**Artículo de investigación**

# Innovative development of construction in russia: economics, technologies, management

Desarrollo innovador de la construcción en Rusia: economía, tecnologías, gestión

Desenvolvimento inovador de construção na rússia: economia, tecnologias, gestão

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**Abstract**

The main directions of innovative development of the construction industry in the views of different authors are considered. From the perspective of the state programs "Innovative Russia - 2020" and "Strategy for the Scientific and Technological Development of the Russian Federation", proposals were developed to make the innovation process on improving technologies, organization and management of construction industry more orderly and systematic. The system-synergistic and cluster approaches to the formation of innovative practices in capital construction based on the use of BIM-technologies have been substantiated.

**Keywords:** capital construction, innovation efficiency, construction technologies, BIM, construction clustering, reliability indicators, single-bucket excavators, field tests.

**Resumen**

Se consideran las principales direcciones de desarrollo innovador de la industria de la construcción en las opiniones de diferentes autores. Desde la perspectiva de los programas estatales "Rusia innovadora - 2020" y "Estrategia para el desarrollo científico y tecnológico de la Federación de Rusia", se desarrollaron propuestas para hacer que el proceso de innovación para mejorar las tecnologías, la organización y la gestión de la industria de la construcción sea más ordenado y sistemático. Los enfoques de sinergia de sistemas y de grupos para la formación de prácticas innovadoras en la construcción de capital basada en el uso de tecnologías BIM se han comprobado.

**Palabras claves:** construcción de capital, eficiencia de innovación, tecnologías de construcción, BIM, agrupación de construcción, indicadores de confiabilidad, excavadoras de un cucharón, pruebas de campo.

**Resumo**

As direções principais do desenvolvimento inovador da indústria de construção nas visões de autores diferentes são consideradas. Do ponto de vista dos programas estaduais "Rússia inovadora - 2020" e "Estratégia para o desenvolvimento científico e tecnológico da Federação Russa", foram desenvolvidas propostas para tornar o processo de inovação na melhoria das tecnologias, organização e gestão da indústria da construção civil mais ordenada e sistemática. As abordagens sinérgicas do sistema e cluster para a formação de práticas inovadoras na construção do capital com base no uso de tecnologias BIM foram comprovadas.

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**Palavras-chave:** construção de capital, eficiência de inovação, tecnologias de construção, BIM, agrupamento de construção, indicadores de confiabilidade, escavadeiras de balde único, testes de campo.

## Introduction

The changing needs of the Russian economy necessitate the adequate development of domestic capital construction: the renewal of equipment and technology, organizational and economic improvement. Achievements of applied science create favorable conditions for the modernization of the construction complex on a new organizational and technological basis, which is commonly called innovative development. Multidimensionality of the innovative development problem in the construction sector, on the one hand, and new design, technological, and organizational-economic possibilities for its improvement based on applied research and new information technologies, on the other, determine the feasibility of system-synergistic and institutional reproduction approaches to implementing innovations in the industry (Popov et al, 2016; Natalia et al, 2017; Tereso et al, 2018).

In recent years, new steels and composite materials for reinforced concrete, organoplastics for load-bearing and enclosing structures, nanotubes of fillers for complex solutions, and technologies for manufacturing high-strength binding and highly dispersed compounds of inert fillers for concrete mixtures and plaster solutions, plasticizers and hardening agents for solutions, other insulating and finishing materials have been developed. In combination with more advanced construction machines and mechanisms, they give a new production and technological quality to the construction process. However, its separation from the corresponding organizational and managerial innovations does not allow obtaining the maximum synergistic effect of growth achieved as a result of seamless uniting heterogeneous components of a process or phenomenon (Marx & Engels, 1961).

The BIM *(Building Information Modeling)* technologies that have emerged in recent years, at the modern level of their development make it possible to successfully accomplish the task on combining the above-mentioned elements and stages of the building complex into a single process of designing, coordination of changes, development and improvement with corresponding economic comparisons and forecasts.

The processes observed in the modern world indicate a slight increase in uncertainty. In contrast to agriculture and industry, capital construction serving the interests of customers is characterized by a higher degree of uncertainty which exacerbates the complexity of forecasting and planning innovations in the building complex (Popov et al, 2017).

Difficult to predict marketing results, highly volatile economic processes characteristic of the modern world, as well as of the Russian economy, necessitate the development of new models and management response schemes for the volatility of the building complex environment (Nehaj et al, 2017).

