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The Membrane Method of Assessment of Organizational and Technical Reliability and Aggregate Risk of NPP Construction Projects

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Abstract

The results of the research article are based on the analysis of practical activities of the participants of the construction project of a unique and technically complex NPP facility, aimed at improving the organizational and technical reliability of design solutions at all stages of the project life cycle under risk conditions. The conducted system analysis is the basis of methodical recommendations on the selection of a rational option for the organization of the construction of a nuclear power plant (NPP). Conclusions and practical recommendations have been made on the basis of the author's membrane-method simulation model of risk analysis, developed using a modern approach to the application of automated systems of production process planning for the implementation of the NPP project.

Keywords: *Nuclear Power Plant (NPP) Construction, Organizational and Technical Reliability Management, Mathematical Modelling, Computer Risk Modelling, Risk Management, Industrial Construction.*

INTRODUCTION

When studying modern theoretical and practical problems faced by the contractor and the customer of an EPC-contract (Wikipedia, the free encyclopedia, n.d.), used as a modern risk management tool (Grabovoy, 2012; Neftegaz.ru, 2012), there is a need for a comprehensive study of the issue related to the distribution of responsibility and emerging risks of non-compliance with the schedule and cost of megaprojects implemented under international contracts and intergovernmental agreements (Gusakova, Pavlov, 2022; Mazur, Shapiro, 2010). This matter is becoming more and more relevant in the field of nuclear energy and application of "peaceful atom" technologies, as it might entail significant economic losses for the customer.

At the same time, the very application in practice of the EPC-contract for NPP project realization, on the one hand, makes it possible to transfer, delegate risks to another project participant, and on the other hand, the management system itself is transferred to the contractor's area of responsibility, offering a mechanism for reducing

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and compensating the consequences of various types of risk. However, the project risks themselves remain, often even intensified, or new types of risks emerge (Grabovy, 2017; Ovsyannikova, 2004). This once again confirms that the application of EPC-contracts does not remove the risks and they are treated in their pure form, impersonally and independent of economic agents, Customer or Contractor.

SCIENTIFIC APPROACHES AND RESEARCH METHODS OF THE MEMBRANE METHOD OF AGGREGATE RISK ASSESSMENT AND MANAGEMENT

The basis for using the proposed membrane method is organizational and technical reliability of decisions taken at the pre-investment stage under conditions of risk for the NPP construction organization (Fig. 1). This provides methodological guidelines for selecting a rational option for the management of various types of risks, taking into account the developed project risk map, and at subsequent stages its use in the technical specification of the planned NPP.

