UDC 658.511

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Formation of risk factors for construction of nuclear power facilities in Latin American countries

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The analysis of the development of the international nuclear power construction market makes it possible to identify and assess the problems of economic reliability and risks in the implementation of international projects of the State Corporation Rosatom. For many years, Rosatom has been consistently conducting international cooperation and support for various projects abroad, developing the company's and peaceful atom's competencies in other countries. The main directions in the field of international cooperation are the maintenance and implementation of nuclear power plants, as well as the development of a new promising area of international business development for the construction of nuclear research and technology centres. The article considers an example of the implementation of the centre for nuclear research and technology in the multinational state of Bolivia. The Centre for Nuclear Research and Technology is a complex innovative technical project that embodies a complex of nuclear technologies for the development of various fields at the state level (research, agricultural development, advanced training, medicine, expertise, etc.). The project is being implemented within the framework of an agreement between the Government of the Russian Federation and the Government of Bolivia, which also makes it possible to obtain a new contract in the Latin American market in the future. Examples of international cooperation in the field of international activities of the Rosatom are considered. An expert risk analysis of the project in Bolivia was carried out. Thus, in the future, several large pilot innovative high-tech projects will be implemented in Latin America, as well as further implementation of similar projects in other parts of the world (Africa and Asia).

Keywords: *Rosatom, nuclear construction industry, international cooperation, markets, risks, Centre for Nuclear Research and Technology*

INTRODUCTION

The constant increase in scale and engineering complexity, the introduction of new advanced technologies, the complexity of solutions used in design and construction, the need to use modern building structures, materials and modern construction equipment, the high dynamism of the external environment of the project form the factor space of a construction company in the field of nuclear energy construction and nuclear technologies operating in the foreign market. This leads to an increase in the degree of risk and uncertainty in its economic activities [1, 2].

The main risk factors in foreign construction are the following groups of factors: international risks, socio-political risks, economic risks, regional risks, risks of an energy construction company, project risks.

International political and economic risks are unmanageable.

Regional risk takes into account the characteristics specific to a particular region.

The *risk of an energy construction company* is generated by the characteristics characteristic of the operation of a particular company and includes business risk and financial risk. Business risk is determined by the level of competitiveness of the company, the setting of marketing work. Financial risk is caused by the national financial policy and requires the creation of a special mechanism for rapid response to changes in the financial environment.

The *risk of a construction project* takes into account the specifics of a specific project, the implementation and maintenance of which is carried out by a construction company (General Contractor) [3, 4].

Rosatom unites more than 360 organizations and implements a huge number of the most diverse complex technical projects, including innovative ones in the Russian Federation and abroad (energy, medicine, science, education, transport, space, medicine, industry, military-industrial complex, etc.) (Table 1). Participation in such projects It implies a large number of emerging risks, which requires business entities to develop mechanisms for effective management of them (Fig. 1).

Many years of experience in the construction of nuclear power plants and acquired competencies, authority, resources, etc. allowed Rosatom not only to become one of the world leaders in the construction of nuclear power plants, but also to master new areas of activity that open up further prospects for further development. At the moment, in the field of nuclear energy use, Rosatom is one of the most in-demand companies in the world in terms of the number of high-power nuclear power plants of the latest generation 3+ being built simultaneously (Table 2)[1, 2] [5–9].

One of the key activities and priority goals of Rosatom is the development of global products to ensure effective import substitution processes within the country and occupy leading roles in international and global markets (Fig. 2).

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1 Construction of most nuclear reactors is behind schedule. URL: https://www.economist.com/graphic-detail/2017/01/30/construction-of-most-nuclear-power-reactors-is-behind-schedule

2 Approaches to reducing costs for the construction of nuclear power facilities, Practical guide for stakeholders. Nuclear Energy Agency Organization for Economic Cooperation and Development. 2020; 33-34. URL: https://www.rosatom.ru/upload/docs/Unlocking_eductions_in_Construction_Costs_of_Nuclear.pdf (rus.).