A high degree of uncertainty in the innovative development of the construction complex is a result, on the one hand, of uncertainty in the development of the productive forces of Russia, and on the other, uncertainty of modern domestic urban planning (Russia in numbers, 2016).

The significant duration of the investment and construction cycle, the expansion of developer practice in conditions of high volatility in the field of marketing and finance increase the need for making changes, starting from their early stages. This actualizes the task of expeditiously carrying out adequate adjustments to dependent elements of the cycle; which, as practice shows, this task can be effectively solved on the basis of the development of appropriate software products. Unlocking the potential of BIM technologies in relation to the innovative development of the Russian construction industry implies the need to introduce an ordering principle to such practices based on a more pronounced systematic approach.

## Literature Review

Fundamental theoretical and methodological principles on functioning and development of complex economic systems have been formed in the works of K. G. Marx, D. M. Keynes, L. V. Kantorovich. Theoretical, scientific and applied aspects of the development of Russian production and economic systems are covered in the works of L.I. Abalkin, N. Ya. Petrakov, A. G. Aganbegyan, S. Yu. Glazyev, G. B. Kleiner, and also specialists from school of thought formed in

MAU. The works by O. V. Inshakov and V.N. Ovchinnikov were devoted to the study of the active function of the institutes on the innovative development of production units. The issues of innovative synergistic development of industrial organizations, improvement of industrial technologies were covered in the works by A. D. Zaretsky, T. E. Ivanova, R. S. Golov, A. V. Myl'nik. Problems of evaluating the effectiveness of scientific and technical innovations in industry and construction, digital methods for evaluating innovative construction projects are highlighted in the works by N. S. Ziyadullaev, Ya. S. Matkovsky, A. N. Dmitriev, and I. G. Lukmanov.
The problems of innovation in urban planning in the face of uncertainty are highlighted in the works of Yu. M. Moiseev. The studies of I. V. Danilina are devoted to the use of BIM technologies at the stage of urban planning. Economic and technological factors of various technologies in the construction industry are investigated in the works of S. E. Shmelev. Issues of information modeling of construction processes, and BIM-technologies are discussed in the publications of specialists of Huazhong University (China). Different approaches to the analysis of information models of buildings and construction complexes, and also design problems in the BIM-environment are covered in the works of P. D. Chelyshkov, L. Yu. Voropaeva V. P. Mamugina.

Questions of innovative materials science, improvement of building technologies are covered in the works of I. A. Antakov, S. V. Nikolaev, I. N. Tikhonov, D. V. Portae, O. V. Smirnova, E. V. Andreev, V. T. Erofeev, A. D. Bogatova. The problems of increasing the potential of construction organizations, their technical equipment and machinery on a new technological basis are considered in the works of E. P. Pankratov, O. E. Pankratov, and Z. R. Tuskayeva. The issues of information systems functioning at the stage of operation of the constructed facilities are covered in the works by N.V. Knyazeva.

The experience of using BIM-technologies has been localized only in certain areas of the building complex, mainly at the stage of detailed design.

The high variability of conditions for the functioning of building complex organizations prompts the need for additional research of a number of theoretical and applied research questions on their innovative development, and improvement of the management tools subjected to obsolescence. In our opinion, the institute for managing the development of the building complex needs to be added with such components that would stimulate the expanded reproduction of its components on an innovative basis using network modeling tools and BIM technologies applied to the new economic quality of the Russian economy. It requires a more strategic focus with a focus on extracting the “multiplying effect” of the activities of organizations engaged in scientific and applied research in the field of materials science, design and construction technologies. The main limiting factor in speeding up the concreting of multi-storey buildings is still the time (period) for gaining strength by concrete. composite fittings are still applicable only in low-rise construction. The reserves of prefabricated construction efficiency, including large-panel housing construction, have not been fully realized. Low-rise construction requires technological improvement. Despite the obvious success, many technological problems are also associated with the work in the permafrost conditions.

**Materials and Methods**

The sources of statistical information for the study were the data of Rosstat (Federal State Statistics Service), other state statistics bodies (1, 2, 3), the published results of scientific and applied research of various authors, and observations in the field of the object of study (Russian statistical yearbook, 2017; Russia in numbers, 2016; Krasnodar region, 2016; Davoodabadi & Shahsavari, 2013; Bakhshandeh et al, 2015).