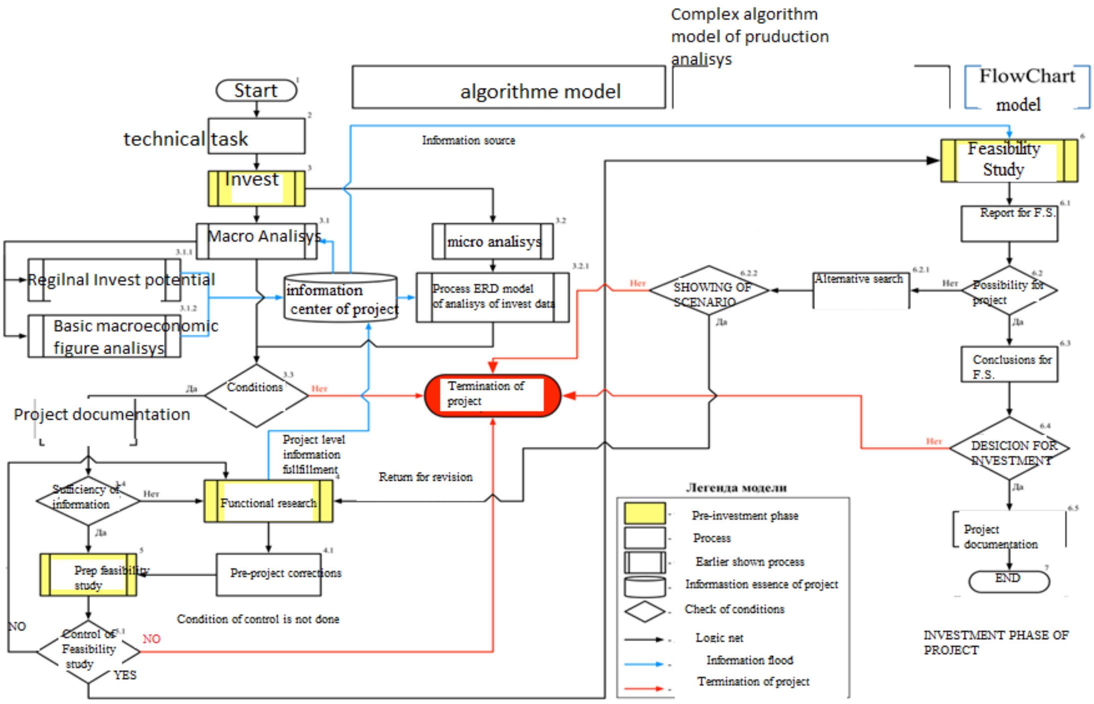

Figure 1. Algorithm for Selecting an Effective Scenario and Feasibility Study of NPP Construction by a Responsible Organization (Pre-Investment Stage)

The concept of the membrane method assumes the assessment of organizational and technical reliability and risk management taking into account the choice of an effective management strategy associated with the application of long-term, medium-term and short-term planning of NPP construction on the basis of a specially created automatic control system of technical process ACSTP[C]. The ACSTP is based on the following requirements:

[C]Automated Control System of Technical Process is a set of hardware and software that carry out control and management of production and technological processes,

1. The control system is developed for a certain layer of the "membrane" of the investment project (Fig. 2);
2. The system stabilizes the specified modes of the technological process using the developed map of project risks in real time (Fig. 1, item 4.1);
3. By analysing the current state of the technological process, the system allows identifying types of risks associated with pre-emergency situations and preventing accidents by transferring technological units to a safe state (both in automatic mode and under the control of operating personnel);
4. The system provides the engineering and technical personnel of the enterprise with the necessary information about the technological process to solve the tasks of control, accounting, analysis, planning and management of the production process (Grabovy, Lapidus, 2022; Sezyomin, 2022).

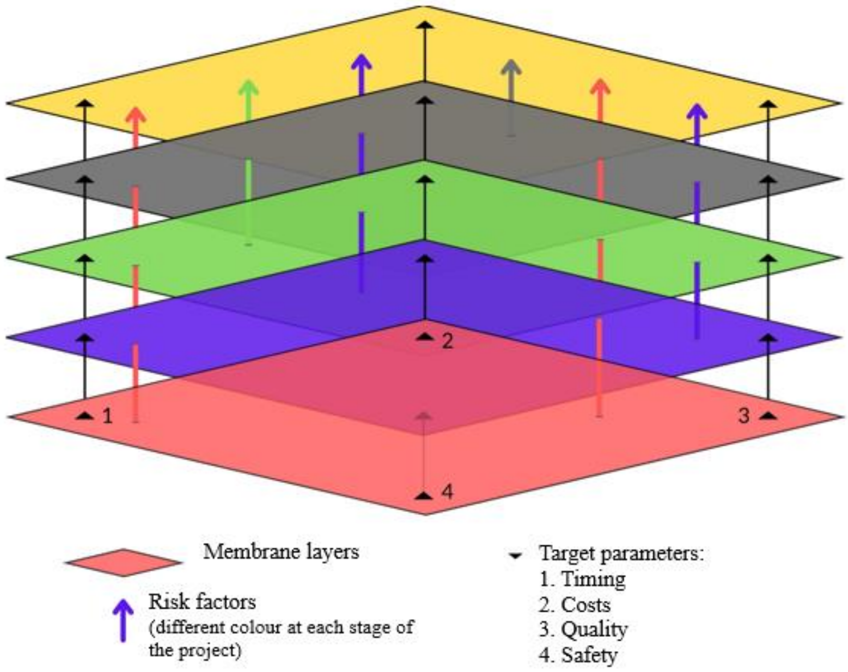

Figure 2. General Scheme Illustrating the Membrane Method for Assessing the Organizational and Technical Reliability of the Project and Aggregate Risk Exposure

As is known, risk in general form is a possible danger or threat of an unfavourable event, as well as an unexpected (including favourable) result of actions or event development, measured through the probability of occurrence of the event and the amount of damage (result adjustment) due to a certain action (Alshreideh et al., 2023; Gavrilov, Krasavina, n.d.; Ramenskaya, Pivovarova, 2018);

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maintain continuous feedback and actively influence the course of the process at deviation from set parameters; they also ensure the regulation and optimization of the controlled process.