Table 1. Rosatom State Corporation in the international energy market

A place in the international market	Indicator
No. 1 in the world	According to the portfolio of projects for the construction of nuclear power plants abroad (35 power units)
No. 1 in the world	Uranium enrichment (38 % of the global market)
The only one in the world	Nuclear Icebreaker Fleet
No. 2	By uranium reserves
No. 2	In terms of uranium production (15 % of the global market)
No. 3	In the nuclear fuel market (17 % of the global market)
19.7 %	The share of nuclear power plants in electricity generation in the Russian Federation
362	Organizations within the Corporation

Note: data from the public report of Rosatom State Corporation[3, 4, 5, 6].

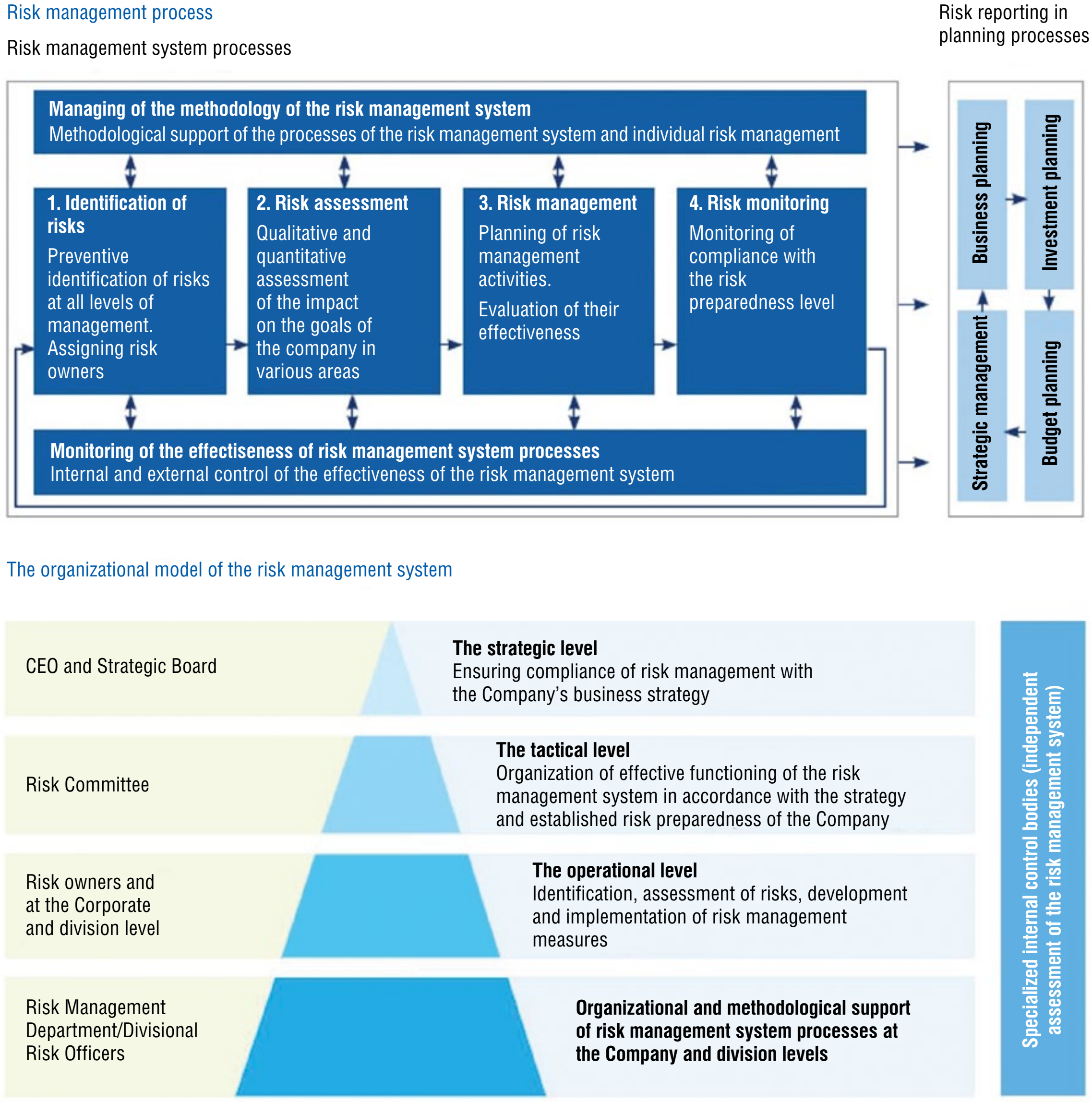

Fig. 1. Organizational model of RMS (risk management system) (data from the public report of Rosatom State Corporation[3, 4, 5, 6])

3 Public report of Rosatom State Corporation for 2019.
4 Public report of Rosatom State Corporation for 2020.
5 Public report of Rosatom State Corporation for 2021.
6 Official website of the State Corporation Rosatom. URL: https://rosatom.ru/production/design/stroyashchiesya-aes

Table 2. Financial and economic results of the activities of Rosatom Group from year to year

Key financial indicators, trillion rubles			
Indicator	2019	2020	2021
Intangible assets	0.170	0.199	0.199
Assets	4.295	4.722	5.219
Revenue	1.151	1.207	1.447
Profitability indicators, %			
Return on sales by net profit (ROS)	11.55	13.00	13.39
Return on assets by net profit (ROA)	3.10	3.32	3.71
Return on equity by net profit (ROE)	5.10	5.58	6.34

Note: data from the public report of Rosatom State Corporation[3, 4, 5, 6].