The methodological basis of the study was the works of the classics in the field of economic theory, organization and technology of production and technical processes in the field of capital construction, models and methods of modern authors within the range of the subject matter. In the analysis of processes and states, the system-synergetic and institutional-reproductive approaches are used as a methodological basis.

The methods of statistical, functional, production, cost analysis, grouping, modeling, extrapolation, SWOT analysis have been applied in the paper.

**Discussion**

The last quarter of the XX century in Russia has been marked by cardinal changes in the economic system, including in the sphere of capital construction. The volume of construction and installation works has increased, especially in housing construction; state-of-the-art technologies were used in building sporting and entertainment facilities on a large scale (this is confirmed by the success in holding the Winter Olympics, the World Football Cup, international competitions, Formula-1 racing), airport terminals, shopping and entertainment centers, and others. Somewhat less noticeable was the success in industrial construction, which is explained by a certain shift in priorities towards the social sphere. Nevertheless, we believe that the objective needs of economic growth will inevitably lead to increased attention to the development of productive forces and related industrial construction, especially of enterprises producing goods with a high share of value added. One of the incentives for this will be an increase in the number of able-bodied population due to pension reform, a positive dynamic of natural population growth, plus migration balance (people go to live in Russia). Manifestations of such imperatives to industrial growth can be seen in the new objectives set by the Russian leadership to regional leaders and corporate leaders. This implies an appropriate development and improvement in the construction industry.

**- Where to send funds.** In summary, the quality of the Russian economy can be characterized by data on the use of gross domestic product (Table 1).

Table 1. Changes in use of GDP in the Russian Federation (Russian statistical yearbook, 2017)

| Expenses | 2011 | 2014 | 2015 | 2016 |
|---|---|---|---|---|
| Total cost | 100 | 100 | 100 | 100 |
| Final consumption expenditures | 67.6 | 71.3 | 69.7 | 70,8 |
| Gross accumulation including fixed capital | 24.4<br>21.5 | 22.2<br>21.3 | 22.3<br>20.7 | 24.0<br>21.6 |

The above data indicate a slight increase in the share of final consumption expenditures and a decrease in the share of expenditures for gross accumulation, with which one can hardly agree in the conditions of insufficient, in our opinion, rates of industrial modernization. In recent years, a decrease in investment activity has been observed in Russia (Table 2).

Table 2. Growth rates of investments in fixed assets in the Russian Federation, in % to the previous year (1, p. 300)

| Investments | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| In general, national economy-wide | 106.3 | 110.8 | 106.8 | 100.8 | 98.5 | 89.9 | 99.1 |

In the structure of investments in fixed assets there is some reduction in the share of machinery and vehicles, that is, the innovation-active part of them (Table 3).

Table 3. Structure of investments in fixed capital in the Russian Federation, in % (Russian statistical yearbook, 2017)

| Investments | 2000 | 2010 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|
| Total | 100 | 100 | 100 | 100 | 100 |
| Buildings and constructions | 43.1 | 43.3 | 40,8 | 43.7 | 45.2 |
| Machinery and vehicles | 36.6 | 37.9 | 36.3 | 31.5 | 30.6 |

In the context of such a large region of Russia as the Krasnodar Territory, the investment activity is characterized by the following indicators (Table 4).

Table 4. Investments in fixed assets in the Krasnodar Territory (Krasnodar region, 2016)

| Indicators | 2010 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|
| Indicators of physical volume of investments in fixed capital, in % to the previous year | 141.5 | 102.3 | 113.6 | 78.9 | 73.6 |
| Investments in fixed capital per capita, thousand rubles | 112.9 | 150.4 | 178.0 | 138.2 | 107.0 |
| Share of investment in vehicles, in % to the total volume | 31.7 | 21.3 | 25.6 | 28.0 | 25.7 |

The data in Table 4 indicate that the changes of investments into fixed assets in the region are negative (in 2016, this indicator was 70.7% by 2015), what can hardly be considered normal. At the same time, a somewhat encouraging factor is the growing volume of investment in vehicles, which is a priority for our country, including the Krasnodar Territory.

The main sources of investment costs in the Russian Federation are own resources of organizations (45-50%), borrowed and budget funds (table 5).

