds of uncertainties [5], the "ability" of the organization to adapt to changes that are initiated from within or under the influence of the outside comes to the fore. One of the drivers of these changes is risks as an integral element of economic, political and social life, accompanying all areas and spheres of activity. Identification, assessment of risks and opportunities, as well as complex risk management is becoming a key task, on the effectiveness of the implementation of which the future of the organization depends [6–12]. This fully applies to projects, since the complexity of their implementation is determined by many external and internal factors, including the dynamism of the environment, the number of participants, the feasibility of requirements, and the degree of adaptability of the project implementation timeline [13].

The paper discusses the design organization of the State Atomic Energy Corporation Rosatom, which provides services for the design of nuclear power plants within the framework of EPC contracts in the Russian Federation and abroad [14]. The portfolio of foreign projects as of December 31, 2019 included 36 NPP units [15]. A complex ecosystem is being formed in the design organization of State Atomic Energy Corporation Rosatom, which is determined both by external conditions, including the requirements of contractual obligations and the regulatory and legal framework in the field of nuclear energy, and by the internal

organizational and management processes of the organization. In this regard, the activities of this design organization as a whole are characterized by a high degree of uncertainty.

The classic project constraints are time, cost and scope of work [16], which form a project triangle, the area of which determines the quality of the project. Changing any constraint affects at least one of the remaining ones and, accordingly, in general – quality. Thus, any actions to maintain and improve the quality of the project are essential [17]. Taking into account the specifics of the nuclear industry, the balance of the project triangle is established as follows: the scope of work corresponds to the reference design of the NPP and is regulated by the requirements of the supervisory authority of the owner country, as well as the budget determined at the stage of pre-contract work, which are the most fixed areas of the project, all other things being equal. The main parameter that depends on changes in the external and internal conditions for the implementation of the project is the implementation period. Thus, ensuring the fulfillment of deadlines is a priority in increasing the efficiency of project implementation [18].

2. MAIN PART

The paper presents the use of risk-oriented modeling tools in project management to ensure the fulfillment of contractual deadlines.

The term "risk" will be understood as the uncertainty of the occurrence of some event that affects the duration of the planned activities, and the "risk factor" will be defined as a circumstance that affects the likelihood or consequences of risk realization, but is not necessarily its immediate cause.

Within the framework of project management, three goals of risk management are established, which are related to achieving project goals, increasing the efficiency of activities within the framework of project implementation, and creating favorable conditions for sustainable development.

So, one of the important tools for planning, assessing and adjusting the time and cost parameters of the project is the activity progress method (analysis of the sequence, start and end dates of work on the project), which allows linking the execution of various works and processes in time, obtaining the total duration of the entire project implementation [19]. The tasks of activity progress planning are [20]:

- formation of volumes, composition and time periods of work performance;
- determination of the order of chronological execution (including those implemented sequentially and in parallel, drawing up an activity progress chart);
- distribution of work between performers.

Due to the fact that there are many factors affecting the actual duration of the work, the timing of the activities on the schedule deviates from the planned ones. To update the schedule, taking into account the goals of the project and contractual obligations, the correction of inconsistencies that have arisen during the execution of project activities is used. In the event of a change in the timing of work, the financial component of the project changes, therefore it is necessary to constantly monitor and update the schedule.

One of the ways to manage timelines when working with activity progress charts is risk modeling. Risks should be determined for each specific job and include the deviation of the timing of the corresponding work from the planned values [21]. The schedule is also supplemented with information about risks, their probabilistic characteristics and the magnitude of the degree of influence on the time of performance. When using risk-oriented modeling, it becomes possible to monitor the progress of work, as well as to control the entire project by assessing the predicted values of the terms of the upcoming work on the project, which allows saving material and time resources and making management decisions based on the model data. Thus, as a project management tool, it is proposed to consider the integration of risk management methods into the planning process by building a simulation model of the project development activity progress chart. The essence of this approach is to simulate the onset of risk events and assess their consequences for the organization in question [22].