The membrane method of assessment of organizational and technical reliability (P_t^{rel}) taking into account the total risks (V_{ij}) of a technically complex production system is based on the following parameters:

1. Risk-expert council is a collegial body (project group) specially formed for the project implementation, which includes experts for each type of risk, as well as staff and hired specialists for the development and implementation of software representing the corresponding membrane-type simulation model
2. Risk probability degree is probable, unlikely and improbable possibility of occurrence of this type of investment risk (V_{inv}) depending on the possibility of occurrence;
3. An indicator of the risk value V_z for a specific type of risk (M) from the initial level (formula 1)

$$V_z = -\frac{M^-}{M^+ = \frac{M\{x - z\}x \leq z}{M\{x - z\}x \geq z}} \quad (1)$$

4. Main types of risk are the most significant risks by value;
5. Risk map (risk register) includes types of risks defined as significant for a particular technically complex production system;
6. Acceptable aggregate risk (V_{min}) is the degree of risk, which is allowed by the simulation membrane model;
7. Compensatory measures form a set of actions leading to the reduction of the risk value to an acceptable one;

Fig. 3 presents the aggregate risk model in general form, which further allows to determine:

1. Risk owner – a person responsible for a certain risk or group of risks within the project;
2. Risk management – a system of risk analysis adopted by the enterprise, aimed at influencing the identified or predicted and modelled risks;
3. Risk factor – cause, event, action (inaction), activity, influencing the occurrence and possibility of risk adjustment;
4. Risk management measures – planned and emergency actions taken to manage risks;

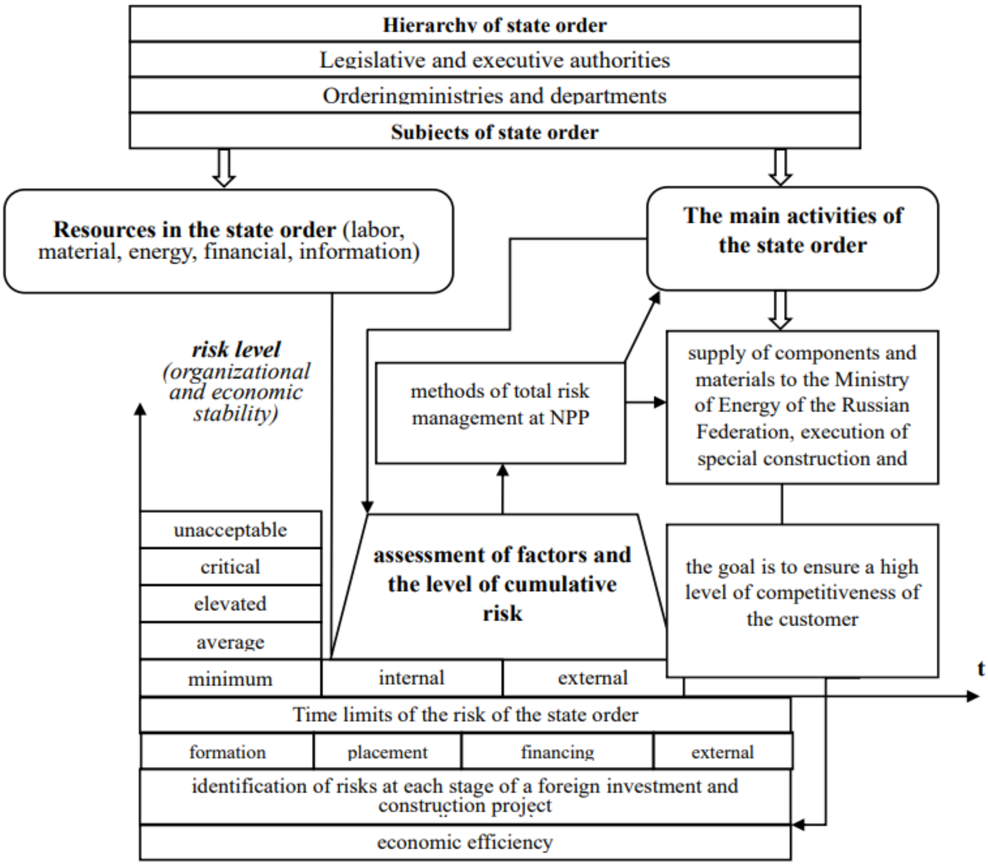

Figure 3. Model of the aggregate risk of the public contracting authority (state customer) in construction of a unique technically complex NPP project.