Table 5. The structure of expenditures connected with investment activity in the Russian Federation (Russian statistical yearbook, 2017)

| Expenditures | 2000 | 2010 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|
| Total | 100 | 100 | 100 | 100 | 100 |
| Own funds | 47.5 | 41.0 | 45.7 | 50.2 | 50.9 |
| Involved funds, | 52.5 | 59.0 | 54.3 | 49,8 | 49.1 |
| of them: | | | | | |
| - bank loans | 2.9 | 9.0 | 10.6 | 8.1 | 10.4 |
| - borrowed funds of other organizations | 7.2 | 6.1 | 6.4 | 6.7 | 6.0 |
| Budget resources | 22.0 | 19.5 | 17.0 | 18.3 | 16.5 |

The data in Table 5 indicate a slight decrease in investment activity performed at the expense of funds from involved organizations, what is a reflection of the high volatility of the economic environment and uncertainty of the business. The share of budget funds in investments has a tendency to reduce, what indicates a certain reduction in the corresponding resource base. During the survey, more than half of the respondents identified the following as main constraints of investment activity: lack of own funds; a high percentage of commercial loans; investment risks; the uncertainty of the economic situation in the Russian Federation (Russian statistical yearbook, 2017). This necessitates an appropriate managerial. response, since the revival of investment activity is one of the urgent tasks of modern industrial entrepreneurship in the Russian Federation.

In the field of mining, manufacturing, production and distribution of electricity, gas and water, there is a slight decrease in the share of organizations engaged in technological innovation. At the same time, the share of innovative goods, works and services increased, what indicates a slight revival of work process in this direction (Table 6).

Table 6. Share of organizations implementing technological innovations in the total number of surveyed organizations of the Russian Federation, % (Russian statistical yearbook, 2017)

| Technological innovations | 2000 | 2010 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|
| Total | 100 | 100 | 100 | 100 | 100 |
| Mining, manufacturing, production and distribution of electricity, gas and water | 10.6 | 9.3 | 9.7 | 9.5 | 9.2 |
| The share of innovative products, works, services in the total volume of goods shipped, and work performed, % | 4.4 | 4.9 | 8.2 | 7.9 | 8.4 |

Along with high achievements in construction technology, one can notice some losses suffered by the Russian construction industry, namely: multiple reduction of pre-cast large-panel and unit precast construction, reduction of precast concrete plants, multiple reduction of hydraulic and industrial construction and elimination of relevant industrial bases, reduction of the standard design spectrum. Some of these losses have known their better days, and in our opinion, others deserve a revival on a new technological basis (Nikolaev, 2018).

For many decades of development, domestic construction science and practice has accumulated a wide experience in organizing construction projects, solving unique technological problems, implementing serialization in the design and construction of residential, civil and industrial facilities, and the construction of unique buildings and structures. Some of these technological approaches, forms and methods of organizing construction are of methodological value today. From the standpoint of new technological capabilities, one can approach the prefabricated and cast-in-place and precast construction versions of residential and civil buildings, including the use of steel structures. Comparison of technical and economic indicators of prefabricated and monolithic housing construction indicates fairly high competitive qualities of prefabricated construction technology (table 6).

Table 6. Technical and economic indicators of the construction of residential buildings from precast and cast reinforced concrete in the Russian Federation (Shmelev, 2016)

| Indicators | Precast concrete buildings | Cast reinforced buildings |
|---|---|---|
| Share of the apartments area of in the total area of the floor | 0.79 | 0.89 |
| Construction time of a two-section house | 8-9 months | 14-18 months |
| The cost of 1 square. m of construction | 25-30 thousand rubles | 35-40 thousand rubles |
| Exterior finish | Three-layer panels, finished in the workshop | Brick cladding at the construction site |

We can agree with the opinion that in the perspective large-panel housing construction should focus on the construction of multifunctional housing with rooms of 80-100 square meters in size. In this perspective, it seems promising to use large-span ceilings in large-sized buildings, switching to a system of buildings with longitudinal load-bearing walls, what will expand the range of their application in residential and civil construction (Nikolaev, 2016). With regard to the modern technological situation, new development of the Central Housing Research and Design Institute (TSNIEPzhilishcha) on constructive solutions for residential and civil buildings in a precast with cast-in-place concrete design deserve new study. In particular, if to build stair-lift blocks in a sliding formwork with a lifting speed of 0.2 m / h, this will take 15-20 days for a 20-storey building; the subsequent installation of prefabricated frame elements, including external walls, will require 120-150 days. In this case, interior finishing works can be performed in a heated building and do not depend on outside temperatures (Karpanina et a, 2017; Volkov et al, 2017). Concrete surfaces made in a shop conditions have increased quality and do not require additional labor and materials for finishing, what is not always achieved when performing construction of cast reinforced concrete.