A process-based approach is used to build a model of an activity progress chart, i.e. a chronological sequence of events with an average level of abstraction is used.

Risk-oriented modeling allows determining the most likely schedule configuration, optimistic, real, and pessimistic scenarios, forming a pool of preventive measures and types of work and the corresponding risks that make the greatest contribution to the shift of the schedule towards an increase in terms.

The most important aspect of risk-oriented modeling is the subsequent use of the activity progress chart to identify risk events that make the greatest contribution to lengthening the project timeline, and, accordingly, to develop preventive and compensatory measures, such as: rescheduling, reallocation of resources, both material and labor ones, revision of the cost of work, etc.

The process of planning and executing work is the main activity for the implementation of any project and will be considered within the framework of this study as

the main process for testing risk-oriented modeling tools. The accuracy of the baseline project schedule, which is built taking into account historical data on similar projects and expert assessments of the current conditions for the implementation of the project, will allow controlling the terms of work on the project, thereby ensuring customer satisfaction with the quality of the project, maintaining and improving the reputation, and affecting the financial performance of the organization by reducing penalties for deviating from contractual obligations in terms of timing.

Thus, the use of risk-based models in project management within the planning process can be a tool to improve the efficiency of the organization [23].

The documentation developed by Rosatom in the field of risk management for all organizations of the corporation (mechanical engineering, design and construction of nuclear power plants, geological exploration and mining of uranium, conversion and enrichment of uranium, generation of electrical energy, etc.) is unified and determines risks in accordance with the corresponding types of activities.

Risk factors for the design process have been identified at the level of Rosatom:

- "lack of a "detailed design schedule";
- "the appearance of unforeseen work";
- "failure to comply with the schedule for the development of documentation";
- "incomplete information about the project work";
- "low accuracy of planning the timing of work performance".

The paper discusses the key risks established by the State Atomic Energy Corporation Rosatom for the design organization. Within the framework of the study [24], the most significant risks of failure to meet the deadlines for the fulfillment of contractual obligations for the delivery of project documentation to the customer are detailed, which is presented in Table 1.

Table 1. Analysis of critical risks and risks associated with violation of contractual periods

No.	Risk	Risk factors	Responsive activities	Preventive measures
R1	Failure to meet deadlines for reviewing previous revisions of documentation	Lack of competencies; lack of a documentation hierarchy, including the intended composition of the documentation	Transfer (shift of the schedule with official justification from the counterparty)	Establishment in the contract of payment methods and / or methods of securing obligations that reduce the level of risk based on network design
R2	Top-level documents are not approved	The emergence of new requirements; lack of competencies; lack of staff	Mitigation (agreement with the customer in the working order of the principles and the scope of development, is fixed by the protocol)	Changes to the planning process - the inclusion of a verification stage and the correlation of the timing of the development of documentation with the timing of the development of top-level documents Formation of time reserves for key works
R3	Uncertainty of the composition of the document on the part of the customer	The emergence of new requirements; Lack of competencies; Lack of a documentation hierarchy, including the intended composition of the documentation	Mitigation (agreement with the customer in the working order of the principles and the scope of development, is fixed by the protocol)	Recording customer requirements in a separate document; Establishment in the contract of the maximum number of deviations of documentation in connection with new requirements

In the course of analyzing the data obtained in the study [24] on the execution of the activity progress chart, it was determined that only 4.5 % of the documentation is handed over to the customer on time. Thus, a high percentage of work not completed on time within the project defines a serious problem that requires a scientific approach to the analysis of risks affecting the timing of the fulfillment of contractual obligations for the development of project documentation.

The input data for building a simulation model are:

- bill of works for the project;
- estimated data on the duration of the development of documentation;
- historical data on risks – a list of risks and an expert assessment of the shift in terms of the project in the event of its implementation.

As part of the preparation and analysis of data for modeling, the columns that will be used were

determined, and the removal of low-quality data was performed. Calculations of the average values of the duration of the development of documentation of each type, depending on the specialty, were made.

The Gantt chart based on the initial data was built in MS Project, taking into account the sequence of development of documentation, as well as quantitative characteristics (Table 2).

