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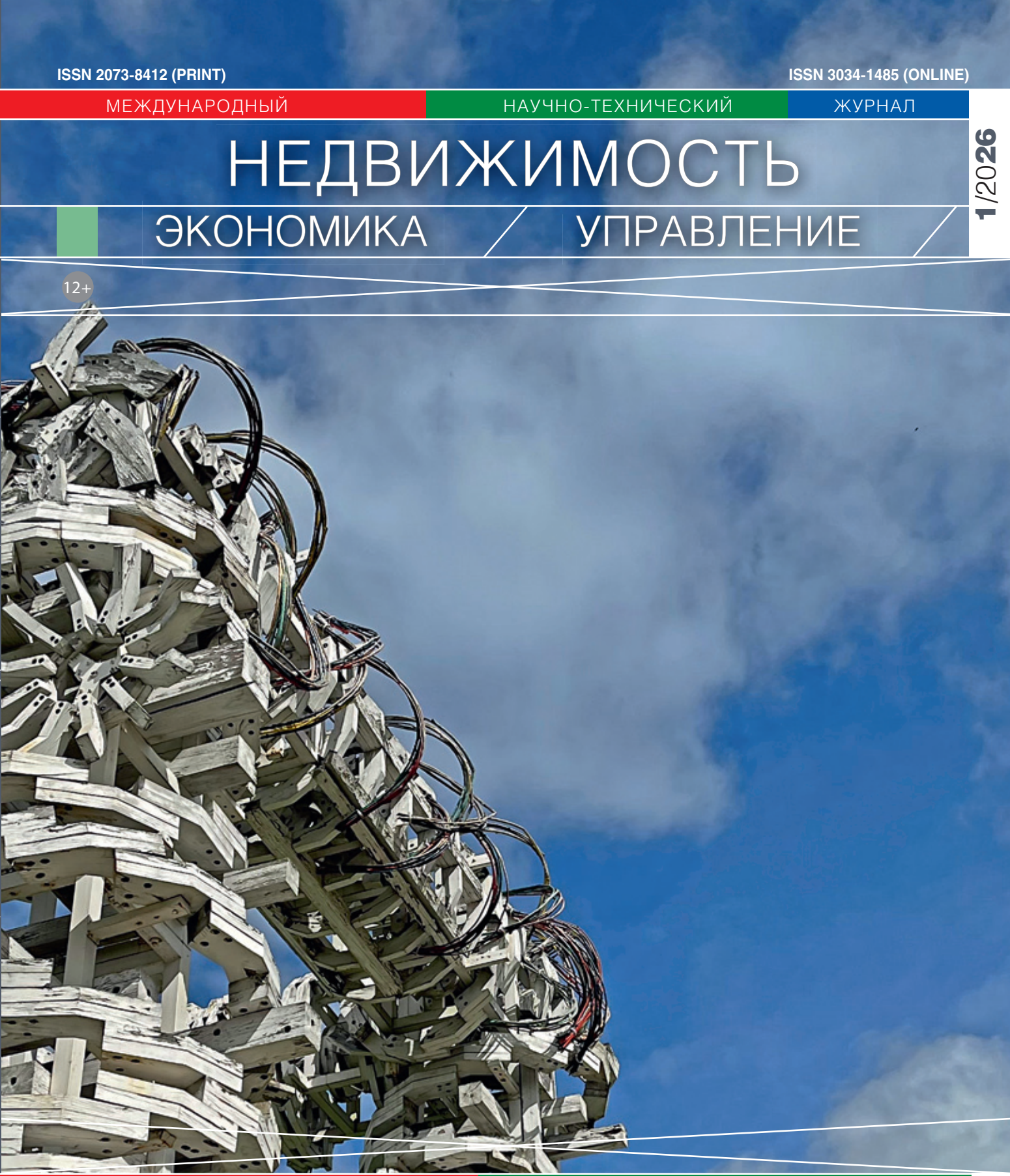
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Главный редактор, **Пётр Грабовый**

Dear Readers!

The investment and construction sector of Russia represents a continuously evolving spatial, technical, organizational, economic, and social system. It comprises interconnected structural elements, including mechanisms for integrated territorial development, a set of construction enterprises and utility providers, as well as the population residing within the given territory.

The primary objective of integrated territorial development is to ensure balanced and sustainable development of settlements, municipal districts, and urban areas by improving the quality of the urban environment and enhancing the visual appearance, architectural style, and other characteristics of capital construction facilities.

A key prerequisite for the effective management of sustainable integrated territorial development is the implementation of a comprehensive program for the territorial and reproductive development of the real estate sector. The presence of such programs enables effective integration across all elements of the overall cause-and-effect chain: “territories → → resources → reproduction → development.” It is within this conceptual framework that the articles in this issue of the journal are presented.

Sincerely, **Peter Grabovyy**
Editor-in-Chief

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Khrustalev B.B., Razumov D.M.
Developers, as the primary initiating actors of investment and construction activities, have a significant impact on the development of regional housing markets. When analyzing construction processes, it is necessary to determine their organizational structure, the approaches applied to real estate development, and their interaction with other participants in the construction process

Kulakov K.Yu., Abdalov R.E.
Given the imperfection of the integrated territorial development program, a strategically important decision on investing a development organization in a comprehensive territorial development project should be made based on an assessment of a number of criteria that take into account the characteristics of the developer and the specifics of the project, along with a deep systematic analysis of past and present experience, as well as future market trends

Kurakova O.A., Chubarkina I.Yu., Dmitrova E.D.
The digital twin of a territory is considered as a visualized information and analytical system combining spatial, transport, engineering, social and economic data. Unlike standard geographic information systems, which only store and display data, the digital twin of the territory is characterized by the possibility of scenario modelling

Zvonov I.A., Molchina N.A.
The traditional assessment of dormitories is based on the availability of space, optimal capacity, level of sanitary conditions, and other values. As research and student survey results show, compliance with regulatory requirements does not always ensure high satisfaction with the environment

Geraskin Yu.M., Mikheev S.A.
The form of organization of the production base has a significant impact on the technical and economic indicators of the project, and its assessment is a multi-criteria task, the solution of which requires an analysis of many parameters, including the regional conditions of the construction site, the availability of existing production facilities, investment strategy and the need for a multiplier effect of the development of the regional economy

Migunova N.A., Sychev I.S.
International practice demonstrates that in the construction sector, the social franchising format can serve as an effective mechanism for solving the shortage of social housing, promoting “green” energy-efficient construction and introducing universal design principles into urban development

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Khrustalev B.B.
Razumov D.M.

The Influence of Construction Industry Enterprise Concentration on Housing Development in the Moscow Agglomeration

The paper presents an analysis of the dynamics of formation and development of the housing market in Moscow and the Moscow Region, taking into account the degree of concentration of construction industry enterprises within the study area. The analysis is based on statistical data from the Unified Register of Developers (ERZ) for the period 2017–2025. The study employs statistical methods, as well as systems analysis and dynamic analysis. In addition, system-based, dynamic, and geoinformation approaches are applied. The research identifies key patterns in the influence of the concentration level of industrial housing construction on the intensity of construction activity across districts of Moscow and the Moscow Region. Areas with a high degree of market concentration are identified, where more than half of the total floor area of housing under construction is developed by ten large developers within each region. Geoinformation analysis reveals the formation of several stable territorial clusters ("construction islands"), located primarily along the administrative boundary of Moscow and effectively forming a unified zone of housing market development together with the adjacent agglomeration. The paper demonstrates that the localization of construction projects is directly related to the spatial distribution and concentration of construction industry facilities. The obtained results can be used in planning the flow-line construction of residential real estate projects and in the development of the required regional infrastructure.

Keywords: *housing construction, statistical analysis, geoinformation analysis, construction flows, system analysis, construction industry, construction dynamics*



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INTRODUCTION

At present, the construction industry faces the task of increasing the rate of commissioning of real estate facilities and reducing construction timelines. Achieving this objective requires the development of a long-term program aimed at forming object-specific and specialized construction flows.

The formation of such flows necessitates consideration of three principal regional components:

- the region as a territory;
- the predominant type of residential construction;
- the number of developers operating within the region.

The region as a territory constitutes a complex system that includes buildings and structures, transport infrastructure, facilities of the construction industry, and the geographical distribution of construction industry facilities relative to the most actively developing areas within the region, taking into account local geographical characteristics.

The predominant type of residential construction — namely monolithic and panel housing construction — significantly reduces the duration of real estate development and forms the basis for the establishment of corresponding construction flows. Each housing type is characterized by specific cost, time, spatial, and resource parameters that influence output performance in the implementation of investment and construction projects.

Developers, as the principal initiating entities of investment and construction activity, exert a substantial influence on the pattern of regional housing market development. The study of construction flow functioning requires the identification of their organizational structure, the construction approaches they apply, and their interaction with other participants in the construction process.

MATERIALS AND METHODS

The study employed statistical methods of analysis, including the processing and interpretation of quantitative data; systems analysis to assess interactions among construction industry facilities and their flow characteristics; dynamic analysis to examine temporal changes in key indicators; and geoinformation analysis. The empirical basis of the research consisted of statistical and other informational sources, materials characterizing the production and economic activities of developers, expert assessments, and other documentation related to the construction sector.

The study was based on data obtained from the Unified Register of Developers (ERZ) database for the period from 2017 to 2025.

RESULTS

At present, the city of Moscow and the Moscow Region represent the largest territories in terms of residential construction rates. This region is particularly suitable for analysis, as it demonstrates the highest population growth while simultaneously exhibiting a high population density [1].

According to the Unified Register of Developers[1], as of October 2025, 18,754,280 m^2 of residential real estate is under construction in Moscow and

[1] Unified Register of Developers : official website. URL: https://erzrf.ru/ (rus.).

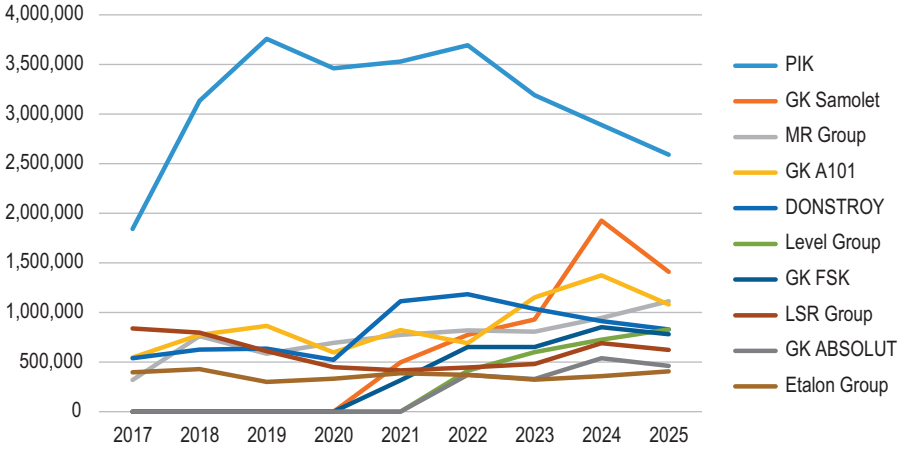


Fig. 1. Volume of construction of apartment buildings, m², 2017–2025, by Moscow developers

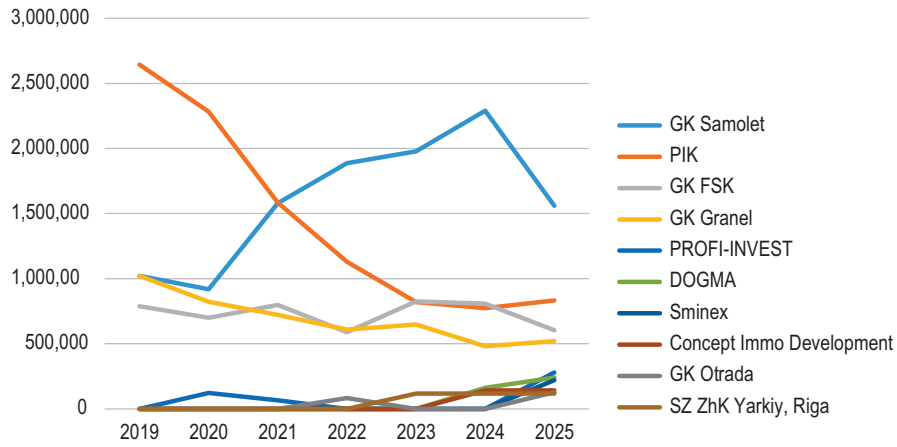


Fig. 2. Volume of apartment building construction, m², 2019–2025, by developer in the Moscow region

8,175,970 m² in the Moscow Region. More than half of the total construction volume is concentrated among the top 10 developers by residential construction output: 10,116,240 m² (53.95 %) in Moscow and 4,640,518 m² (56.77 %) in the Moscow Region. The analysis of developer activities in this region constitutes an important aspect of studying the application of organizational and technological mechanisms, as developers plan and structure construction flows for residential projects and determine rational technological and organizational approaches to project implementation [2]. As of October 2025, the largest developers in Moscow are: GK "PIK" — 2,589,966 m²; GK "Samolet" — 1,409,821 m²; MR Group — 1,112,324 m²; GK "A101" — 1,081,616 m²; "DONSTROY" — 828,662 m²; Level Group — 826,947 m²; GK "FSK" — 779,638 m²; LSR Group — 623,169 m²; GK "ABSOLUT" — 459,810 m²; and Etalon Group — 404,287 m² (Fig. 1).