One of the promising directions of the reinforced concrete application is the use of glass composite and basalt composite reinforcement, including with prestressing (Antakov, 2018). The advantages of such reinforcement are higher tensile strength than that of steel, light weight, corrosion resistance, low thermal conductivity; its shortcomings are elasticity angle less than that of steel, and brittle fracture behavior, low thermal stability, susceptibility to creep during prolonged loads. This indicates the need for further research and experimentation in this area, and expanded innovative practice.

Along with this, reinforcement from steel, in particular, the use of reinforcement from high-strength steel deserves further research and promotional activities. The current price field in the construction of the Russian Federation is characterized by the condition that the cost of concrete and reinforcement in railway concrete structures ranges within 1:1. Therefore, a decrease (or increase) in costs for any of these elements has a very significant effect on the total cost of construction and installation works. The use of reinforced concrete structures for civil and industrial construction of reinforcement class A500 instead of reinforcement class A400 in reinforced elements reduces amount of reinforcement to 20% (Tikhonov et al, 2018). The technology of using prestressed wire rope reinforcement may be of interest for arrangement of long-span slabs. A specific feature of this method is that the ropes are located along the line repeating the plot of bending moments in the structure (Portaev, 2011).

One of the promising ways to accelerate concrete curing is an introduction of nanosuspensions into the concrete mix, including: re-milled portland cement in planetary mills; silica fume formed as a by-product in the preparation of elemental silicon and silicon-containing alloys; sludges generated during the water cleaning and softening process in boiler rooms; natural or artificially created nanotubes (Krivoborodov & Elenova, 2016). The extremely developed surface of the nanotubes ensures the extended contact with the reagents in the process of cement hydration and accelerates the formation of cement stone, and the curing of concrete.

The expanded use of organic materials in construction actualizes the problem of biological protection of structures. The purpose of improving the resistance of composites (cement, gypsum) to the effects of biologically aggressive media can be the introduction to them of such biocidal additives developed in Russia as “Stop-plessen”, “Ultrasept”. Studies have shown that such additives not only prevent biological contamination, but also increase the strength of structures (Erofeev et al, 2018).

In accordance with this approach, when determining the reliability of construction machines, it is proposed to limit ourselves to the following estimate indicators (Shipilova et al, 2016; Sus et al, 2017):

Availability factor ( K a ) which is determined by the formula

$К_a = \frac{T_o}{T_o + T_d}$, (1)

where: To - the total time of proper operation of the object; T d - the total time of downtime.

The operating efficiency coefficient ( K oe ) is determined by the formula:

$К_{oe} = \frac{Т_o}{Т_o + Т_{rep}}$, (2)

where: T o - the total time the system is in operating condition for some long period of operation; T rep - the total time of repairs and maintenance for the same period of operation.

Also, the operating efficiency coefficient ( K oe ) can be calculated by the formula:

$К_{oe} = \frac{К_{ut}}{Кa}$, (3)

Where: K ut – the time utilization factor; K a – the availability factor.

The efficiency ratio is calculated by the formula:
$К_e = \frac{К_{ut}}{К_t^{max}}$, (four)

Where: K ut - the time utilization factor; $K_t^{max}$- the maximum value of the time utilization facto for the estimated time interval (per month).
Random values of the time utilization factor K ut, availability factor (K a), the operating efficiency coefficient (K oe) and efficiency coefficient (K e) are subjected to economic and statistical treatment, the results of which are used to determine reliability indicators for the specific

types of construction machines (single bucket excavators, bulldozers, pile-driving units, cranes, etc.). An example of calculating the technological reliability coefficients of a single-bucket excavator is shown in diagrams (Figures 1, 2, 3, 4, 5).