Table 2. Gantt chart for the project

No.	Type of work	Duration, days	Start	End	Previous processes
1	Procedure (088)	20	24.11.2020	21.12.2020	0
2	Classifier (021)	168	22.12.2020	12.08.2021	1
3	Concept (000)	159	22.12.2020	30.07.2021	1
4	Concept (021)	242	02.08.2021	05.07.2022	3
5	Requirements specification (021)	58	06.07.2022	23.09.2022	4
6	Requirements specification (022)	43	02.08.2021	29.09.2021	3
7	Quality plan (000)	85	22.12.2020	19.04.2021	1
8	Quality plan (021)	101	20.04.2021	07.09.2021	7
9	Explanatory note (000)	190	20.04.2021	10.01.2022	7
10	General information (021)	185	26.09.2022	09.06.2023	2,5
11	Explanatory note (021)	153	12.06.2023	10.01.2024	2,10
12	Specification (021)	143	29.11.2023	14.06.2024	13
13	Scheme (021)	122	12.06.2023	28.11.2023	10,2
14	Quality plan (022)	126	20.04.2021	12.10.2021	7
15	Explanatory note (022)	201	13.10.2021	20.07.2022	14,6,8
16	Specification (022)	223	21.07.2022	29.05.2023	14,15
17	Scheme (022)	197	21.07.2022	21.04.2023	15
18	3D model (000)	68	29.11.2023	01.03.2024	13,17
19	Calculation (021)	63	04.03.2024	29.05.2024	18
20	Calculation (022)	110	04.03.2024	02.08.2024	18
21	List (000)	26	05.08.2024	09.09.2024	19,20
22	Conclusion (000)	47	05.08.2024	08.10.2024	19,20
23	Project database (000)	15	04.03.2024	22.03.2024	16,18

The estimated completion date of the project under the given conditions and the starting date 24.11.2020 is 08.10.2024. Determination of possible deviations in the timing of the completion of the project will be determined using progress activity modeling taking into account risks in specialized software for risk modeling – Tamara. As a result of modeling the project development process in Tamara software, the probability distribution plot of the project completion at the end date was obtained, which is shown in Figure 1.

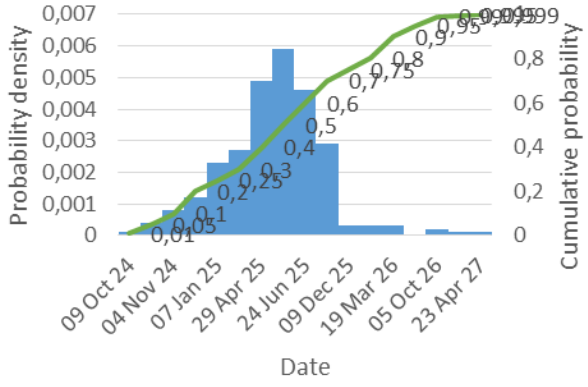

Figure 1 Probability Distribution Plot.

The simulation results are presented in Table 3.

Table 3. Simulation results

No.	Statistics	Value (date)
1	Plan	Planned completion date according to the schedule: 08.10.2024
2	Average	10.06 2025
3	Min	08.10.2024
4	Max	17.03.2027
5	10 %	23.01.2025
6	50 %	30.05.2025
7	90 %	11.11.2025

Interpretation of results:

- planned completion date according to the schedule: 08.10.2024;
- average date of completion of the project: 10.06.2025;
- minimum completion date (no risk was realized): 08.10.2024;
- maximum date of completion of the project (all risks were realized): 17.03.2027;
- 10 % probability that the project will be completed on 23.01.2025;

- 50 % probability that the project will be completed on 30.05.2025;
- 90 % probability that the project will be completed on 11.11.2025.

The distribution diagram of the types of documentation that bring the greatest contribution to the increase in the development time of the project under study is presented in Figure 2.