5. Risk immanence – the state of the system, in which the risk, as well as its analysis and management are a permanent internal property of the system, inherent in the project and requiring continuous on-going monitoring, due to empirically achieved understanding of the possibility of new unplanned risks at any stage of implementation of a technically complex project;
6. Risk reporting – the process of preparation and approval of data on risk analysis, results of risk analysis, risk management measures taken and the economic effect of these measures, formalized in accordance with the internal regulations of the company (reporting procedures), as well as the requirements of GOST standards for each risk or group of risks at all stages of the life cycle of a technically complex project.
7. Risk response strategy – a decision made based on the results of risk identification and its economic result, including such actions as (from smaller to larger) reduction, acceptance, increase to an acceptable value, elimination, and stage delay (postponement)[D].

[D]Note: in the presented work the concept of risk transfer to an external counterparty is not considered due to the fact that regardless of the person responsible for the risk, this risk is subject to management, both on a contractual basis and on the basis of labor relations and internal regulations of the company, and the owner of the risk remains the same but their competencies are expanding, having absorbed the function of "risk curator," a person responsible for interaction with the counterparty, technically assuming the risk.

The study of aggregate risk exposure in NPP construction includes the following sequence of activities:

1. Assessment of objective and subjective factors affecting a particular type of risk;
2. Analysis of the factor space;
3. Assessment of a specific type of risk and its influence in the total value of a specific type of risk;
4. Determination of acceptable risk level;
5. Analysing individual operations in accordance with the selected level of risk; and
6. Development of risk reduction measures.

In order to form a risk analysis system based on membrane-based reliability and risk management, we propose to divide the process into the following steps:

1. Search and identification of risks;
2. Verification of risks with the help of system methods used in the organization (checklist, decision tree, event tree, "what will happen if" method, as well as the expert method);
3. Entering risks into a unified system adopted at the enterprise and using network schedules, test reports, surveys of specialists with data entry into questionnaires;
4. Identification of planned risk parameters, deviations from which are planned to be controlled and, if necessary, corrected subsequently;
5. General description of risk is performed for all types of risk and includes: a) description of risk; b) possible consequences of risk by options; c) the impact of risk on the timing of the project; d) the monetary value of risk, affecting the total cost of the project; in this case, compensation measures, the decision taken, as well as the result of such a decision are formalized at a later stage of the membrane-based risk management process. The general formulation of the risk should contain, in addition to the name of the risk, its causes, consequences of its occurrence and the degree of impact on the project objectives, according to the membrane method, and an assessment of the impact on the overall economic performance of the project. It should be noted that to assess the risks of technically complex production systems, it is proposed to abandon the often used so-called pyramidal system of risk accounting, based on hierarchical structuring of risks, because newly emerging risks at any stage of the life cycle of the system can and will claim a more important place in the already formed pyramid of risks. The membrane type of overlapping layers of risk makes it possible to supplement the already existing structure of identified risks with new arrivals in the system and create an interpenetrating fine-cell structure of all types of project risks.
6. After determining all risks of the system (with understanding of the immanence of risks of the project system), their classification is carried out, which can be based on the method of TECOP SH – technical,

economic, commercial, organizational, political, supplemented by such a group of risks as demographics, the company's position in society, its reputation, etc. Note: According to the data collected by the authors of the article "Development of risk classifier as a stage of successful risk management" published in the scientific and practical journal "Problems of risk analysis" (Brykalova et al., 2021), Rosatom Corporation uses the TECOP classification as a basic approach to the classification of risks. And this classification was the basis for the development of the Electronic Risk Classifier as part of the Unified System of Classification and Coding of Nuclear Energy (USCC NE) (Gavrilov, Krasavina, n.d.).

7. Cumulative risk assessment V_{i-j} (the result of the process of assessing different types of risks) is to identify the impact of a particular type of risk on the project parameters embedded in the feasibility study. Risk assessment – the result of the risk assessment process is the determination of the impact of a certain risk on the project parameters included in the feasibility study. Qualitative risks are divided by the degree of influence on the project; quantitative risks differ on the basis of probabilistic assessment.