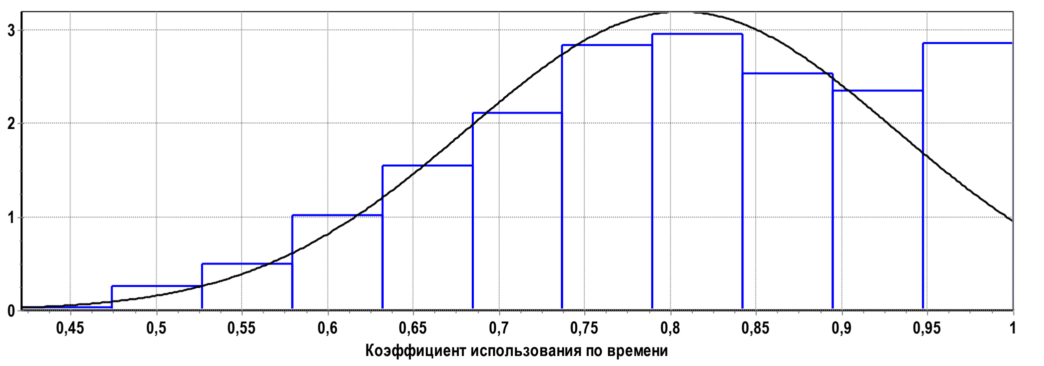


Figure 1. Probability density function (y-axis) depending on the time utilization factor (x-axis)

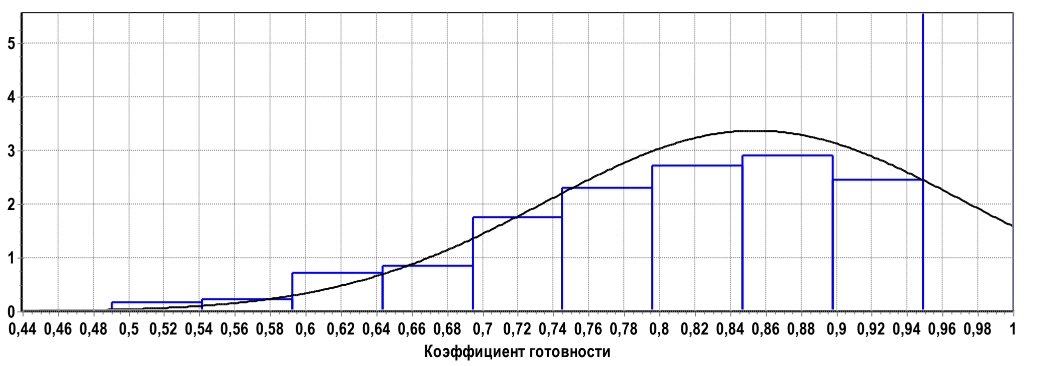


Figure 2. Probability density function (y-axis) depending on the availability factor (x-axis)

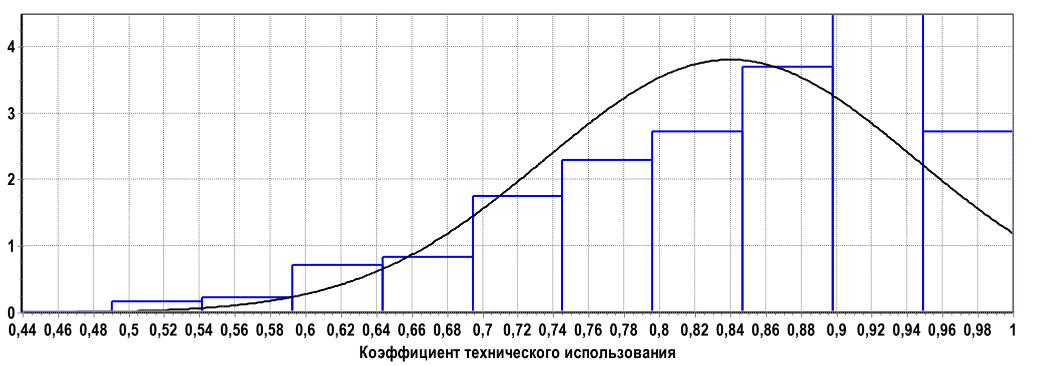


Figure 3. Probability density function (y-axis) depending on the operating efficiency coefficient (x-axis)