In the Moscow Region, the largest developers are: GK "Samolet" — 1,559,975 m²; GK "PIK" — 833,157 m²; GK "FSK" — 604,627 m²; GK "Granel" — 519,696 m²; "PROFI-INVEST" — 278,648 m²; "DOGMA" — 238,671 m²; "Sminex" — 219,950 m²; "Concept Immo Development" — 142,774 m²; GK "Otrada" — 127,204 m²; and SZ ZhK Yarkiy, Riga — 115,816 m² (Fig. 2).

Among the ten largest developers by construction volume, GK "PIK" and GK "Samolet" are particularly prominent. As of the end of 2025, they jointly account for 21 % of all residential construction in Moscow and 29 % in the Moscow Region. Their combined share among the top ten developers amounts to 40 % in Moscow and 52 % in the Moscow Region.

The two companies employ distinct organizational strategies. GK "PIK" implements a development model characterized by pronounced vertical integration. The company relies on its own production facilities, including large-scale house-building plants such as DSK-2 and DSK-3[2]. These enterprises specialize in the production of primary structural elements, enabling GK "PIK" to maintain greater control over key stages of construction component manufacturing. This approach enhances the level of industrialization and facilitates large-scale construction output [3–5]. At the same time, the company rationally combines internal production capacities with the involvement of external contractors and subcontractors, with a significant share of on-site construction work performed by third-party organizations.

In contrast, GK "Samolet" follows a classical development strategy. The company does not possess its own production facilities; instead, it operates through an internal general contractor, LLC "Stroy-Development", which coordinates the activities of contracted firms and specialized subcontractors[3]. On the one hand, this production organization model may increase construction costs and

[2] RAO PIK SZ: Company Profile. Construction News Agency. URL: https://m.asninfo.ru/companies/22-pao-pik-sz (rus.).

[3] Samolet Group of Companies: Company Profile. Mail Finance. URL: https://finance.mail.ru/card/gruppa-kompanij-samolet-715 (rus.).

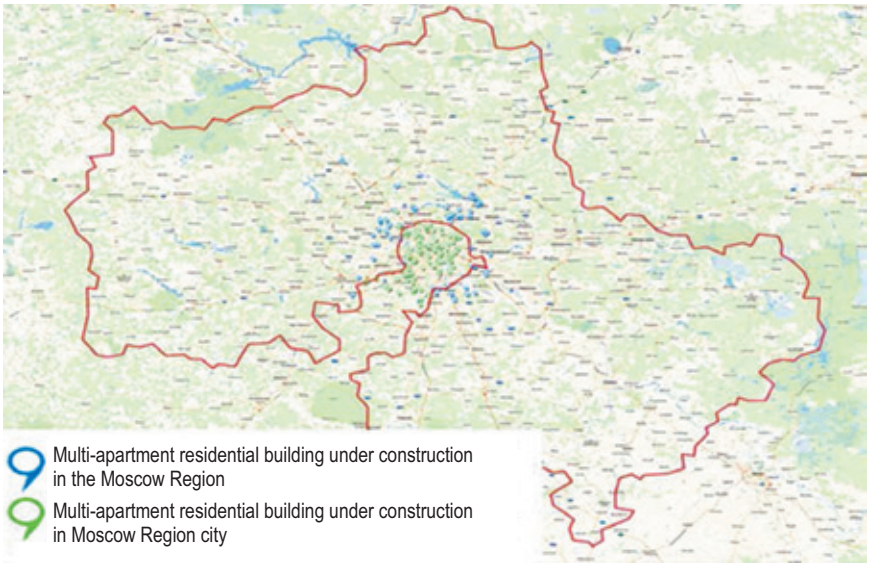


Fig. 3. Concentration of multi-apartment residential buildings under construction in Moscow and the Moscow Region as of October 2025

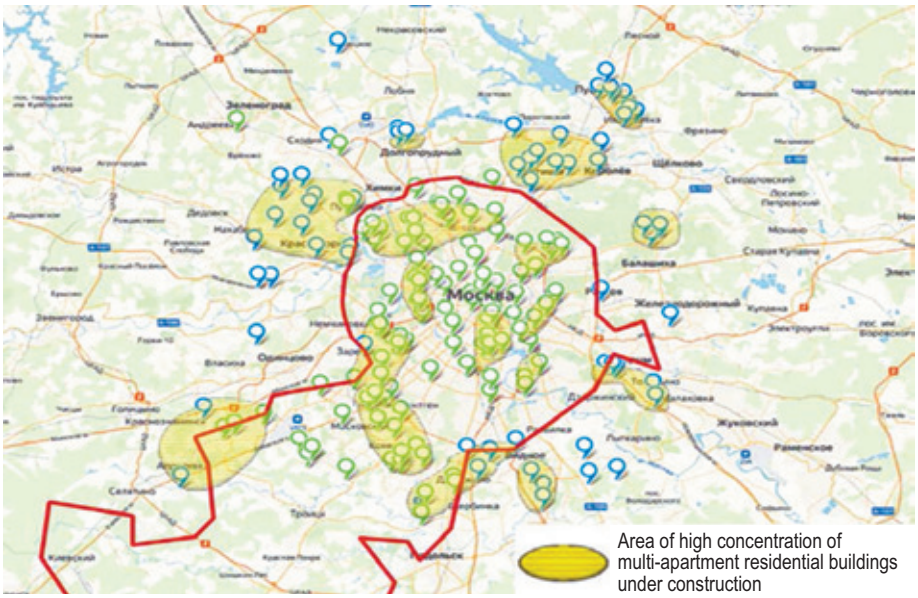


Fig. 4. Areas of high concentration of multi-apartment residential buildings on the map of Moscow and the Moscow Region

reduce direct control over processes that determine the critical path. On the other hand, it eliminates the need to maintain fixed production capacities, provides greater organizational flexibility and investment adaptability, and contributes to the sustainability of construction flows in residential development [6–10]. As of October 2025, these developers are constructing 187 multi-apartment residential buildings (126 in Moscow and 61 in the Moscow Region). Notably, the majority of projects in the Moscow Region are located in close proximity to the administrative boundary of Moscow (Fig. 3).

Fig. 3 demonstrates that the region includes territories with both high and low concentrations of construction activity. The most intensive development is observed in Moscow and adjacent areas. However, for the efficient utilization of regional territory, the housing market should develop not only within the capital and its immediate surroundings, but throughout the entire Moscow Region.

The uneven distribution of development activity can be explained by the fact that the nearest agglomeration beyond Moscow's administrative boundary should be regarded as a natural extension of the city, as its economic activity is closely integrated with the capital. The largest towns of the Moscow Region are likewise located near Moscow and are economically oriented toward it, effectively functioning as components of the metropolitan agglomeration [11]. At present, several development "zones" can be identified — areas with the highest concentration of multi-apartment residential construction (Fig. 4).

These high-concentration zones have emerged due to two territorial factors. The first factor is strong consumer demand for housing located as close as possible to the capital. Such housing allows residents to maintain economic and social connectivity with Moscow while benefiting from lower prices, typically associated with lower land costs [12]. The second factor is the presence of a wide

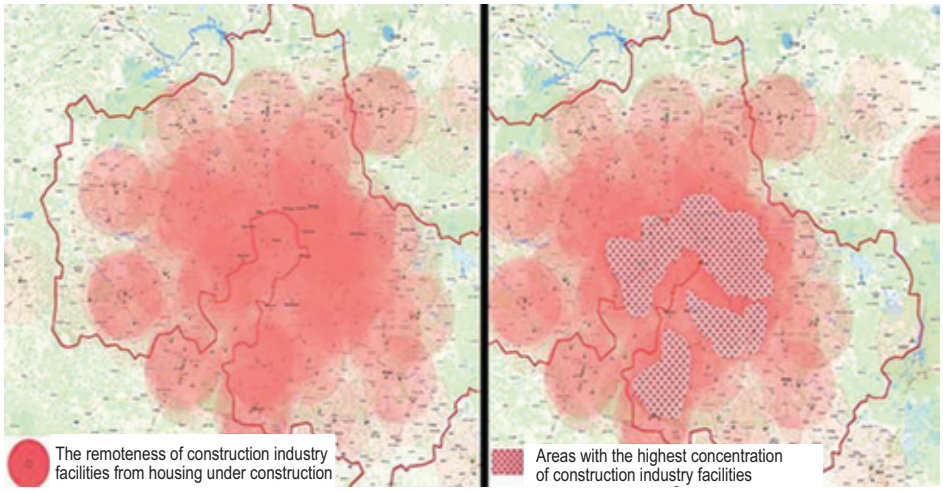


Fig. 5. Territories of the city of Moscow and the Moscow region depending on the density of construction industry facilities in these territories

range of construction industry enterprises oriented toward residential development within these zones [13] (Fig. 5).

As shown in Fig. 5, certain areas of the region exhibit a high concentration of construction industry facilities, which corresponds to an increased concentration of residential development. In other territories, this indicator is lower, implying either the need to establish new construction industry facilities or to improve the utilization of existing capacities while addressing issues of mobility and sustainability.

CONCLUSION

The analysis of residential construction in Moscow and the Moscow Region has identified areas with a high concentration of housing development. More than half of the total residential construction volume is carried out by ten developers, with GK "PIK" and GK "Samolet" being the largest. Geoinformation analysis has revealed the formation of several stable development clusters ("zones"), predominantly located along the administrative boundary of Moscow, in territories functioning as a continuation of the metropolitan agglomeration. This pattern should be taken into account, as despite their formal administrative affiliation with the Moscow Region, these territories effectively operate as extensions of the capital. The results obtained in this study may be applied in the development of organizational and technological mechanisms aimed at transferring the most complex and labor-intensive processes from construction sites to industrial production facilities. Such an approach would contribute to reducing overall costs and ensuring high construction rates in the housing market, while integrating construction flows across Moscow and the Moscow Region.

REFERENCES

1. Grabovyy P.G., Khrabrov A.P. Construction of large commercial real estate objects at life cycle stages under risk conditions. Real Estate: Economics, Management. 2024; 3:65-68. EDN BUFJYA.
2. Narnitsky S.V., Gusarov V.S., Belyakov S.I. Development of procedures for selecting contractors and final control of the execution of contract work within the framework of an investment and construction project. Real Estate: Economics, Management. 2025; 3:226-230. URL: https://n-eu.iasv.ru/index.php/neu/issue/view/37/48 (rus.).
3. Ma Sh., Li Zh., Zhang Sh. Two Technological Paths towards Construction Industrialization: Prefabricated and On-site Industrialized Construction. International Journal of Structural and Civil Engineering Research. 2024; 13(4):137-143. DOI: 10.18178/ijscer.13.4.137-143. EDN TMYBSC.
4. Khrustalev B.B., Razumov D.M. Development of warehouse infrastructure serving the process of construction of real estate objects in the housing market. Real Estate: Economics, Management. 2024; 4:19-23. EDN IUOWKO.
5. Khrustalev B.B., Antipov V.A., Lunyakov M.A. Principal development features of the investment and construction complex in the Russian Federation. Real Estate: Economics, Management. 2022; 2:6-9. DOI: 10.22337/2073-8412-2022-2-6-10. EDN WMNVKI.
6. Khrustalev B.B., Grabovyy P.G., Grabovyy K.P., Kargin A.A. Taking into account the impact of various types of losses when using information modeling technology in construction. Journal of Law and Sustainable Development. 2023; 11(2):e289. DOI: 10.55908/sdgs.v11i2.289. EDN ZUIXKZ.
7. Khrustalev B.B., Razumov D.M. Integrated development of residential areas using organizational and technological mechanisms. Real Estate: Economics, Management. 2025; 3:155-158. URL: https://n-eu.iasv.ru/index.php/neu/issue/view/37/48 (rus.).
8. Grabovyy P.G., Korolev N.I. Main features of construction of real estate facilities in the formation of the system of relations of the participants in their construction. Real Estate: Economics, Management. 2024; 3:56-58. EDN EXGQCR.
9. Wang X., Xie Sh., Wei Zh., Wang J. A study on the impact of China's prefabricated building policy on the carbon reduction benefits of China's Construction Industry Based on a Difference-in-Differences Method. Sustainability. 2024; 16(17):7606. DOI: 10.3390/su16177606
10. Simionov R.Yu., Azhimov T.Z. Supply chain management in industrial housing construction: specifics, problems, methods, performance indicators. Real Estate: Economics, Management. 2024; 2:37-40. EDN CEOEJV.
11. Xiahou X., Yuan J., Liu Y., Tang Y., Li Q. Exploring the driving factors of construction industrialization development in China. International Journal of Environmental Research and Public Health. 2018; 15(3):442. DOI: 10.3390/ijerph15030442
12. Ji Y., Zhu F., Li H.X., Al-Hussein M. Construction industrialization in China: current profile and the prediction. Applied Sciences. 2017; 7(2):180. DOI: 10.3390/app7020180
13. Luo T., Xue X., Xue W., Wang Y., Tan Y. A systematic overview of prefabricated construction policies in China. Journal of Cleaner Production. 2021; 280:124371. DOI: 10.1016/j.jclepro.2020.124371. EDN KDRNMA.