For qualitative assessment of risks, it is proposed to introduce weighting of each risk individually and in groups, with a total weight of 100 (Formula 2). The classification of risks provides a set of main factor indicators and forms a generalized assessment of the aggregate risk for the investment construction project in question according to the main phases of its life cycle. Expert analysis of the aggregate risk of the construction project, taking into account the industry-specific and regional situation, is considered by the authors as additive-weighted integration of risk scores:

$$V_{i-j} = \sum_{i=1}^{N} A_j * V_j; V_i = \frac{1}{M}\sum_{i=1}^{n_i} a_{ij} a_{ij}; \quad (2)$$

where V_{ij} is a score of the i-th factor in j type of risk;
a_{ij} is the weight of the first factor in j type of risk;
n_i is the number of considered factor attributes in the j type of risk;
M is the boundary of the point scale (from 1 to 100);
A_j is the weight of the j-th type of risk
V_j is assessment of j type of risk;
V is a generalized indicator of aggregate risk.
$0<Vj < 1$ и $0<Vi<1$.

In order to construct the risk curve and determine the level of losses, the authors introduce the concept of "risk areas" in the customer's activity is introduced.

The risk area of the construction project realized by a developer is a certain area of total losses in the external construction market, within the boundaries of which the losses do not exceed the limit value of the established risk level.

It is proposed to organize the activity within a single scale from risk acceptance to risk avoidance (exclusion of action) and then divide the risks into groups depending on the degree of riskiness of action:

1. Acceptable risks are those that can be accepted at a given stage of the project life cycle; it should be noted that risks at different

stages of the project life cycle are also distinguished by the degree and the actions that need to be taken to bring the risk to an acceptable level.

2. Risks that should be reduced are those whose management reduces the likelihood of an event. Staff training is a prime example.
3. Risks that should be increased are those leading to positive effects for the project.
4. Planned risks are risks for which it is possible and acceptable to develop and implement an action plan to reduce risk to acceptable levels.
5. Transferable risks, for which the best solution is to transfer them on a contractual basis under certain guarantees and responsibility of the contractor.
6. Avoidable risks are those that result in the avoidance of a given action or such a significant change in the operation of the system that eliminates the risk.

In this regard, the authors identify five main degrees of the customer's risk at the main stages of the NPP construction life cycle: the area of minimal risk; the area of average risk; the area of increased risk; the area of critical risk; the area of unacceptable (catastrophic) risk (Fig. 3).

In order to implement the strategic goals of the Rosatom State Corporation it is proposed to separately identify and analyse the risks that may hinder the implementation of a particular NPP construction project, namely:

1. Increasing the share in the international nuclear power markets;
2. Reduction of production costs;
3. Reduction of production process time;
4. Introduction of new products to the market;
5. Global leadership in the field of technology (Grabovy, 2018).

The introduction of the membrane method of risk assessment allows monitoring of all types of risks at all stages of the NPP construction project life cycle due to the unified systematization of all types of risks in one software program. This constant monitoring is achieved by the idea of development and implementation of a sub-function of regular system queries within a single software product.

CONCLUSIONS

The authors would like to highlight the main novelty ideas of the Membrane Method of risk analysis developed by Denis Sezyomin.

1. Distribution of risks by membrane layers. Each membrane layer is a stage (and its internal sub-stages) of the life cycle of the system; each risk presented in the membrane system is taken into account and considered a "sprout" that starts its way in the

layer where it appears (or manifests itself) and can grow through all membrane layers, affecting the target indicators of the project;