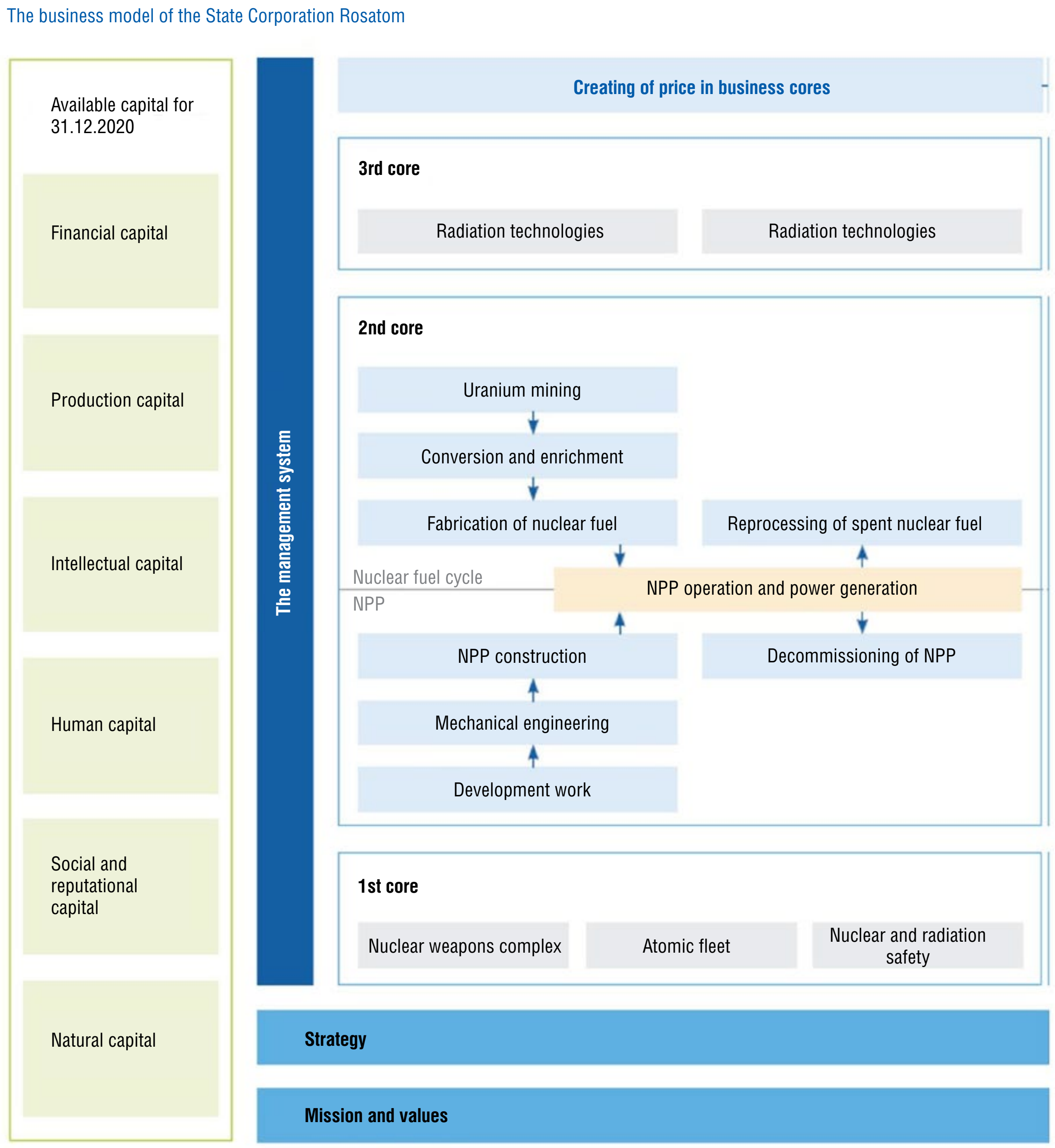

Fig. 2. Rosatom business model (data from the public report of Rosatom State Corporation[3, 4, 5, 6])

ANALYSIS OF NUCLEAR POWER CONSTRUCTION PROJECTS ABROAD

For many years, Rosatom has been consistently conducting international cooperation and support for various projects abroad, developing the company's and peaceful atom's competencies in other countries. The main directions in the field of international cooperation are the maintenance and implementation of nuclear power plants, as well as the development of a new promising direction for the development of international business for the construction of nuclear research and technology centres [1–4].

The most illustrative examples of interaction and international cooperation can be identified:

1. People's Republic of China (PRC) (cooperation, construction of nuclear power plants).

2. Close cooperation with the Atomic Energy Agency and the State Energy Administration of the People's Republic of China continued. The completion of the strategic package deal with Chinese partners has been ensured: general contracts for the construction of power units No. 7, 8 of the Tianwan NPP and power units No. 3, 4 of the Xudapu NPP have been signed. A dialogue has begun on expanding the agenda of bilateral cooperation in the field of nuclear energy. Such areas as the closure of the nuclear fuel cycle, the reprocessing of spent nuclear fuel and the deepening of cooperation in the field of science and technology, including basic science, were being worked out.

3. Republic of Belarus (construction, maintenance and commissioning of nuclear power plants).

4. During the construction and maintenance of the Belarusian NPP, cooperation was carried out with various ministries and state authorities on a wide range of issues related to the development of the regulatory framework in the field of atomic energy, safe and peaceful use of atomic energy.

5. Within the framework of the Treaty on the Creation of the Union State, a program for the development of nuclear energy in the Republic of Belarus has been defined.

6. India (cooperation, construction of nuclear power plants).

7. The support of various stages of the Kudankulam NPP project, the performance of various types of work and tasks continued: operation of power units, supply of technological and other equipment, development and transfer of documentation.

8. Preparations are underway for the possible implementation of a separate project for the construction of a new generation high-power nuclear power plant with a capacity of 1,200 MW.

9. The Republic of Bangladesh (cooperation, construction of nuclear power plants).

10. Support and implementation of the construction of the Ruppur NPP is carried out.

11. The multinational State of Bolivia (construction of the CNRT Centre for Nuclear Research and Technology with a research reactor).

Construction and installation works were carried out. The production, delivery and installation of the main and auxiliary equipment for the NPP was carried out. Staff training was conducted, including on the basis of the Rosatom Academy in the Russian Federation.