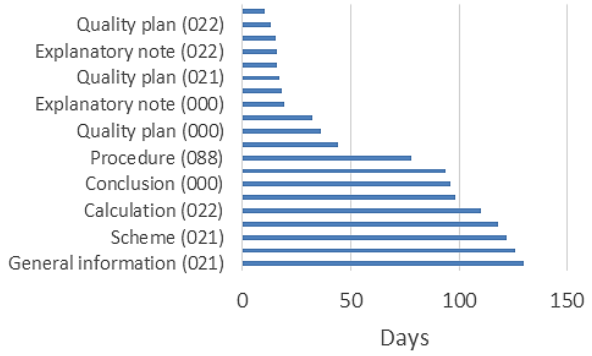

Figure 2 Diagram of the distribution of work performance terms.

The diagram of the distribution of risks that bring the greatest contribution to the increase in the project development time is shown in Figure 3.

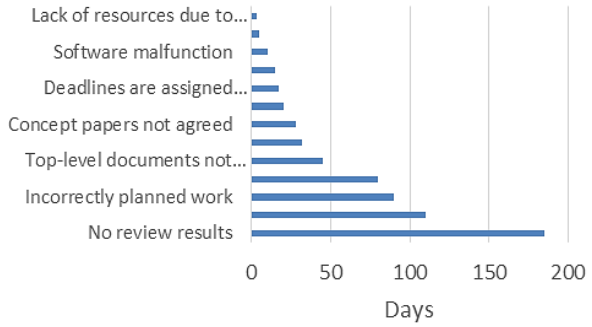

Figure 3 Diagram of distribution of risks of increase in terms of work.

Thus, to solve the problem considered in this paper, the following measures were taken:

- prerequisites for the use of risk-oriented models in project management have been determined;
- a list of the main types of risks was compiled with the consequence of implementation in the form of a failure to meet the deadlines for the development of project documentation;
- a risk map was built;
- in the course of quantitative analysis, data for building a model were obtained (probabilistic characteristics and deviations);
- a risk-oriented model of the project was built;
- the results of modeling were interpreted, and the obtained conclusions were systematized.

3. CONCLUSIONS

The carried out risk-oriented modeling allows obtaining the following results:

- the distribution of the probabilities of the end of the project is determined in relation to the date and corresponds to the condition, which allows establishing risks; their probabilities and impact are defined as points for the development of preventive or compensating measures in relation to risks;
- the most important components of the project documentation that have the maximum impact on the success of the project are identified, including “General information of the project”, “Specification of project requirements” and “Scheme”, which require the most careful development and analysis;
- the risks that have the maximum impact on the success of the project are identified. In this case, such risks are: risk “No review results”; risk “IDD (external) not received”; risk “Incorrectly planned work”.

One of the options for preventive measures may be the introduction of additional control points in the process of developing documentation and exchanging data with the customer and contractors.

Evaluation of the obtained modeling results determines the relationship between the duration of the planned activities and the occurrence of the corresponding risks, which justifies the need for risk management. When taking measures to reduce the likelihood and magnitude of the impact of unfavorable risks on the project schedule, the project will change in a more optimistic way. If no preventive or compensatory measures are taken, then the estimated increase in terms is from 2 months to 30 months. The obtained results can be used in any high-tech, capital-intensive industry characterized by high requirements for meeting project deadlines.

The development and use of the considered risk-oriented project management model allows “seeing” the general state of the project and allows making management decisions based on facts and data. The method of expert assessments can be used as an additional tool for verifying decisions made.

From the point of view of the authors of the paper, the proposed risk-oriented approach to project management should be built on deep detailing of the description of processes, including the definition of logical relationships with the allocation of key positions

and systematic monitoring of the organization's operating activities on an ongoing basis to form a statistical base. Thus, the use of risk-oriented modeling tools makes it possible to implement a permanent process of improvement and control of project management.

AUTHORS' CONTRIBUTIONS

All authors conceived and designed the study. Daria Timshina conducted the modeling and interpretation of the results. Titiana Leonova and Svetlana Kuzmina made a contribution to reviewing and revising the paper for its intellectual contribution. All authors contributed to manuscript revisions. All authors read and approved the final manuscript.

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