2. The Membrane Method represents a unified system of risk analysis regardless of risk category and degree, based on three – quantitative, qualitative and parametric – methods;
3. By analogy with the medical method of contrast ultrasound (CT), the system allows using the colour contrast function to visually track certain types of risk, a more intense colour will indicate an area of increased risk;
4. It will allow visual and numerical data necessary for making management strategic and operational decisions to be displayed on the monitors of project managers at corporate headquarters.
5. Development of Membrane SDE software product on the basis of Sezyomin's Membrane Method of risk analysis will provide software independent from Microsoft and Apple systems, with the parallel task of creating software-specific libraries.
6. The created libraries (of errors and risks) should be published on a paid basis, including accessibility to foreign users under the condition of their multistage accreditation in accordance with legally defined procedures.
7. Automatic generation of periodic reports (monthly, quarterly, annually, at the end of a stage, as well as for the entire project).
8. The ability to generate any report in one click, taking into account the principle of priorities of managers and technical specialists in accordance with the specified scope of authority in the field of risk management of the company.
9. The system is configured in such a way that the notification about necessity of preparation by risk owners of the updated information on groups of risks for the monthly (quarterly) report is displayed automatically on a personal device of the risk owner and also the head of the company. Such a set of actions minimizes the risk of human factor influence on the execution of simple instructions for preparation of reporting in time (there will be no delay in execution). This is especially important for situations of new risk occurrence at any stage of the NPP project life cycle.
10. The software based on the Membrane Method of risk assessment by Sezyomin makes it possible to apply a new concept of internal digital signature in the company, which will allow transferring materials for studying and collecting data confirming that the employee of the subdivision has read the document, in electronic form. *Note: the costs of preparation, printing, collection of signature sheets and archiving in the physical sense of document flow should be estimated in monetary terms and compared with the costs of implementing electronic document flow using internal digital signature in the Corporation.*
11. In the corners of the stacked layers of the membrane system are four target parameters of the project: economic parameters (costs,

project budget, rate of return, net profit), time-related parameter – realization of the project within the terms set by the feasibility study, qualitative parameters, and safety parameters of the project.

Therefore, the purpose of the research presented in the article has been achieved: the task of determining and assessing the risk of NPP megaproject by applying the membrane method has been solved.

REFERENCES

Alshreideh, M., Yengovatov, I., Morozenko, A. (2023, January 24). *Issues of NPP life cycle management. Energy Policy*. Retrieved from: https://energypolicy.ru/voprosy-upravleniyazhiznennym-cziklom-aes/energetika/2023/19/24/?ysclid=lqm65v851c52085139

Brykalova, S. M., Trifonov, V. Y., & Gurieva, E. A. (2021). Development of risk classifier as a stage of successful risk management. *Scientific and Practical Journal Problems of Risk Analysis, 18*(6), 40-53. https://doi.org/10.32686/1812-5220-2021-18-6-40-53

Gavrilov, K. A., Krasavina, L. N. (n.d.). *Risk. The Great Russian Encyclopaedia, 2004–2017*. Retrieved from https://old.bigenc.ru/economics/text/3510546#:~:text=РИСК%20(франц.%20risque%2C%20от%20итал.,в%20обыденном%20и%20политич.%20дискурсе

Grabovy, P. G. (2012). *Risk management in real estate: Textbook*. Moscow: Prospekt.

Grabovy, P. G. (2017). *Risks in modern business: A monograph*. Moscow: IIA Prosvetitel.

Grabovy, P. G. (2018). *Organization of construction and real estate development. Part I: Organization of construction*. Moscow: ASV Publishing House, IIA Prosvetitel.

Grabovy, P. G., Lapidus, A. A. (2022). *Construction management. Part I. Organizational models of management and contract constructions of the capital construction project: Textbook in two parts and practicum (Part 3)*. Moscow: ASV Publishing House, Prosvetitel.

Gusakova, E.A., Pavlov, A.S. (2022). *Fundamentals of organization and management in construction: Textbook and workshop for universities*. Moscow: Yurait Publishing House.

Mazur, I. I., & Shapiro, V. D. (2010). *Project management: Textbook*. Moscow: Omega-L.

Neftegaz.ru. (2012, November 15). *EPC kontrakt [EPC Contract]*. Retrieved from https://neftegaz.ru/tech-library/menedzhment/141747-epc-podryad-kontrakt/#:~:text=EPC%20-%20контракт%20(Engineering%2C%20Procurement%2C,фиксированной%20цене%20к%20фиксированной%20дате

Ovsyannikova, T. Y. (2004). *Economics of the construction complex. Economic substantiation and realization of investment projects: Textbook*. Tomsk: TGASU.

Ramenskaya, A. V., & Pivovarova, K. V. (2018). *Methodological guidelines: The Monte Carlo method and instrumental means of its realization*. Orenburg: FGBOU of Higher Education Orenburg State University.

Sezyomin, D. E. (2022). *Integrated development of undeveloped territories. Experience of NPP Akkuyu construction by Rosatom State Corporation (Türkiye)*. Paper presented at the National scientific and practical conference, October 21–22, 2022, NI MGSU, Moscow, Russia.

Wikipedia, the free encyclopedia. (n.d.). *EPC (kontrakt) [EPC (contract)]*. Retrieved from https://ru.wikipedia.org/wiki/EPC_(контракт)