Negotiations are underway to identify promising opportunities for international cooperation in these regions, as well as neighboring regions and countries in Asia and Latin America:

1. Iran (cooperation, nuclear power plant operation).
2. Consultations and cooperation in the field of safe and peaceful use of nuclear energy, in accordance with the regulatory legislation of the Russian Federation and international obligations in the field of nuclear safety during operation of the Bushehr NPP.
3. Turkey.
4. Egypt.
5. Uzbekistan.
6. Hungary.
7. Finland.

In these countries, various types of work and consultations were carried out on the implementation of projects to prepare for the construction of nuclear power plants[1] [5–8].

THE NEW DIRECTION OF ROSATOM STATE CORPORATION IS AN INNOVATIVE PROJECT IN BOLIVIA

As an example of risk management abroad in the “novice” state, the consistent implementation of a pilot project in the multinational state of Bolivia will be considered: the Centre for Nuclear Research and Technology (CNRT) is a complex innovative technical project that embodies a complex of nuclear technologies for the development of various fields at the state level (research, agricultural development, raising the level of, medicine, expertise, etc.). The project is being implemented within the framework of the Agreement between the Government of the Russian Federation and the Government of Bolivia dated 06.03.2016, as well as the EPC contract dated 09.09.2017.

The centre consists of a research reactor, a multi-purpose radiation centre, a preclinical cyclotron radiopharmacological complex, and a laboratory of radiobiology and radioecology. This will allow you to solve several important tasks at once. It will contribute to increasing the pace of development of the national industry and agriculture, improving the level of health in Bolivia, improving the investment climate in the region and creating jobs for Bolivian citizens. It is planned that Bolivian specialists with specialized education will be employed at the research centre. In total, it is planned to create about 500 jobs for Bolivian citizens under the contract.

The reactor complex will allow for fundamental and applied research, which will provide additional tools for the development of various sectors of the economy, including the lithium industry.

Lithium is currently one of the most promising and critical elements for the development of energy storage systems and applications in a number of high-tech industries.

In June 2023, Rosatom State Corporation and the Bolivian state Company signed an agreement on the construction of an industrial complex for the extraction and production of lithium carbonate. This implies the creation in Bolivia (the country with the largest lithium reserves in the world) of a full-fledged scientific and production chain from the extraction of lithium raw materials to the production of a ready-made market product. This is a pilot foreign project of Rosatom State Corporation in the field of lithium production, while Rosatom will receive not only a profitable long-term contract, but also control over a part of the strategic resource, the demand for which only continues to grow. It is worth noting that a serious struggle was waged against companies from the USA, China, etc. for obtaining this contract. For example, Tesla and Lilac and Solutions participated in the tender from the USA.

Thus, in the future, several large pilot innovative high-tech projects will be implemented in Latin America, as well as further implementation of similar projects in other parts of the world (Africa and Asia).

RISK ANALYSIS OF THE PROJECT IN BOLIVIA

Analysis of risk events that could not be prevented by the Customer or Contractor. These are the risks associated with:

1. A political crisis (the resignation of the president, riots and looting in the country in 2019, which could lead to the loss of expensive equipment in warehouses and buildings of the centre).

2. The global COVID epidemic of 2019–2020 (inability to continue work and delivery of equipment).

3. The geopolitical situation (conducting a special military operation, subsequent sanctions against the Russian Federation and enterprises). The economic consequences associated with the refusal to cooperate with foreign suppliers, as a result of the disruption of supplies, the conclusion of new contracts, the selection of analogues, the change and increase in the cost of logistics, the need for redesign, etc. (Table 3).

These events can be classified as unmanageable risks. Nevertheless, the management and organizational decisions taken made it possible to minimize losses and continue the successful implementation of the project. Each of these risky events had a significant impact on the timing of the implementation of this project with a 3-year delay in delivery. This entailed additional financial costs (additional losses), but did not stop the construction and commissioning of the centre's facilities. In 2023, the commissioning of the centre's facilities and the active construction of the reactor complex will continue.