Влияние концентрации предприятий стройиндустрии на формирование и развитие жилищного строительства в Московской агломерации

В статье представлен анализ динамики формирования и развития рынка жилья в Москве и Московской области с учетом степени концентрации предприятий строительной индустрии на данной территории. Проведенный анализ базируется на основе статистических данных Единого реестра застройщиков (ЕРЗ) за период 2017–2025 гг. При исследовании были использованы статистические методы, методы системного и динамического анализа. Также были применены системный, динамический и геоинформационный подходы. В ходе проведения исследования были выявлены основные закономерности влияния степени концентрации индустриального домостроения на степень строительной активности по районам Москвы и Московской области. Установлены районы с высокой степенью концентрации рынка объектов недвижимости, где больше половины площадей строящегося жилья возводится десятью крупными застройщиками в рамках каждого региона. Геоинформационный анализ показал формирование нескольких устойчивых территориальных кластеров («островов» застройки), располагающихся преимущественно на границе города Москвы и фактически образующих единую зону строительного развития рынка жилья с прилегающей агломерацией. В статье показано, что локализация строительных проектов связана напрямую с размещением и концентрацией объектов стройиндустрии. Полученные результаты могут быть использованы при планировании поточного возведения объектов недвижимости на рынке жилья и развитии требуемой региональной инфраструктуры.

Ключевые слова: *жилищное строительство, статистический анализ, геоинформационный анализ, строительные потоки, системный анализ, строительная индустрия, динамика строительства*

СПИСОК ИСТОЧНИКОВ

1. Грабовый П.Г., Храбров А.П. Особенности возведения крупных объектов коммерческой недвижимости на этапах жизненного цикла в условиях риска // Недвижимость: экономика, управление. 2024. № 3. С. 65–68. EDN BUFJYA.
2. Нарницкий С.В., Гусаров В.С., Беляков С.И. Развитие процедур выбора подрядных организаций и итогового контроля выполнения подрядных работ в рамках инвестиционно-строительного проекта // Недвижимость: экономика, управление. 2025. № 3. С. 226–230. URL: https://n-eu.iasv.ru/index.php/neu/issue/view/37/48
3. Ma Sh., Li Zh., Zhang Sh. Two Technological Paths towards Construction Industrialization: Prefabricated and On-site Industrialized Construction // International Journal of Structural and Civil Engineering Research. 2024. No. 13 (4). Pp. 137–143. DOI: 10.18178/ijscer.13.4.137-143. EDN TMYBSC.
4. Хрусталев Б.Б., Разумов Д.М. Девелопмент складской инфраструктуры обслуживающего процесса возведения объектов недвижимости на рынке жилья // Недвижимость: экономика, управление. 2024. № 4. С. 19–23. EDN IUOWKO.
5. Хрусталев Б.Б., Антипов В.А., Луняков М.А. Основные особенности развития инвестиционно-строительного комплекса Российской Федерации // Недвижимость: экономика, управление. 2022. № 2. С. 6–10. DOI: 10.22337/2073-8412-2022-2-6-10. EDN WMNVKI.
6. Khrustalev B.B., Grabovyy P.G., Grabovyy K.P., Kargin A.A. Taking into account the impact of various types of losses when using information modeling technology in construction // Journal of Law and Sustainable Development. 2023. No. 11 (2). P. e289. DOI: 10.55908/sdgs.v11i2.289. EDN ZUIXKZ.
7. Хрусталев Б.Б., Разумов Д.М. Комплексное развитие территории жилой застройки с применением организационно-технологических механизмов // Недвижимость: экономика, управление. 2025. № 3. С. 155–158. URL: https://n-eu.iasv.ru/index.php/neu/issue/view/37/48
8. Грабовый П.Г., Королев Н.И. Основные особенности строительства объектов недвижимости при формировании системы взаимоотношений участников их возведения // Недвижимость: экономика, управление. 2024. № 3. С. 56–58. EDN EXGQCR.
9. Wang X., Xie Sh., Wei Zh., Wang J. A study on the impact of China's prefabricated building policy on the carbon reduction benefits of China's Construction Industry Based on a Difference-in-Differences Method. Sustainability. 2024. No. 16 (17). P. 7606. DOI: 10.3390/su16177606
10. Симионов Р.Ю., Ажимов Т.З. Управление цепями поставок в индустриальном домостроении: специфика, проблемы, методы, показатели эффективности // Недвижимость: экономика, управление. 2024. № 2. С. 37–40. EDN CEOEJV.
11. Xiahou X., Yuan J., Liu Y., Tang Y., Li Q. Exploring the driving factors of construction industrialization development in China // International Journal of Environmental Research and Public Health. 2018. No. 15 (3). P. 442. DOI: 10.3390/ijerph15030442
12. Ji Y., Zhu F., Li H.X., Al-Hussein M. Construction industrialization in China: current profile and the prediction // Applied Sciences. 2017. No. 7 (2). P. 180. DOI: 10.3390/app7020180
13. Luo T., Xue X., Xue W., Wang Y., Tan Y. A systematic overview of prefabricated construction policies in China // Journal of Cleaner Production. 2021. No. 280. P. 124371. DOI: 10.1016/j.jclepro.2020.124371. EDN KDRNMA.

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Content and principles of investment analysis and business planning for IDT development projects

The scientific paper is devoted to the urgent topic of the need for methodological support for the implementation of projects of the integrated territorial development programme (IDT), which has been steadily increasing its potential and has become an advanced tool for spatial transformation. In conditions of instability of the economic environment and the presence of many features of the IDT mechanism, it is important for the developer to implement an integrated approach to the pre-investment study of the project in order to make a rational investment decision on participation in the project. In this regard, the problems and some important features characteristic of the IDT mechanism are noted, which affect aspects of pre-investment activities. The authors analyzed the conceptual and categorical apparatus of the "pre-investment stage" and considered the issue of the process content of this stage. In order to determine the possibility and specifics of using the developer's practical activities, the investment decision-making tools, investment analysis and business planning, are considered through the prism of the IDT. For these processes, general characteristics are presented and behavioural principles in the conditions of the IDT are noted, which require consideration in the investment and construction activities of the development implementation. The results of the study led to a conclusion about the versatility, complexity and importance of investment analysis and business planning processes in the framework of the pre-investment study of the IDT.
Keywords: *Integrated development of territory (IDT), investment analysis, business planning, real estate development, organizational and economic sustainability of the developer*



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Current trends in the domestic development of urban spaces dictate the need for a systematic approach to the qualitative transformation of territories. This need is being met today through the mechanism of integrated development of territories (IDT), which is aimed at improving the urban environment by reorganizing depressed areas and misused territories and forming modern blocks of residential, commercial, and social real estate in their place with modernized transport and engineering infrastructure and well-developed landscaping.

Despite the pace of development and scale of coverage that has been increasing annually since 2020, the existing IDT mechanism has a number of bottlenecks that require solutions due to its "youth".

The analysis of the research indicates that there are significant gaps in legislation that can cause conflict situations between stakeholders involved directly or indirectly in the implementation of the IDT. Such gaps include provisions on the seizure of land plots for the implementation of the IDT, some issues of bidding for the right to conclude an IDT agreement, the unambiguity of interpretation and transparency of the terms of the IDT agreement, and other legal features [1, 2].

Also, the issue of the ambiguous attitude of residents to measures for their resettlement during the housing development is considered important. Such a problem of public anxiety is caused by the lack of clarity or even lack of legislative guarantees on relocation options and the specifics of housing provided in return [3].

A number of researchers speak about the problems of the economics of IDT projects, in particular, they express opinions about the potentially low economic efficiency of the IDT project for the investor due to the obligations to reproduce social and commercial real estate, as well as transport and engineering infrastructure, which is often supposed to be transferred to the ownership of a public entity for free [4]. In this regard, a significant role in assisting the investor can be played by the financial and economic justification of the IDT project performed by a public entity in the process of establishing the boundaries of the IDT and forming a decision on the IDT [5]. Such a justification should presumably include sufficiently detailed parameters for the investor's implementation of the IDT project (capital (CAPEX) and operating (OPEX) expenses, prospective generated revenues), as well as an assessment of the investment effectiveness of a particular project.

Against the background of these circumstances, the consistent issue of achieving the goal and beneficial effect of the concept of the IDT on the territory of the Russian Federation is the task of forming a comprehensive practice-oriented methodological support for its implementation, taking into account in detail the legal, organizational, economic and other features of the concept of the IDT. One of the subjects of such provision may be the tools of pre-investment study in order to make an investment decision on the implementation of the IDT project by a development organization.

Given the imperfection of the IDT programme, a strategically important decision on investing a development organization in the IDT project should be made based on an assessment of a number of criteria that take into account the characteristics of the developer and the specifics of the project, along with a deep systematic analysis of past and present experience, as well as future market trends. The consistency inherent

Analysis of the conceptual and categorical apparatus of the "pre-investment stage" (compiled by the author on the basis of [10–13])

The author(s) of the scientific work	Name of the concept	Interpretation of the concept
P.G. Grabovyy and others	Pre-investment stage (pre-project stage, conceptual stage)	Four areas of research within the stage: • concept creation; • project analysis (including financial, investment, technical, marketing, etc.); • feasibility study; • development of a business plan. Main tasks: • real estate market analysis; • formation of conditions for attracting investments; • coordination of regulatory issues; • forming a project team; • choosing the optimal time period for the implementation of the development project
S.V. Bovteev	Pre-investment phase (initial phase, concept)	Works as part of the phase: • preliminary studies; • comparative evaluation of alternative options; • submission and examination of proposals; • project feasibility analysis; • strategy development
A.N. Asaul	Pre-project stage (initial stage)	Components of the pre-project stage: • real estate market analysis; • choosing a property; • development of a project strategy; • investment analysis; • registration of initial permits; • attraction of credit investment funds
S.V. Pupentsova	Pre-investment phase	The pre-investment decision phase includes: • exploring the possibilities of a future project; • conducting feasibility studies; • comprehensive assessment of future design solutions; • comparison of alternatives; • financial analysis; • preparation of the design plan

in the philosophy of such an analysis implies the integration of many process components, each of which is aimed at a specific area of the project (urban planning, financial, legal, etc.). In a typical economic environment of hierarchical information flows and multifactorial nature, it is extremely important to consider these elements together in order to understand their interrelationship and influence on each other [6–8].

The developer makes an investment decision within the framework of the IDT project based on forecasting a possible profit. The main principle of investing and, consequently, the primary goal of the developer is to extract financial profit from the implemented project. In addition to financial enrichment, the benefits sought may also include:

- strengthening or enhancing the organization's reputational image;
- development of the asset portfolio and expansion of market influence;
- acquisition of experience and development of the intellectual and technological capital of the organization.

It is advisable for the investor to carry out an analysis of any investment and construction project at the pre-investment stage (phase) of the project life cycle in order to form a comprehensive and holistic understanding of the project features, which allows predicting potential difficulties and pre-planning optimal solutions before investing funds or completely abandoning the idea of investing.

In the ideology of decomposition of the life cycle of a development project, including for the IDT projects, the pre-investment stage is regarded as a stage of familiarization and in-depth study of the specifics of the project. In practice, this stage involves carrying out a set of consistent analytical and research processes aimed at substantiating the expediency and rationality of investing in the project [9].

Over the past decade, the scientific and business communities have been paying special attention to the pre-investment stage, including the process content of this stage. In order to systematize knowledge and find commonalities between the concept of "pre-investment stage" in investment and construction activities and terms similar to it, reflected in the research of various authors, an analysis of the conceptual and categorical apparatus was carried out (Table) [10–13].

The analysis illustrates that the pre-investment stage is regarded by researchers as a fundamental stage of an investment and construction (development) project, the analytical and research processes of which are focused on a multidimensional assessment of investor opportunities and project specifics. At the same time, it is fair to emphasize the existence of contradictions in terms of the structure and content of interpretations, which sets the direction for further theoretical and methodological developments in order to improve the preparation phase of investment and construction projects.

The identified gaps related to the pre-investment activities of the development project in the context of the IDT programme are further complicated by the imposition of provisions characteristic of the mechanism:

- the IDT mechanism involves the initiation of a project — the preparation of a solution and the "completion" of the project with urban planning and technical and economic indicators and implementation requirements — by a public entity (authority), except in cases of the IDT implementation on the initiative of the copyright holder;
- the IDT mechanism primarily involves the implementation of a project by a person engaged in the development of the territory (investor, developer), through bidding for the right to conclude an IDT agreement (with the exception of the type of IDT initiated by the right holders and the independent implementation of the IDT by a public entity (authority));
- the IDT mechanism, in comparison with a traditional development project, assumes the closest interaction, including the need to fulfill obligations, of the person responsible for the development of the territory (investor, developer) with a public entity (authority) within the framework of the IDT agreement.

The conjuncture of the IDT implies that the person carrying out the development of the territory (investor, developer) is not the direct initiator of the project, as is the case with a traditional development project, when, based on an assessment of investment attractiveness, he acquires a land plot for specific project objectives based on the results of a pre-investment study. In the conditions of the IDT, the authority, except in cases of independent project implementation, actually offers the developer to become a partner in the implementation of the IDT, that is, the developer is considered a potential "buyer" (contractor).

Separately, it is worth noting two features of the concept of the IDT related to the temporal aspect and determined on the basis of the practice of the authors in the most average case:

- the period from the moment of publication of the decision on the IDT to the selection of the contractor for the implementation of the IDT project based on the results of the auction is about 2 months;
- the deadline for the implementation of the IDT project is from 7 to 15 years.