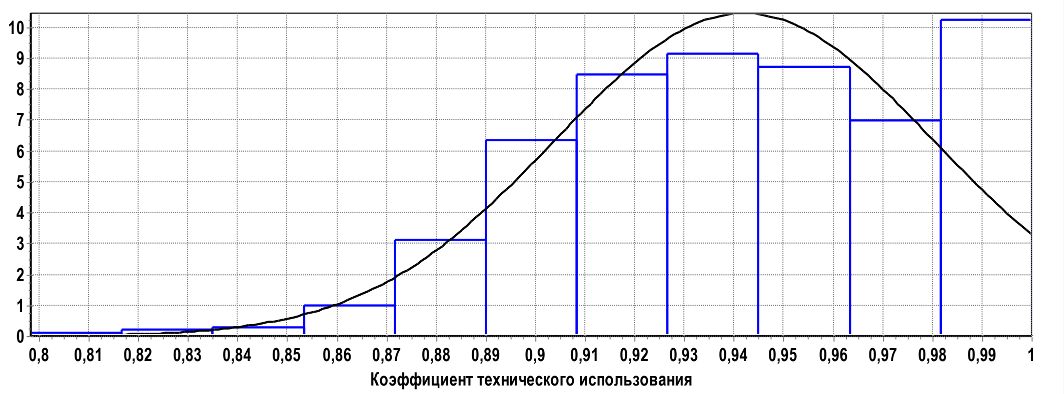


Figure 4. Distribution density (y-axis) depending on operating efficiency coefficient (x-axis) (formula 3)

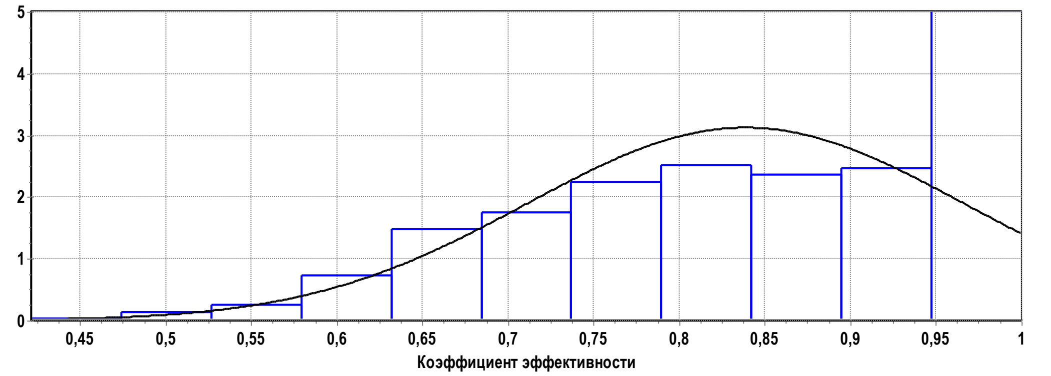


Figure 5. Distribution density (y-axis) depending on the efficiency ratio (x-axis)

Modern Russian materials and construction engineering science is developing at an accelerating pace and offers the building complex all new applied developments. It is important to apply systematically such developments, to introduce more expressively a coordinating principle in their implementation, subordinating them to the current strategic objectives of the industry from the perspective of innovative development. This involves improving the management of applied research, embedding them in a single reproductive process of functioning and development of the construction complex by moving from the general to the particular.

## Conclusion

In general, the study of the innovative development problems actual for capital construction in the Russian Federation provides the basis for the following conclusions:

- The construction industry in Russia is subject to global processes of high technological variability and economic volatility, which makes it necessary to systematically update the technology, organization and economics of construction; this is necessary both in quantitative terms and in qualitative form, what is due to the need to maintain stable competitive positions;
- In the course of economic and technological restructuring of the Russian construction complex, some problems have been revealed, including: relative stagnation in industrial construction, excessive dispersion of contracting organizations, the backlog of the domestic construction base. Nevertheless, the renewal of the engineering and manufacturing facilities, broad erudition and a high level of professional training of the engineering staff and construction workers are a favorable prerequisite for overcoming difficulties, and also for innovative growth;
- In the conditions of scientific and technological revolution penetrating in all spheres of activity, including capital construction, the most expedient is the innovative way of development of the building complex based on the use of new materials, technologies, forms of organization and management on a large scale. From an organizational perspective, this is more achievable in large organizations, which necessitates the clustering of construction projects in forms acceptable for a market economy;

- One of the promising areas of innovative development of the domestic construction complex is the introduction of BIM technologies into all stages of the life cycle of the investment and construction process, starting with business planning and up to a period of operation. The experience of network modeling accumulated at Russian construction sites, including using computer technologies, is a good basis for the spread of BIM technologies from architectural design to the fields of economics and construction management, as well as development.

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