As part of the operation of the project in Bolivia, the author has established a list of risks, risk owners, conducted a risk assessment, and implemented measures to manage them.

The analysis of key risks affecting the financial stability of the company (General Contractor) was carried out on the basis of expert assessments received, in accordance with a previously defined list of identified risks.

For a qualitative assessment of the magnitude of the risks of the project in Bolivia, the Harrington scale was used (Table 4).

Table 3. Classification of risks during the construction of a nuclear research and technology centre in Bolivia

Risc	Risk assessment
International risk	4
Socio-political risk	4
Currency risk	3
Economic risk	3
Industry risk	3
Investment risk	2
Project risk	2
Reputational risk	2
Technogenic risk	2
Interest rate risk	2
Operational risk	2
Credit risk	2
The risk of industrial safety and labour protection	1
Liquidity risk	1
Risk in the field of services related to the nuclear fuel cycle	1
Environmental risk	1

Table 4. The Harrington scale

Qualitative characterization of probability	Quantitative characterization of probability in relation to risk components	Quantitative characterization of probability, %
Very low	1	0–20
Low	2	20–37
Average	3	37–63
High	4	63–80
Very high	5	80–100

ANALYSIS OF THE FINANCIAL STABILITY OF THE COMPANY (GENERAL CONTRACTOR)

The analysis of the financial stability of the enterprise (General Contractor) is carried out using an approach related to the assessment of the expediency of costs and is focused on the identification of potential risk areas.

In addition to unmanageable risks leading to cost overruns, excess costs may also arise due to the unanticipated or incorrectly predicted influence of the following manageable factors:

- incorrect design and further need for redesign;
- incorrect calculation of the cost;
- incorrect definition of the need for labor resources;
- incorrect forecasting of inflation.

Taking as a basis the list of key risks of the project, it is possible to further detail the risks and build a management and control system for each project individually, taking into account local characteristics (political, economic, cultural, logistical, etc.).

It is possible to minimize the capital at risk by breaking down the project allocation approval process into stages (areas). The approval stages should be linked to the design phases and based on additional information about the project as it is developed. At each stage of approval, having an analysis of the funds at risk, the investor can decide to terminate the investment.

It is proposed to determine three indicators of the financial stability of the company, in order to determine the degree of risk of financial resources.

Such indicators are:

- excess (+) or shortage (–) of own funds ($\pm E^c$);
- surplus (+) or shortage (–) of own, medium-term and long-term borrowed sources of reserves and costs ($\pm E^t$);
- surplus (+) or shortage (–) of the total value of the main sources for reserves and costs ($\pm E^h$).

The balance sheet model of the financial stability of the General Contractor has the following form:

$$F + Z + R^a = S^o + C^m + C^0 + R^p,$$

where F is fixed assets and investments;

Z — inventory and costs;

R^a — cash, short-term financial investments, accounts receivable and other assets;

S^o — a source of own funds;

C^m — medium-term, long-term loans and borrowings;

C^0 — loans not repaid on time;

R^p — accounts payable and borrowed funds.

To analyze the funds at risk, the overall financial condition of the company should be divided into five financial areas (Fig. 3):

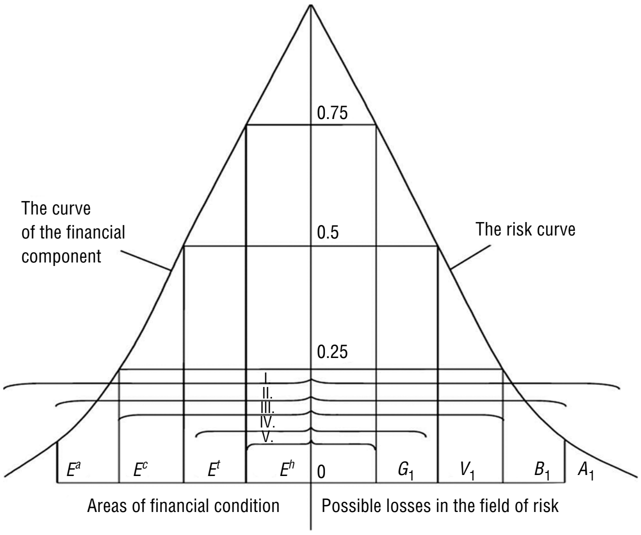

Fig. 3. The risk and financial condition curve [2, 3]