These features cause a temporary dichotomy in the behaviour of the IDT mechanism, which must necessarily be taken into account by the developer before analyzing a specific project. This dichotomy lies in the fact that the pre-investment study and the adoption of an investment decision should be carried out in a fairly short time, urgently, while the implementation of the IDT project itself is protracted with strict boundaries. In the first case, the developer needs to show operational efficiency, flexibility and mobility, and in the second case, the developer needs to have a high level of long-term strategic planning with advanced techniques for managing changes and reallocating resources during the implementation of the IDT project.

In the current situation, it is proposed to make an investment decision on joining or abandoning the IDT project from the perspective of the developer's current and long-term opportunities and risks, fully taking into account the design parameters and contractual conditions. Thus, the most adequate category for determining the expediency of a developer's investment in a real estate development is the organizational and economic stability of the developer, which characterizes, in a general sense, the ability to withstand the effects of external and internal factors, maintain at a certain balanced level the multidimensional indicators of production and economic activity and ensure stable long-term development of the organization.

Based on this consideration, the pre-investment study of the IDT project may involve the inclusion of the most common complex processes — investment analysis and business planning.

Investment analysis (IA) in investment and construction activities is a multi-stage set of techniques and practical tools, the main purpose of which is to assess the effectiveness of the investment activity of a developer in relation to a potential project based on multidimensional indicators and conditions of investment and project parameters [14].

The theoretical and methodological provisions reflected in the scientific works of Russian scientists, as well as the results of the analysis of modern development activities, made it possible to identify the main components of IA [15–18]:

- financial analysis;
- technical analysis;
- legal analysis;
- marketing analysis.

We will describe in the most detail each of the presented types of analysis in relation to the specifics of the IDT.

The financial analysis of the IDT project is aimed at a multi-level assessment of the macroeconomic situation, the attractiveness of the IDT project and the financial stability of the developer. The parameters defined in the course of each of the directions (cost analysis, revenue forecast, cash flow planning, identification of sources, schemes and conditions of financing, indicators of the viability of the organization) are elements of the financial model of the development project of the IDT, based on the results of which the indicators of the effectiveness of participation in it are determined (NPV, IRR, PP, PI, ROI, Gross Margin and others).

The technical analysis within the framework of the IDT includes an assessment of the features of the territory involved in terms of the possibility of reproducing capital and non-capital construction facilities and linear structures on it. In this regard, the issues of placement on the territory and in the immediate vicinity of existing real estate and non-capital buildings, engineering and technical support networks, road infrastructure facilities, as well as geological and hydrogeological conditions of the land plot are being studied. In addition, the main limitations and potential of the implementation of the planning, spatial, architectural and construction plans of the developer are preliminarily determined.

The legal analysis should be aimed at supporting the legitimacy and transparency of the procedures for concluding and executing a land management agreement between a public entity and an executor, as well as identifying all possible land management, urban planning, and technical limitations of a land management project through the study of tender documentation, title deeds, legal and regulatory acts, and law enforcement practice.

The marketing analysis in the context of the IDT is based on performing a set of studies of macro-, meso- and microlevel environments. It is important for a developer to know the key global trends (the geopolitical situation, demographic statistics, socio-cultural situation), the conjuncture of the investment and construction sector and the real estate market (supply and demand for real estate, competitor analysis) and adequately assess the level of the corporate development product and the possibilities of marketing tools.

Business planning (BP) in the investment and construction sector is regarded as a form of presenting the project under consideration to prospective stakeholders and a tool for achieving target indicators at the strategic, tactical and operational levels [19–21].

The result of the BP is a developed document (business plan), which, in its most general form, contains information about market conditions, marketing strategy, organization of work, financial indicators and risks of the project [19]. In addition, a business plan can be drawn up for different time periods — for 1 year, for 3–5 years, for 5–10 years.

In the practical activity of a developer, the BP of the IDT project differs significantly from the BP of a development project according to the classical scheme involving the purchase or lease of a land plot. Moreover, the BP tool in modern development practice, including in the framework of the IDT, in comparison, for example, with innovative projects, is gradually losing its relevance and value and is becoming a vestige.

However, the authors believe that the applicability of the BP by a developer in the field of the IDT may be determined by the need to form, based on the results, including investment analysis, a unified strategic programme of the organization's production and economic activities for the period of implementation of a specific IDT project as a target and auxiliary "beacon". In this case, the task of the BP in the conditions of the IDT is not only to justify the expediency of participating in the project, but also to identify areas of inefficiency and control levers, as well as to predict non-financial bonuses from the implementation of the project. In addition, the strategic concept developed in this way can be presented to the banking structure as a document confirming the intentions and viability of the developer in order to obtain the necessary debt financing.

Turning to practice, the author's observations of the activities of large development organizations confirm the existence in their organizational structures of a clear division of the IA and BP activities between competent departments. Performing the type of pre-investment study assigned to the functional, structural divisions provide reporting and analytical information based on its results and, as part of participation in a joint discussion (at the investment committee) with top management, make a positive or negative decision on the expediency of investing in the IDT project.

Summarizing the results of the study, the IA and BP processes described above in the focus of the IDT should meet certain principles, including:

- the principle of interdisciplinarity, according to which the IA and BP should take into account the managerial complexity of IDT projects and, therefore, imply processes based on the integration of the results of studying several subject areas at once;
- the principle of taking into account the territorial context, according to which, within the framework of the IA and BP, the parameters of not only the land plot involved in the development process (as, for example, in point development projects, but also the immediate environment for the harmonious implementation of a new project into the urban fabric) should be considered;
- the principle of taking into account the infrastructural and institutional load, according to which, when performing the IA and BP, it is necessary to distinguish which components of the load are investments and which are resource costs;
- the principle of functional distribution, according to which the IA and BP should take into account the balanced maintenance of real estate (residential, social, commercial), infrastructure (transport, engineering) and landscaping of the territory involved in the development;
- the principle of scripting, according to which the IA and BP should be implemented according to several scenarios, assuming different outcomes for the developer, as well as other stakeholders;
- the principle of strategic effect, according to which the IA and BP should be focused not only on obtaining financial benefits, but also on long-term, strategic positive results.

Thus, the analysis of the specifics and principles of the IA and BP in the framework of the pre-investment stage of the IDT projects allowed us to form generalizing conclusions that have methodological and applied significance for the theory and practice of investment and construction activities. The multiphase nature of implementation, resource intensity, managerial complexity, infrastructural and institutional burden of the IDT projects require such pre-investment study tools as the IA and BP to provide high accuracy of initial data, breadth and depth of coverage of subject areas, dynamism and iteration of project behaviour and sensitivity assessment, and detailed forecasting.

The information obtained during the IA and BP is a basis, the rational use of which makes it possible to minimize uncertainty through the possibility of more accurate planning and modeling of target urban planning, technical, economic and other indicators of the project, as well as indicators of necessary resource provision, which directly reduces the risk component of the project and increases the likelihood of achieving the planned effectiveness in the event of entry into the project IDT.

REFERENCES

1. Shulzhenko S.I. Legal problems of complex development of territories. Part 1. Administrative consulting. 2022; 1(157):165-183. DOI: 10.22394/1726-1139-2022-1-165-183. EDN PKAKJZ. (rus.).
2. Shulzhenko S.I. Legal problems of complex development of territories. Part 2. Administrative consulting. 2022; 2(158):174-189. DOI: 10.22394/1726-1139-2022-2-174-189. EDN UAULLJ. (rus.).
3. Astafyev S.A., Guseva G.V. The problem of resettlement real estate owners in integrated development project. Russian Journal of Housing strategies. 2022; 9(3):243-260. DOI: 10.18334/zhs.9.3.115252. EDN MTINEW. (rus.).
4. Popkova A.A., Konev Yu.M., Kanyukov M.V. Integrated development of territories: current state and problems of implementation. Proceedings of Higher Educational Institutions. Sociology. Economy. Politics. 2023; 16(2):38-53. DOI: 10.31660/1993-1824-2023-2-38-53. EDN AVWSDT. (rus.).
5. Gershovich A.Y. Issues of financial and economic justification of integrated territorial development projects. Property Relations in the Russian Federation. 2023; 6(261):8-19. EDN QAMKTO. (rus.).
6. Gao R., Wang H., Qi Y., Zhang Sh. Crucial factors for decision-making in international real estate development projects: Evidence from Chinese developers. Ain Shams Engineering Journal. 2024; 15(12):103120. DOI: 10.1016/j.asej.2024.103120. EDN OXPXZU.
7. Kauškale L., Geipele I. Integrated Approach of Real Estate Market Analysis in Sustainable Development Context for Decision Making. Procedia Engineering. 2017; 172:505-512. DOI: 10.1016/j.proeng.2017.02.059
8. Belyakov S.I. Mechanisms of formation and development of the investment portfolio of the organizations realizing in the integrated development of territories. Real estate: economics, management. 2023; S3:164-167. EDN BKEDCL. (rus.).
9. Abdalov R.E., Kulakov K.Yu. The pre-project stage of a development project: strategic prerequisites for the formation of new management mechanisms. Real estate: economics, management. 2024; S3:66-71. EDN BYRZUX. (rus.).
10. Volgin V.V., Vongai A.O., Grabovyy K.P., Girya L.V., Grosheva T.I., Enin A.E. et al. Organization of Construction and Real Estate Development. Vol. 2. Real Estate Development : textbook in 2 Volumes and Workshop (Volume 3), 5th ed. Under the general scientific editorship of prof. P.G. Grabovyy. Moscow, ASV, 2024; 708. EDN ICEILJ. (rus.).

11. Bovteev S.V. Management of investment and construction projects: fundamentals of management of investment and construction projects : study guide. St. Petersburg : Publishing house of the Polytechnic University. 2014; 196. URL: https://search.rsl.ru/ru/record/01006767869 (rus.).
12. Asaul A. Real Estate Economics : textbook for Universities. 3rd ed. St. Petersburg, Piter, 2013; 416. EDN SDRKWT. (rus.).
13. Pupentsova S.V. Models and Tools in Economic Evaluation of Investments. St. Petersburg, Peter the Great St. Petersburg Polytechnic University, 2014; 187. EDN XMQBEN. (rus.).
14. Sternik G.M., Sternik S.G., Tulinova N.V. Real Estate Development. Investment Analysis and Project Consulting: a tutorial. Moscow, Prospect, 2017; 304. URL: https://search.rsl.ru/ru/record/02000024110 (rus.).
15. Larionova V.A., Platonov A.M., Mashkin O.V., Cherepanova N.N., Stepanova N.R. Assessment and analysis of development and infrastructure projects for territorial development : a textbook. Ed. S.I. Bazhenov. Ekaterinburg, Publishing House of the Ural University, 2020; 228. EDN XKIPNH. (rus.).
16. Shim H., Kim Ja. Determinants of the Economic and Financial Feasibility of Real Estate Development Projects: A Comparative Analysis between Public and Private Development Projects in South Korea. Sustainability. 2022; 14(4):2135. DOI: 10.3390/su14042135. EDN HXQAVG.
17. Sdino L., Rosasco P., Magoni S. The Financial Feasibility of a Real Estate Project: The Case of the Ex Tessitoria Schiatti. Procedia — Social and Behavioral Sciences. 2016; 223(10):217-224. DOI: 10.1016/j.sbspro.2016.05.352
18. Likos M., Nakip M., Gökmen A. Real Estate Marketing and Factors Impacting Real Estate Purchasing: An Application on Turkey. International Journal of Applied Management Sciences and Engineering (IJAMSE). 2019; 6:15-35. DOI: 10.4018/IJAMSE.2019070102
19. Grabovyy P.G., Belyakov S.I., Bizhanov A.Kh., Volgin V.V., Galishnikova V.V., Grabovyy K.P. et al. Organization of Construction and Real Estate Development : textbook in 3 volumes. 5th ed. Moscow, ASV, 2024; 690. EDN ZZZBMQ. (rus.).
20. Galenko V.P., Samarina O.A., Strakhova O.A. Business Planning in an Open Economy : a textbook. 3rd ed., reprinted. Moscow, Academy, 2008; 282. EDN QSYKFL. (rus.).
21. Mason C., Stark M. What do Investors Look for in a Business Plan? A Comparison of the Investment Criteria of Bankers, Venture Capitalists and Business Angels. International Small Business Journal. 2004; 22(3):227-248. DOI: 10.1177/0266242604042377. EDN JMSWEJ.

Содержание и принципы инвестиционного анализа и бизнес-планирования девелоперских проектов комплексного развития территории

Научная статья посвящена актуальной тематике необходимости методического обеспечения реализации проектов программы комплексного развития территории (КРТ), ежегодно наращивающей свой потенциал и являющейся передовым инструментом пространственного преобразования. В условиях нестабильности экономической среды и наличия множества особенностей механизма КРТ девелоперу важно осуществить комплексный подход к предынвестиционной проработке проекта для принятия рационального инвестиционного решения об участии в проекте. В этой связи отмечены проблемы и некоторые важные характерные для механизма КРТ черты, которые влияют на аспекты предынвестиционной деятельности. Авторами осуществлен анализ понятийно-категорийного аппарата «предынвестиционная стадия» и рассмотрен вопрос процессного наполнения данной стадии. С целью определения возможности и специфики использования в практической деятельности девелопера рассмотрены через призму КРТ инструменты принятия инвестиционного решения — инвестиционный анализ и бизнес-планирования. Для данных процессов представлены общие характеристики и отмечены поведенческие принципы в условиях КРТ, требующие учета в инвестиционно-строительной деятельности девелоперской реализации. Результаты исследования позволили сделать вывод о многогранности, сложности и важности процессов инвестиционного анализа и бизнес-планирования в рамках предынвестиционной проработки КРТ.