- area of absolute stability, when the minimum value of reserves and costs corresponds to a risk-free area;
- area of normal stability corresponds to the area of minimal risk when there is a normal amount of reserves and costs;
- area of unstable condition corresponds to the area of increased risk, when there is an excess amount of reserves and costs;
- area of critical condition corresponds to the area corresponds to the area of critical risk, when there is overstocking of finished products, low demand for products;
- area of catastrophic condition corresponds to the area of unacceptable risk, when there are excessive stocks and overstocking of finished products, and the developer is on the verge of bankruptcy [2, 3].

The calculation of three indicators of financial stability ($\pm E^c$, $\pm E^t$, $\pm E^h$) makes it possible to determine the degree of their stability for each area. Next, a three-component financial indicator will be used to identify the area of financial stability:

$$S = \{S(\pm E^c), S(\pm E^t), S(\pm E^h)\}.$$

The author of the article determined the values of financial stability indicators, as well as a three-component financial indicator for the project:

$$\pm E^c \geq 0;$$
$$\pm E^t \geq 0, S = (1, 1, 1);$$
$$\pm E^h \geq 0.$$

These indicators indicate the condition of the construction company, which corresponds to an absolutely stable or stable financial condition.

CONCLUSIONS

The developed classifier of risks of project implementation in foreign construction allows timely identification of negative risks in the construction process at the stages of implementation of an international project and monitoring the dynamics of changes in key risks of the project, timely management and further control to eliminate the negative consequences of risks.

The analysis of the main negative risks in the process of project implementation shows that the greatest risks are associated with the socio-political situation, financial and economic risks.

Indicators of financial and economic stability have been established using the example of an ongoing project in Bolivia.

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Формирование факторов риска строительства объектов атомной энергии в странах Латинской Америки

Анализ развития международного рынка атомно-энергетического строительства позволяет выявить и оценить проблематику экономической надежности и рисков при реализации международных проектов Государственной корпорации (ГК) Росатом. ГК Росатом на протяжении многих лет последовательно ведет международное сотрудничество и сопровождение различных проектов за рубежом, развитие компетенций компании и мирного атома в других странах. Основные направления в области международного сотрудничества: сопровождение и реализация АЭС, а также развитие нового перспективного направления развития международного бизнеса по сооружению центров ядерных исследований и технологий. В статье рассмотрен пример реализации центра ядерных исследований и технологий в многонациональном государстве Боливия. Центр ядерных исследований и технологий — сложный инновационный технический проект, воплотивший в себе комплекс ядерных технологий для развития на уровне государства самых разных областей (исследований, развития сельского хозяйства, повышения уровня медицины, экспертиз и др.). Проект реализуется в рамках Соглашения между Правительством Российской Федерации и Правительством Боливии. Это также позволяет в дальнейшем получить новый контракт на рынке стран Латинской Америки. Рассмотрены примеры международного сотрудничества по направлению международной деятельности госкорпорации Росатом. Выполнен экспертный анализ рисков проекта в Боливии. Таким образом, в перспективе в Латинской Америке предстоит реализация нескольких крупных пилотных инновационных высокотехнологичных проектов, а также дальнейшая реализация аналогичных проектов в других частях мира (Африка и Азия).

Ключевые слова: *Росатом, атомная отрасль строительства, международное сотрудничество, рынки, риски, центр ядерных исследований и технологий*

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For citation: Gusev Yu.S. Formation of risk factors for construction of nuclear power facilities in Latin American countries. *Real Estate: Economics, Management.* 2023; 4:62-68.

Для цитирования: *Гусев Ю.С.* Formation of risk factors for construction of nuclear power facilities in Latin American countries // Недвижимость: экономика, управление. 2023. № 4. С. 62–68.

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