Ключевые слова: *комплексное развитие территории (КРТ), инвестиционный анализ бизнес-планирование, девелопмент недвижимости, организационно-экономическая устойчивость девелопера*

СПИСОК ИСТОЧНИКОВ

1. Шульженко С.И. Правовые проблемы комплексного развития территорий. Часть 1 // Управленческое консультирование. 2022. № 1 (157). С. 165–183. DOI: 10.22394/1726-1139-2022-1-165-183. EDN PKAKJZ.
2. Шульженко С.И. Правовые проблемы комплексного развития территорий. Часть 2 // Управленческое консультирование. 2022. № 2 (158). С. 174–189. DOI: 10.22394/1726-1139-2022-2-174-189. EDN UAULLJ.
3. Астафьев С.А., Гусева Г.В. Проблема расселения собственников жилой недвижимости при реализации проектов комплексного развития территории // Жилищные стратегии. 2022. № 9 (3). С. 243–260. DOI: 10.18334/zhs.9.3.115252. EDN MTINEW.
4. Попкова А.А., Конев Ю.М., Канюков М.В. Комплексное развитие территорий: современное состояние и проблемы реализации // Известия высших учебных заведений. Социология. Экономика. Политика. 2023. № 16 (2). С. 38–53. DOI: 10.31660/1993-1824-2023-2-38-53. EDN AVWSDT.
5. Гершович А.Я. Вопросы финансово-экономического обоснования проектов комплексного развития территорий // Имущественные отношения в Российской Федерации. 2023. № 6 (261). С. 8–19. EDN QAMKTO.
6. Gao R., Wang H., Qi Y., Zhang Sh. Crucial factors for decision-making in international real estate development projects: Evidence from Chinese developers // Ain Shams Engineering Journal. 2024. No. 15 (12). P. 103120. DOI: 10.1016/j.asej.2024.103120. EDN OXPXZU.
7. Kauškale L., Geipele I. Integrated Approach of Real Estate Market Analysis in Sustainable Development Context for Decision Making // Procedia Engineering. 2017. No. 172. Pp. 505–512. DOI: 10.1016/j.proeng.2017.02.059
8. Беляков С.И. Механизмы формирования и развития инвестиционного портфеля организаций, осуществляющих комплексное развитие территорий // Недвижимость: экономика, управление. 2023. № S3. С. 164–167. EDN BKEDCL.
9. Абдалов Р.Е., Кулаков К.Ю. Предпроектная стадия девелоперского проекта: стратегические предпосылки к формированию новых механизмов управления // Недвижимость: экономика, управление. 2024. № S3. С. 66–71. EDN BYRZUX.
10. Волгин В.В., Вонгай А.О., Грабовый К.П., Гиря Л.В., Грошева Т.И., Енин А.Е. и др. Организация строительства и девелопмент недвижимости. Т. 2. Девелопмент недвижимости : уч. в 2 т. и практикум (т. 3), 5-е изд., перераб. и доп. / под общ. науч. ред. проф. П.Г. Грабового. М. : АСВ, 2024. 708 с. EDN ICEILJ.
11. Бовтеев С.В. Управление инвестиционно-строительными проектами : основы управления инвестиционно-строительными проектами : уч. пособие. СПб. : Изд-во Политехнического ун-та, 2014. 196 с. URL: https://search.rsl.ru/ru/record/01006767869

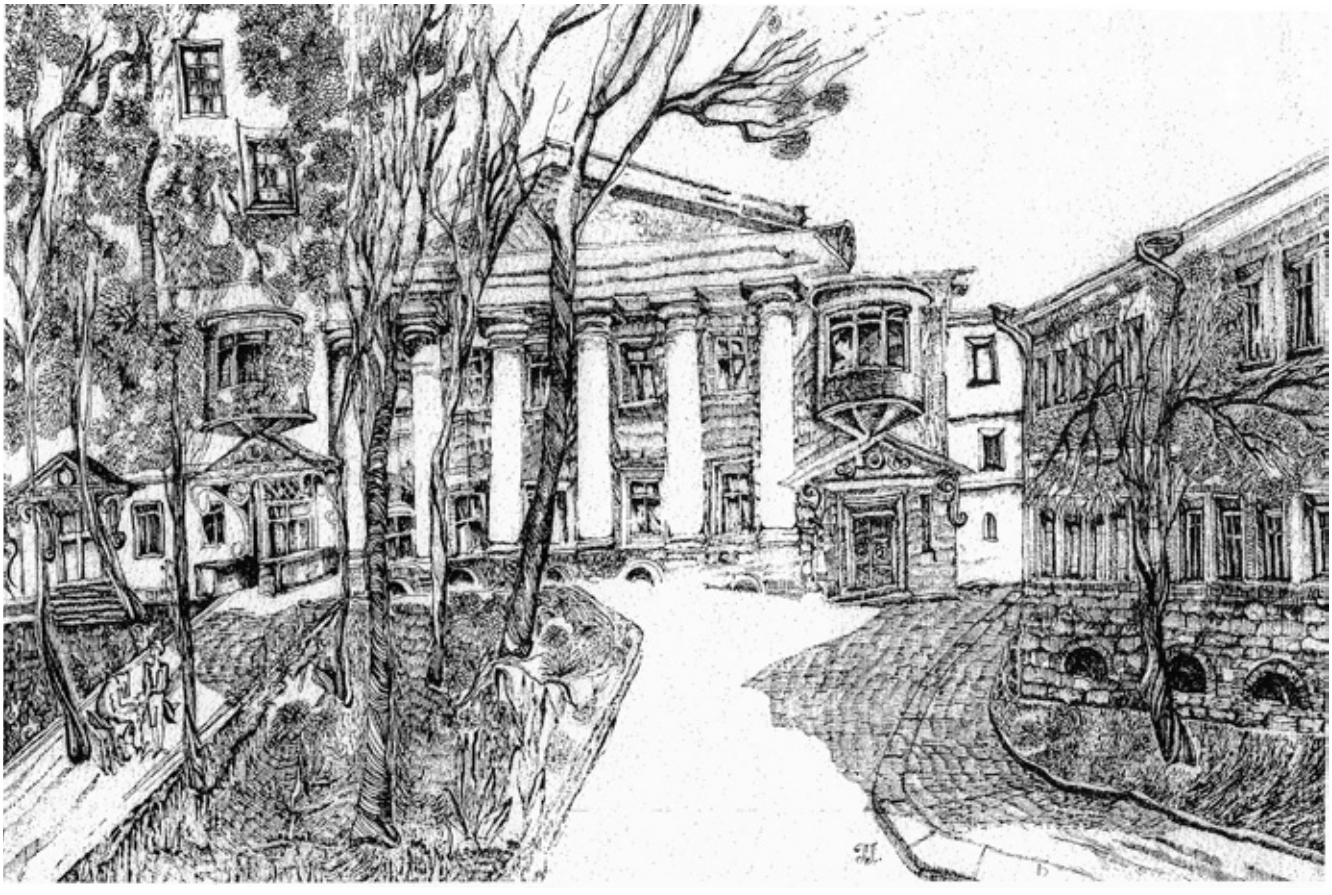
12. Асаул А. Экономика недвижимости : уч. для вузов. 3-е изд. СПб. : Питер, 2013. 416 с. EDN SDRKWT.
13. Пупенцова С.В. Модели и инструменты в экономической оценке инвестиций. СПб. : Санкт-Петербургский политехнический университет Петра Великого, 2014. 187 с. EDN XMQBEN.
14. Стерник Г.М., Стерник С.Г., Тулинова Н.В. Девелопмент недвижимости. Инвестиционный анализ и проектный консалтинг : уч. пос. М. : Проспект, 2017. 304 с. URL: https://search.rsl.ru/ru/record/02000024110
15. Ларионова В.А., Платонов А.М., Машкин О.В., Черепанова Н.Н., Степанова Н.Р. Оценка и анализ девелоперских и инфраструктурных проектов развития территорий : уч. пос. / под ред. С.И. Баженова. Екатеринбург : Издательство Уральского университета, 2020. 228 с. EDN XKIPNH.
16. Shim H., Kim Ja. Determinants of the Economic and Financial Feasibility of Real Estate Development Projects: A Comparative Analysis between Public and Private Development Projects in South Korea // Sustainability. 2022. No. 14 (4). P. 2135. DOI: 10.3390/su14042135. EDN HXQAVG.
17. Sdino L., Rosasco P., Magoni S. The Financial Feasibility of a Real Estate Project: The Case of the Ex Tessitoria Schiatti // Procedia — Social and Behavioral Sciences. 2016. No. 223 (10). Pp. 217–224. DOI: 10.1016/j.sbspro.2016.05.352
18. Likos M., Nakip M., Gökmen A. Real Estate Marketing and Factors Impacting Real Estate Purchasing: An Application on Turkey // International Journal of Applied Management Sciences and Engineering (IJAMSE). 2019. No. 6. Pp. 15–35. DOI: 10.4018/IJAMSE. 2019070102
19. Грабовый П.Г., Беляков С.И., Бижанов А.Х., Волгин В.В., Галишникова В.В., Грабовый К.П. и др. Организация строительства и девелопмент недвижимости : уч. в 3 т. 5-е изд. М. : АСВ, 2024. 690 с. EDN ZZZBMQ.
20. Галенко В.П., Самарина О.А., Страхова О.А. Бизнес-планирование в условиях открытой экономики : уч. пос. 3-е изд., стер. М. : Академия, 2008. 282 с. EDN QSYKFL.
21. Mason C., Stark M. What do Investors Look for in a Business Plan? A Comparison of the Investment Criteria of Bankers, Venture Capitalists and Business Angels // International Small Business Journal. 2004. No. 22 (3). Pp. 227–248. DOI: 10.1177/0266242604042377. EDN JMSWEJ.

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Digital Twin of Urban Areas as a Tool for Improving Development Project Business Planning

In the context of growing competition in the construction market, effective planning is a key tool for optimizing resources and minimizing risks, allowing construction companies not only to survive, but also to achieve sustainable profit growth through accurate forecasting and coordination of all stages of project implementation. One of the important documents in the implementation of a development project is a business plan. This document is developed based on an assessment of the urban development potential of the territory. The amount of project costs, the accuracy of the financial model, and, most importantly, the effectiveness of the project itself depend on how accurately and correctly this analysis is carried out and a business plan is drawn up. Digital technology tools are currently being actively used to improve the accuracy of forecasts and development scenarios, the reliability of set parameters, and the quality of information received. One of these tools is the creation of a digital twin of the territory.
Coordinated development of transport infrastructure and investment projects has also recently become an important factor. Based on the analysis of the transport network and the real estate market, demand is studied and the unmet demand of potential buyers are identified. Based on the data obtained, project concepts are being developed that reflect their uniqueness and attractiveness. Financial modelling, risk assessment, investment justification and forecast of results are carried out, and the developed business plans become the basis for making investment decisions.
Despite the active introduction of digital twins into urban planning practice, the issue of quantifying their impact on the synchronization of transport infrastructure and development projects has not been sufficiently studied in the scientific literature. The relevance of the research topic is due to the need to develop and formalize methods for assessing infrastructure lag and ways to minimize it.
The aim of this study is to develop an integrated model for quantifying the impact of the digital twin of an urban area on transport load parameters and the economic efficiency of development projects. The calculation of transport demand is based on aggregated normative indicators of urban mobility, and the assessment of the economic effect is based on a comparative analysis of investment attractiveness.
The theoretical basis of the research was scientific work in the field of construction organization, real estate development, urban planning and digitalization. Research methods: scenario modelling and comparative analysis.
Keywords: *digital twin, construction, transport infrastructure, residential real estate, infrastructure lag, development project efficiency, business planning*

The current stage of human development is characterized by accelerated rates of urbanization, which, on the one hand, stimulates economic growth, providing more comfortable and safe living conditions, and on the other hand, becomes a source of acute spatial contradictions, irreparable damage to the environment, and an increase in population concentration [1, 2]. According to the UN, by 2050, almost 70 % of the world's population will live in cities (Fig. 1) [3].

In the current context of urbanization, a persistent gap is emerging between the pace of housing construction and the development of transport infrastructure [4, 5]. This contradiction creates the phenomenon of "infrastructure lag", which justifies the need to create and utilize a unified digital environment designed to synchronize spatial planning and transport modelling [6]. Traditional territorial planning tools, based primarily on static documents and disparate information bases, do not provide a sufficient level of systemic management [7]. The lack of a digital tool capable of integrating fragmented data into a single database and modelling solutions is becoming a serious problem, resulting in congestion of the road network,

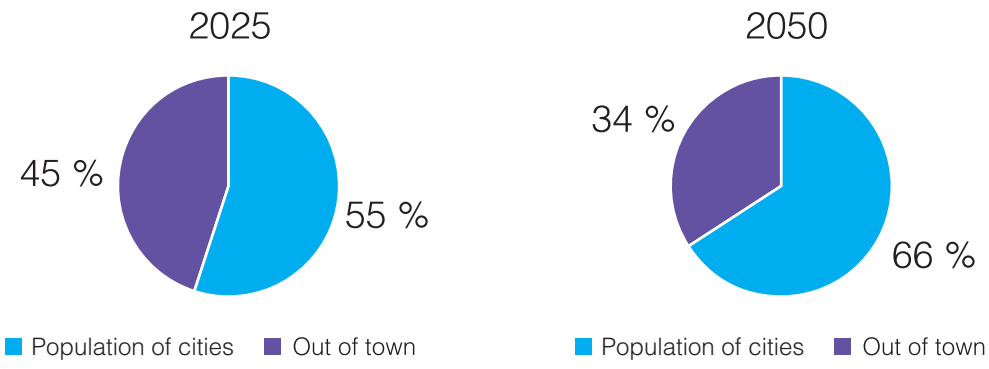


Fig. 1. Rate of urbanization



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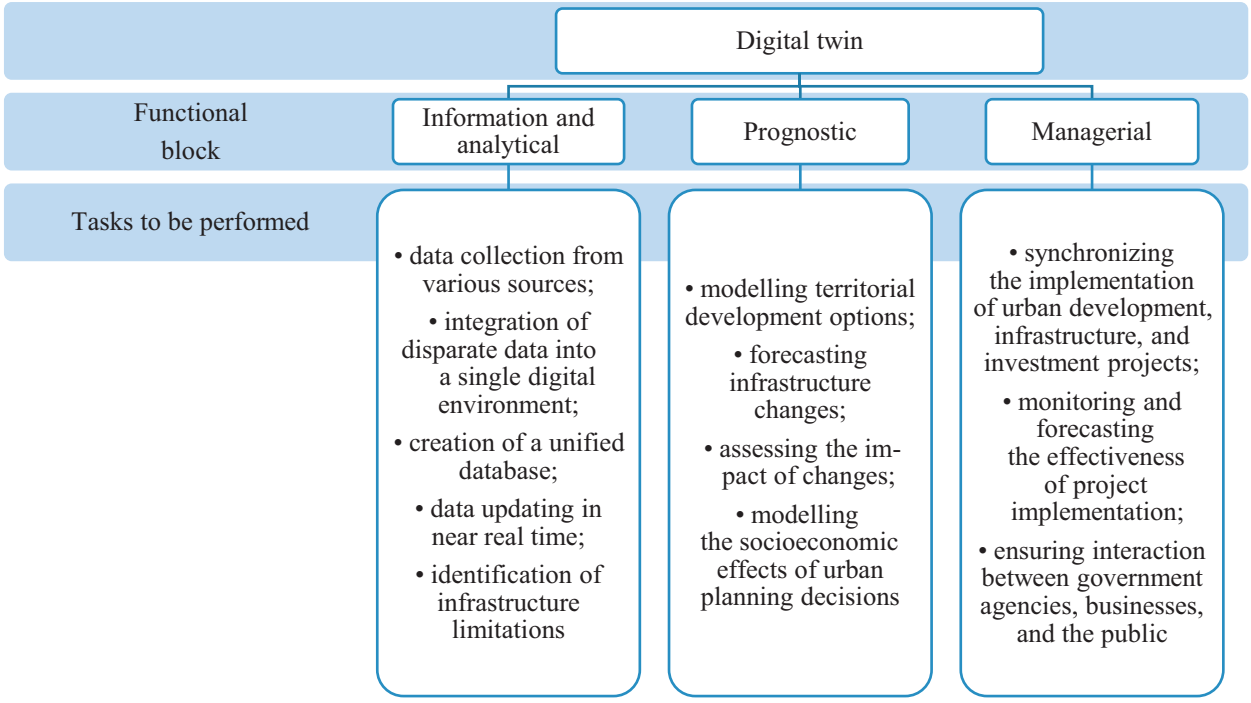


Fig. 2. Tasks of the digital twin of the territory

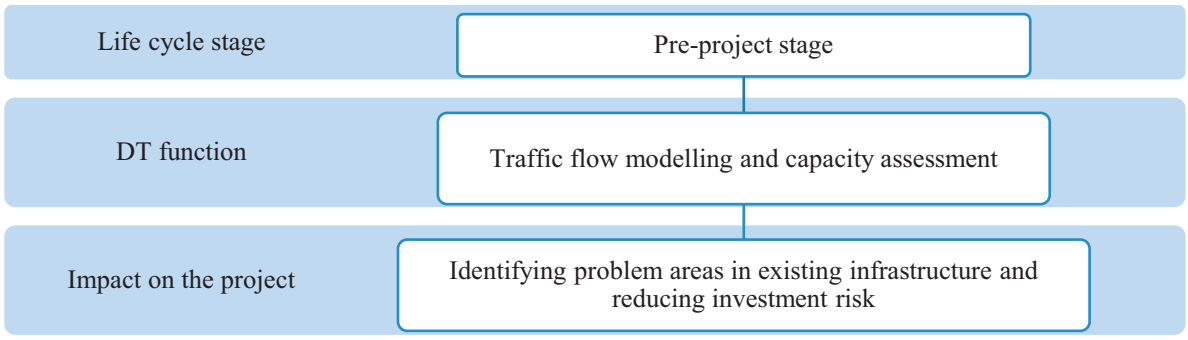


Fig. 3. Application of the DT at the pre-project stage

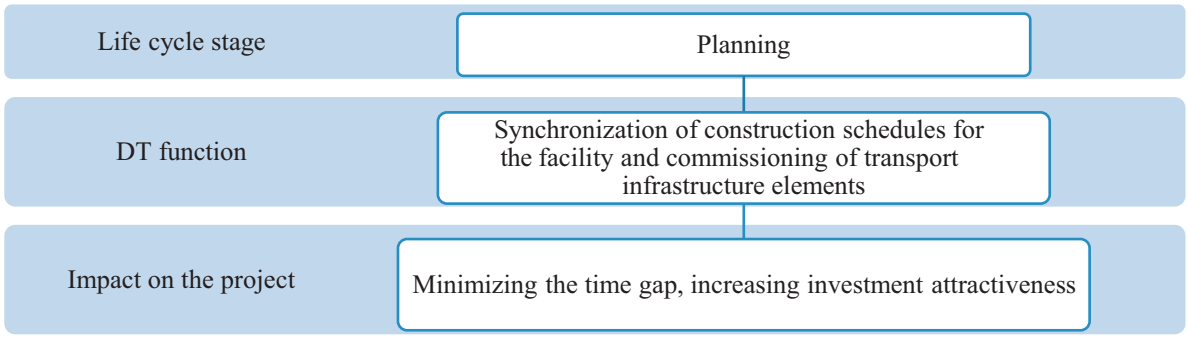


Fig. 4. Application of DT in the planning stage

increased social tension, and a decrease in investment attractiveness for both developers and property buyers [8, 9]. To address this problem, a digital twin of the territory can be used.

A digital twin of a territory (DT) is considered a visualized information and analytical system that integrates spatial, transport, engineering, social, and economic data [10, 11]. Unlike standard geographic information systems, which only store and display data, a DT is distinguished by the possibility of scenario modelling [12]. The tasks solved by a digital twin of a territory are formulated below (Fig. 2) [13].

This article introduces the concept of "infrastructure lag" — the time interval between the commissioning of a capital construction project and its provision with regulatory transport infrastructure [14]. The use of a digital twin of the territory allows the developer to

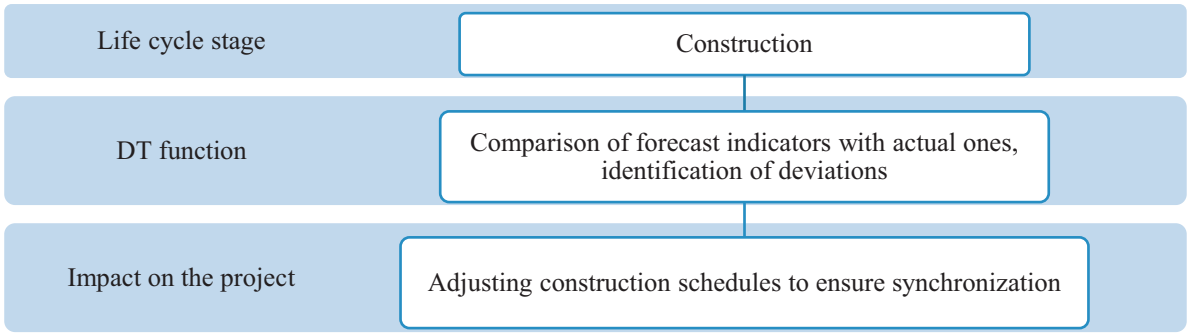


Fig. 5. Application of DT at the construction stage

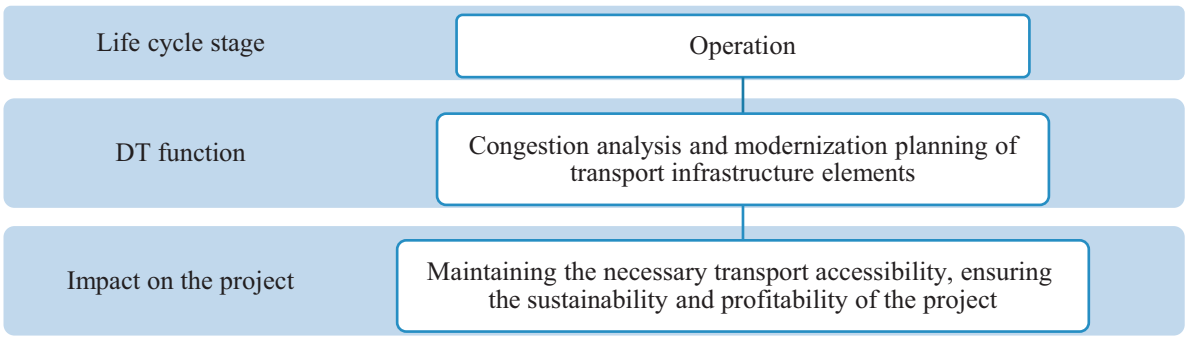


Fig. 6. Application of the DT at the operational stage

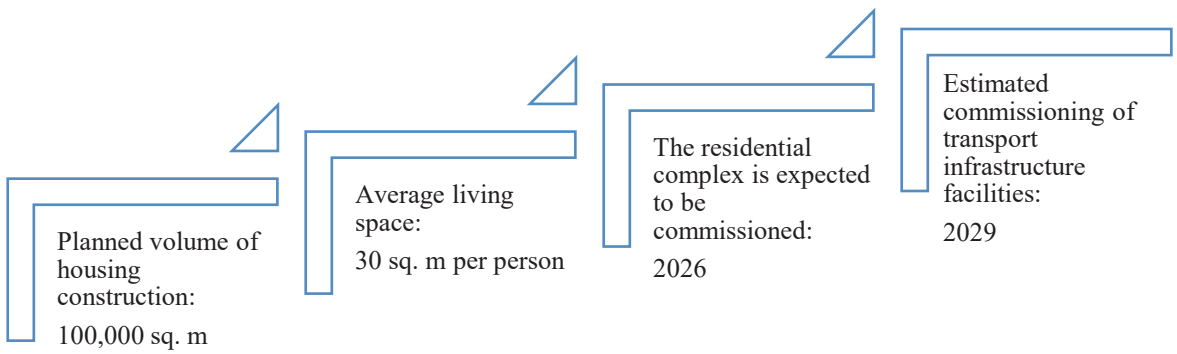


Fig. 7. Initial data of the residential complex development project

influence the size of this interval already at the early stages of the life cycle of the capital construction project (Fig. 3–6) [15, 16].

The conducted analysis of the functional application of the DT in the context of transport infrastructure at each stage of a building's life cycle allows us to conclude that this technology is not simply a tool for digitalizing the urban environment; it is being transformed into a systemic apparatus for managing the time and economic parameters of territorial management.

In calculating the infrastructure lag, we will use (1):

$$L = T_h - T_t, \quad (1)$$

where T_h — date of commissioning of the facility;

T_t — launch date of transport infrastructure facilities.

If $L > 0$, a shortage of transport infrastructure begins. In today's reality, this indicator ranges from 1 to 3 years.

To quantify this indicator, we will consider two scenarios for implementing a residential development project: one with and one without the use of a DT. The initial data will be presented in the Fig. 7.

The calculation of the predicted number of residents P_p can be calculated using the indicator of the volume of residential development V_{rd} and the average housing provision A_{hp} according to (2):

$$P_p = \frac{V_{rd}}{A_{hp}} = \frac{100{,}000\ \text{m}^2}{30} = 3{,}333\ \text{people}. \quad (2)$$

Next, we calculate the daily demand for transport infrastructure, D_{ti}. We take into account that, in the context of urban mobility, the average number of trips, Q, is two trips per person per day (3):

$$D_{ti} = P_p \cdot Q = 3{,}333\ \text{people} \cdot 2\ \text{trips/day} = 6{,}666\ \text{trips}. \quad (3)$$

Note that pendulum migration M_p constitutes the dominant part of urban mobility, and for the calculation we will take the share of 75 % (4):

$$M_p = D_{ti} \cdot 75\ \% = 6{,}666\ \text{trips} \cdot 75\ \% = 5{,}000\ \text{trips/day}. \quad (4)$$

Thus, the baseline scenario assumes a model in which residents will increasingly use personal transport (up to 60 % of all trips) over three years, generating additional vehicle traffic (Fig. 8).

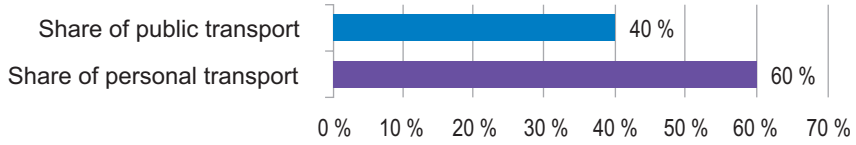


Fig. 8. Baseline scenario

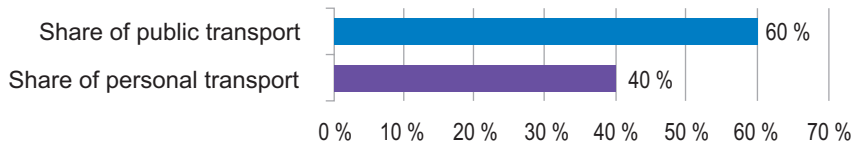


Fig. 9. Complex scenario

Table 1. Calculation results

Basic scenario (without synchronization)	Integrated scenario (using the DT)
Share of trips by car (k) — 60 %: $Q_{auto.b} = M_p \cdot k = 5{,}000 \cdot 60\ \% =$ = 3,000 trips per day. Infrastructure lag (1): $L = T_h - T_t = 2026 - 2029 = 3$ year	Share of trips by car (k) — 40 %: $Q_{auto.k} = M_p \cdot k = 5{,}000 \cdot 40\ \% =$ = 2,000 trips per day. The infrastructure lag is reduced to 1 year by modelling the transport load at the design stage of the project and the phased commissioning of individual buildings
High load maintained for 3 years	Moderate load for 1 year

Meanwhile, the comprehensive scenario assumes a reduction in motorization by up to 40 % (Fig. 9).

Let's conduct a comparative analysis and display the data in Table 1.

Comparison of scenarios and calculation of relative load reduction will be calculated using (5):

$$L_r = \frac{Q_{auto.b} - Q_{auto.k}}{Q_{auto.b}} = \frac{3{,}000 - 2{,}000}{3{,}000} \cdot 100\ \% = 33\ \%. \quad (5)$$

The economic consequences of reducing infrastructure lag are reflected in the increased investment attractiveness of the territory. Research in real estate economics demonstrates a correlation between the property value bonus and proximity to transportation infrastructure [17]. Reducing travel time to key transportation hubs increases the market value of a square meter of residential real estate by 5–10 % [18]. The calculation model assumes an average value of 7 % and a residential real estate selling price of 300,000 rubles per square meter. The calculation is presented in Table 2.

Table 2. Calculation of revenue in the baseline and complex scenarios

Basic scenario (without synchronization)	Integrated scenario (using the DT)
Revenue without the use of DT is:	Revenue using the DT is:
$R_b = V_{rd} \cdot P$ = 100,000 m² · 300 thousand rubles/m² = 30 billion rubles	$R_k = R_b \cdot 7$ = 30 billion rubles × × 7 % = 32.1 billion rubles

The study confirmed that the current misalignment between housing construction and urban transport infrastructure development creates a measurable infrastructure lag, which negatively impacts the performance of both. The proposed modelling allowed for a quantitative assessment of the results of possible development project scenarios and substantiated the positive impact of using a digital twin of the territory.

Thus, in the calculation model, the use of the centralized traffic control system for synchronizing residential and transport infrastructures creates the following effects:

- reducing the load on the road network by 33 %;
- reducing the infrastructure lag from 3 years to 1 year;
- redistributing transport demand in favor of public transport and reducing the share of trips by private car.

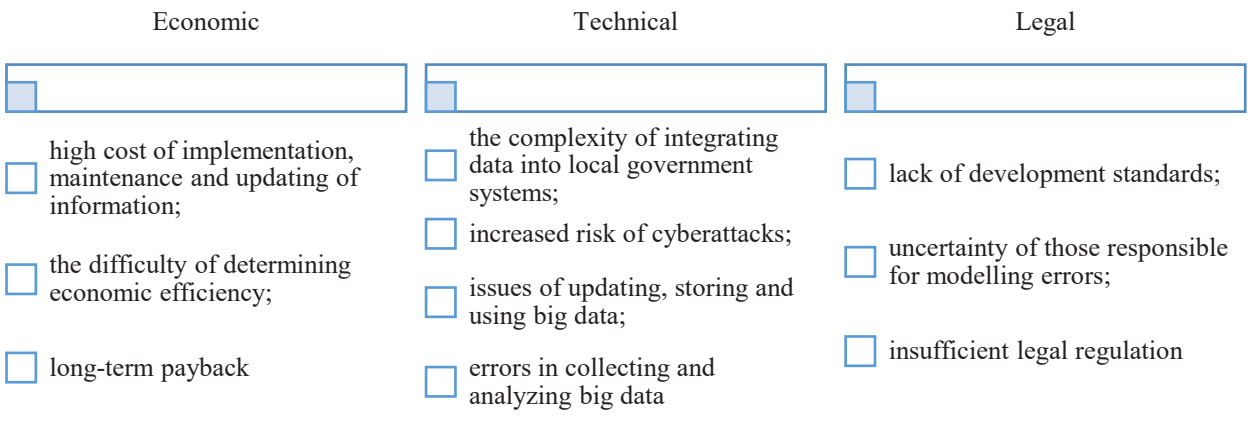


Fig. 10. Limitations on the use of DT

As a result, a more balanced functioning of the urban environment is achieved. Economic calculations show an increase in the project's investment value with improved transport connectivity: with the transport infrastructure development effects assumed in the model, the additional financial benefit amounts to 2.1 billion rubles, corresponding to a 7 % increase in revenue.

The synergy of the obtained modelling results allows us to consider the digital twin of a territory as a necessary tool for strategic management of territorial development, ensuring the coordination of spatial, transport and investment decisions in the life cycle system of capital construction projects.

However, it should be noted that the modelling conducted has a number of limitations related to its scenario-based nature:

- average indicators were used in the calculations;
- the costs of creating and/or accessing the digital twin were not taken into account.

And, despite the full potential of using a territory's digital twin, it has numerous limitations, as outlined in Fig. 10.

As a result, it can be concluded that a digital twin of a territory is an important tool for development projects, which allows for a quantitative assessment of transport load parameters, minimizing infrastructure lag, and increasing the economic efficiency of projects.

REFERENCES

1. Apatova N.V., Uzakov T.K., Volosovets D.V. Economic growth in the economy of data and digital technologies. Simferopol, Arial Printing House, 2024; 234. EDN WAEQND. (rus.).
2. Kirbitova S.V. Business Planning in Foreign Economic Activity in the Context of Economic Digitalization : Study Guide. St. Petersburg, 2021; 146. EDN TBSSFZ. (rus.).
3. Trofimova N.N. Features of the use of traditional methods and modern digital tools in the strategic business management system. Economics and Management: Problems, Solutions. 2024; 1(3-144):11-18. DOI: 10.36871/ek.up.p.r.2024.03.01.002. EDN EWIRYI. (rus.).
4. Volkovskaya V.V., Ternyushchenko V.A., Kovtunenko M.G. Information resources for business planning in construction. Trends in the development of science and education. 2022; 81-1:124-127. DOI: 10.18411/trnio-01-2022-35. EDN XZPQNV. (rus.).
5. Gubeev E.P. Prospects for development of urban infrastructure to improve the quality of life. Science Bulletin. 2023; 2(7-64):245-266. EDN MUJDLK. (rus.).
6. Grosheva E.K., Moskalev M.S., Rasputin A.V. Improving the quality of life of the population as a result of the implementation of the integrated development of the territory project. Business education in the knowledge economy. 2024; 2(28):54-58. EDN ANQPET. (rus.).
7. Burchik V.V., Kuzmich N.P. Construction as the most important tool of socio-economic development of the region. Modern Economy Success. 2024; 2:367-371. DOI: 10.58224/2500-3747-2024-2-368-372. EDN TDOEVH. (rus.).
8. Belov A.V. Problems and prospects of artificial intelligence technologies application in transportation engineering and design. Moscow transport. Science and engineering design. 2025; 1(1):55-65. EDN IDYODV. (rus.).
9. Grabovyy P.G., Bolotin S.A., Grabovyy K.P. Risk management in real estate : textbook. Ed. by P.G. Grabovyy. Moscow, Prospect, 2012; 424. EDN QVEJRH. (rus.).
10. Penzov D.I. Transformation of the methodology for managing the cost of urban real estate in the context of their life cycle: Moscow experience. The Eurasian Scientific Journal. 2025; 17(S2):18. EDN KPVYDW. (rus.).
11. Adamtsevich L.A. Life cycle management of residential buildings and infrastructure facilities in projects of integrated development of territories. Vestnik MGSU. 2025; 20(6):957-966. DOI: 10.22227/1997-0935.2025.6.957-966. EDN XPSHMY. (rus.).
12. Stepanov A.V., Matveeva M.V., Peshkova E.S. Digitalization of the construction industry: prospects and challenges. Proceedings of Universities. Investment. Construction. Real estate. 2024; 14(2-49): 356-366. DOI: 10.21285/2227-2917-2024-2-356-366. EDN SJHHKT. (rus.).
13. Benuzh A.A., Bizhanov A.Kh., Bolotin S.A., Dadar A.Kh., Butyrin A.Yu., Verstina N.G. et al. Organization of construction and real estate development. Part I. Organization of construction. 4th ed., revised and enlarged. Ed. by D. Sc. (Econ.), prof. P.G. Grabovyy. Moscow, Prosvetitel, 2018; 645. EDN YMUVWH. (rus.).
14. Prokopenko I.V. Implementation of information modelling technologies in life cycle management of construction sites. Financial business. 2024; 10(256):42-44. EDN IURHEF. (rus.).
15. Lesyuta O.S., Kuznetsov A.O. Creating a digital duplicate of a road as part of urban renewal. Real estate: economics, management. 2022; S3-1:170-173. EDN HEZITZ. (rus.).
16. Saymanova O.G., Saimanov V.Yu., Alpatov D.Yu., Chirkunova E.K. Problems and efficiency of the implementation of digital technologies in the economy of the construction industry. Bulletin of the Volga State University of Service. Series: Economics. 2023; 19(1-72):35-38. EDN ILNPVC. (rus.).
17. Shirshikov S.P., Svetlova O.I. Prospects for the development of housing construction in Russia in the context of the digital economy. Economics and entrepreneurship. 2025; 7(180):280-284. DOI: 10.34925/EIP.2025.180.7.044. EDN HKWZRP. (rus.).
18. Belov A.V. Problems and prospects of artificial intelligence technologies application in transportation and design. Moscow transport. Science and engineering design. 2025; 1(1):55-65. EDN IDYODV. (rus.).

Цифровой двойник территории как инструмент повышения эффективности бизнес-планирования девелоперских проектов

В условиях растущей конкуренции на строительном рынке эффективное планирование является ключевым инструментом оптимизации ресурсов и минимизации рисков, позволяющим строительным компаниям не только выживать, но и добиваться устойчивого роста прибыли за счет точного прогнозирования и координации всех этапов реализации проекта. Одним из важных документов при реализации девелоперского проекта является бизнес-план. Данный документ разрабатывается на основе оценки градостроительного потенциала территории. От того, насколько точно и правильно проведен данный анализ и составлен бизнес-план, зависит объем затрат в проект, точность финансовой модели и главное — эффективность самого проекта. Для повышения точности прогнозов и сценариев развития, достоверности закладываемых параметров и качества получаемой информации на сегодняшний день активно используются инструменты цифровых технологий. Одним из таких инструментов является создание цифрового двойника территории.

Также в последнее время важным фактором стало скоординированное развитие транспортной инфраструктуры и инвестиционных проектов. На основе анализа транспортной сети и рынка недвижимости изучается спрос и выявляются нереализованные потребности потенциальных покупателей. На основе полученных данных разрабатываются концепции проектов, отражающие их уникальность и привлекательность. Проводится финансовое моделирование, оценка рисков, обоснование инвестиций и прогноз результатов, а разработанные бизнес-планы становятся основой для принятия инвестиционных решений.

Несмотря на активное внедрение цифровых двойников в практику градостроительства, в научной литературе недостаточно изучен вопрос количественной оценки их влияния на синхронизацию транспортной инфраструктуры и девелоперских проектов. Актуальность темы исследования обусловлена необходимостью разработки и формализации методов оценки инфраструктурного лага и способов его минимизации.

Цель работы заключается в разработке укрупненной модели количественной оценки влияния цифрового двойника городской территории на параметры транспортной нагрузки и экономическую эффективность девелоперских проектов. Расчет транспортного спроса выполнен на основе укрупненных нормативных показателей городской мобильности, а оценка экономического эффекта на основе сопоставительного анализа инвестиционной привлекательности.

Теоретическую основу исследования составили научные труды в области организации строительства, девелопмента недвижимости, градостроительного планирования и цифровизации. Методы исследования: сценарное моделирование и сравнительный анализ.

Ключевые слова: *цифровой двойник, строительство, транспортная инфраструктура, жилая недвижимость, инфраструктурный лаг, эффективность девелоперских проектов, бизнес-планирование*

СПИСОК ИСТОЧНИКОВ

1. Апатова Н.В., Узаков Т.К., Волосовец Д.В. Экономический рост в экономике данных и цифровых технологий. Симферополь : Издательство Типография «Ариал», 2024. 234 с. EDN WAEQND.

2. Кирбитова С.В. Бизнес-планирование во внешнеэкономической деятельности в условиях цифровизации экономики : уч. пос. СПб., 2021. 146 с. EDN TBSSFZ.

3. Трофимова Н.Н. Особенности применения в системе стратегического управления бизнесом традиционных методов и современных цифровых инструментов // Экономика и управление: проблемы, решения. 2024. № 1 (3–144). С. 11–18. DOI: 10.36871/ek.up.p.r.2024.03.01.002. EDN EWIRYI.

4. Волковская В.В., Тернющенко В.А., Ковтуненко М.Г. Информационные ресурсы бизнес-планирования в строительстве // Тенденции развития науки и образования. 2022. № 81–1. С. 124–127. DOI: 10.18411/trnio-01-2022-35. EDN XZPQNV.

5. Губеев Э.П. Перспективы развития городской инфраструктуры для улучшения качества жизни // Вестник науки. 2023. № 2 (7–64). С. 245–266. EDN MUJDLK.

6. Грошева Е.К., Москалев М.С., Распутин А.В. Улучшение качества жизни населения в результате реализации проекта комплексного развития территории // Бизнес-образование в экономике знаний. 2024. № 2 (28). С. 54–58. EDN ANQPET.

7. Бурчик В.В., Кузьмич Н.П. Строительство как важнейший инструмент социально-экономического развития региона // Modern Economy Success. 2024. № 2. С. 367–371. DOI: 10.58224/2500-3747-2024-2-368-372. EDN TDOEVH.

8. Белов А.В. Проблемы и перспективы применения технологий искусственного интеллекта в транспортном проектировании // Московский транспорт. Наука и проектирование. 2025. № 1 (1). С. 55–65. EDN IDYODV.

9. Грабовый П.Г., Болотин С.А., Грабовый К.П. Управление рисками в недвижимости : уч. / под общ. ред. П.Г. Грабового. М. : Проспект, 2012. 424 с. EDN QVEJRH.

10. Пензов Д.И. Трансформация методики управления стоимостью объектов городской недвижимости в контексте их жизненного цикла: Московский опыт // Вестник евразийской науки. 2025. № 17 (S2). 18 с. EDN KPVYDW.

11. Адамцевич Л.А. Управление жизненным циклом жилых зданий и инфраструктурных объектов в проектах комплексного развития территорий // Вестник МГСУ. 2025. № 6 (20). С. 957–966. DOI: 10.22227/1997-0935.2025.6.957-966. EDN XPSHMY.

12. Степанов А.В., Матвеева М.В., Пешкова Е.С. Цифровизация строительной отрасли: перспективы и вызовы // Известия вузов. Инвестиции. Строительство. Недвижимость. 2024. № 14 (2–49). С. 356–366. DOI: 10.21285/2227-2917-2024-2-356-366. EDN SJHHKT.

13. Бенуж А.А., Бижанов А.Х., Болотин С.А., Дадар А.Х., Бутырин А.Ю., Верстина Н.Г. и др. Организация строительства и девелопмент недвижимости. Часть I. Организация строительства. 4-е изд., перераб. и доп. / под общ. ред. д-ра экон. наук, проф. П.Г. Грабового. М. : Просветитель, 2018. 645 с. EDN YMUVWH.

14. Прокопенко И.В. Внедрение технологий информационного моделирования в управление жизненным циклом строительных объектов // Финансовый бизнес. 2024. № 10 (256). С. 42–44. EDN IURHEF.

15. Лесюта О.С., Кузнецов А.О. Формирование цифрового двойника автомобильной дороги в рамках реновации городской территории // Недвижимость: экономика, управление. 2022. № S3–1. С. 170–173. EDN HEZITZ.

16. Сайманова О.Г., Сайманов В.Ю., Алпатов Д.Ю., Чиркунова Е.К. Проблемы и эффективность внедрения цифровых технологий в экономике строительной отрасли // Вестник Поволжского государственного университета сервиса. Серия: Экономика. 2023. № 19 (1–72). С. 35–38. EDN ILNPVC.

17. Ширшиков С.П., Светлова О.И. Перспективы развития жилищного строительства России в условиях цифровой экономики // Экономика и предпринимательство. 2025. № 7 (180). С. 280–284. DOI: 10.34925/EIP.2025.180.7.044. EDN HKWZRP.

18. Белов А.В. Проблемы и перспективы применения технологий искусственного интеллекта в транспортном проектировании // Московский транспорт. Наука и проектирование. 2025. № 1 (1). С. 55–65. EDN IDYODV.

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Key factors influencing the mechanisms of formation of the innovative portfolio of gas transportation construction enterprises

High-tech construction companies face the need for continuous implementation of innovative solutions in order to increase production efficiency, reduce costs and increase competitiveness. The mechanisms for selecting and implementing innovative solutions require the formation of effective approaches to an objective assessment of their potential and associated risks. A typical example of a high-tech construction sub-sector is the field of gas transportation construction, whose enterprises are fully affected by the effects of this issue in the current macroeconomic conditions. High-tech enterprises in the gas transmission construction sub-sector are influenced by a complex set of internal and external factors. Solving the scientific problem of organizational and economic modeling of the mechanisms of formation of an innovative portfolio of enterprises involves the need to identify and comprehensively analyze a vast factor space.
As a result of the multi-stage expert analysis conducted by the author, key external and internal factors influencing the mechanisms of formation of the innovative portfolio of gas transmission construction enterprises were identified and classified. The use of a set of identified factors is also possible as part of the assessment of innovations in the production systems of high-tech construction enterprises, which can contribute to the unification of approaches and improve the effectiveness of mechanisms for selecting and implementing innovative solutions, and the formation of an effective innovation portfolio of the enterprise.
Keywords: *innovation, innovation portfolio, high-tech construction, production systems, factors*



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Modern construction is characterized by accelerated development of technologies and materials, increased requirements for product quality and shorter project implementation time [1]. Today, in the context of modern macroeconomic conditions and shifts, the domestic investment and construction complex is facing new challenges and an extensive list of tasks to ensure sustainability, efficiency and accelerated development. Their solution requires the search and use of reserves in the production systems of construction enterprises [2].

This modern problem is particularly relevant for high-tech sub-sectors of the construction complex, for which macroeconomic instability, expressed in restrictions on the import of foreign technologies and equipment, as well as a decrease in the inflow of investment resources from abroad, is often extremely high, and in some cases, critical importance [1]. In these conditions, development mechanisms implemented on an innovative basis are becoming highly in demand.

High-tech construction companies face the need for continuous implementation of innovative solutions in order to increase production efficiency, reduce costs and increase competitiveness. The mechanisms for selecting and implementing innovative solutions require the formation of effective approaches to an objective assessment of their potential and associated risks [1].

Within the framework of such mechanisms, the innovative development of high-tech enterprises in the investment and construction sector is based on modern approaches to planning and implementing technical, technological and organizational innovations that enhance the competitiveness, productivity and economic efficiency of production systems. Modern conditions for the transformation of production systems of enterprises necessitate an adequate restructuring of management systems and processes: the development and implementation of innovative management methods for production systems is the main condition for increasing their competitiveness. Consequently, management innovation solutions that harmonize production process models primarily through the formation, development and optimization of the functioning of organizational and managerial resources and structures of the enterprise are a necessary element ensuring the feasibility of these types of innovations within the framework of a single innovation portfolio of a high-tech construction enterprise [2–7].

A typical example of a high-tech construction sub-sector is the field of gas transportation construction, whose enterprises are fully affected by the effects of all the described issues in the current macroeconomic conditions.

In the proposed paradigm, it is advisable to consider the tasks of forming and implementing a portfolio of innovations of such enterprises in the context of achieving the goals of ensuring their strategic innovative development, including both elements of goal-setting in the field of economic efficiency, competitiveness and growth, as well as the necessary risk management mechanisms and ensuring the strategic sustainability of the enterprise.

Solving the scientific problem of organizational and economic modeling of the mechanisms of forming an innovative portfolio of enterprises involves the need to identify and comprehensively analyze the vast factor space that influences these mechanisms.

The subjects of the considered sub-sector — high-tech enterprises of gas transportation construction — in the course of their functioning experience the multidimensional and multidirectional influence of factors of the internal and external environment.

According to the traditional approach, in the most general classification, the factor space can be formed according to the principle of division into two main groups of factors:

- external factors, the sources of which are beyond the influence of the environment of the system.

In the context of the innovative development of the enterprise, the importance of managing transformational changes is increasing, with the main focus on ensuring the ability of the production system to develop, recover, and adapt in accordance with its internal development resources in the context of the dynamics of environmental factors. The result of such development should, among other things, be an increase in the manageability of the system based on its inherent principles of self-organization, flexibility and adaptability [8–10];

- internal factors, the impact of which is due to the causes and prerequisites related to the functioning of the internal environment of the system.

The influence of internal factors should be considered in at least two aspects [11–14]. On the one hand, internal factors in their quality and combination determine the possibilities of developing the production and economic system of an enterprise, its economic potential in the broadest sense, thereby forming the prerequisites for the adoption of certain management strategies. On the other hand, the analysis of internal factors should help identify areas of inefficiency that hinder the effective development of the enterprise's production and economic system and, as a result, reserves of economic development that can be implemented on an innovative basis.

It is advisable to base the further grouping of factors on the nature of their impact on the production and economic system of the enterprise.

As a result of the multi-stage expert analysis conducted by the author, key external (Table 1) and internal (Table 2) factors influencing the mechanisms of formation of the innovative portfolio of gas transmission construction enterprises were identified and classified.

The complex process of strategic planning of innovative development of a high-tech construction enterprise requires algorithmization with the allocation of key process blocks that ensure the synchronous solution of the tasks of evaluation and selection of innovative solutions, depending on the results of the analysis of the elements of the presented factor space. The central element in this case should be a portfolio of innovations, which in turn is characterized by an internal hierarchy and includes managerial, organizational, technological and technical innovative solutions selected as a result of a multi-criteria assessment of all influencing factors, taking into account their mutual influence.

The key analyzed characteristics of the considered innovative solutions should include the following in accordance with the provisions of current regulatory and scientific and methodological sources[1] [1]:

1. Scientific and technical novelty of the innovative solution.
2. The high-tech nature of the innovative solution.
3. Technical and economic effects resulting from the implementation of an innovative solution.
4. The integral economic effect resulting from the implementation of an innovative solution.

Thus, the proposed approach to developing effective mechanisms for forming an innovation portfolio in gas transmission construction enterprises requires the implementation of diagnostic procedures based on the identified factor framework. These procedures are aimed, among other things, at identifying problematic areas of production activity and determining the causes of deviations from planned (optimal) development parameters. This, in turn, enables the selection of optimal management solutions at the final stage,

[1] On approval of criteria for classifying goods, works, and services as innovative products and (or) high-tech products for the purposes of forming a procurement plan for such products : Order of the Ministry of Energy of the Russian Federation dated December 25, 2015, No. 1026. URL: http://publication.pravo.gov.ru/document/0001201603010009 (rus.).

Table 1. Factorial space for the formation of an innovative portfolio of gas transportation construction enterprises. External factors

Groups of factors	Direction of influence on the innovation portfolio	Factors	
Technical and regulatory	Pressure and need for changes from various regulators	R-F19	Dynamics and volume of changes in industry standards (ecology, industrial safety, technical standards and requirements) that require a review of approaches in the innovation portfolio
		R-F20	The degree of dependence on imported technologies, hardware, and software, and the associated risks to innovation
Macro- and mesoeconomic	External economic conditions	M-F21	Volatility of the cost of key resources (pipes, equipment, energy, machinery) and currency risks affecting the financial model of the portfolio
		M-F22	Availability and cost of credit resources to finance a capital-intensive portfolio of projects
		M-F23	Investment attractiveness and budgetary opportunities of the regions for laying gas transmission systems for PPP or other forms
Political and geopolitical	Strategic risks and opportunities	P-F24	The degree of influence of international political risks on supply chains and technology transfer for the portfolio
		P-F25	The level of support and priority of gas transportation construction projects in state strategic programs
Natural, climatic and ecological	External environmental constraints	EN-F26	The degree to which the portfolio takes into account the specifics of work in various natural and climatic zones (permafrost, seismic, swampiness)
		EN-F27	The level of stricter environmental requirements (for emissions, land use, etc.) affecting project decisions across the portfolio

Table 2. Factorial space for the formation of an innovative portfolio of gas transportation construction enterprises. Internal factors

Groups of factors	Direction of influence on the innovation portfolio	Factors	
Organizational and managerial	Ability to systematically implement new management methods	O-F1	The degree of maturity of corporate project and portfolio management systems (availability of methodologies, templates, digital platforms, and passports)
		O-F2	Availability and quality of knowledge base (solutions, metrics, templates) from completed gas transportation construction projects for replication of innovations
		O-F3	The degree of adaptability of the company's project office to various types of projects in the portfolio (new construction, reconstruction, modernization of facilities)
		O-F4	The portfolio team's proficiency in strategic analysis, risk management, and engineering tools
		O-F5	The degree of elaboration and standardization of contract models for typical scenarios of gas transportation construction
Technological and production	Influence of technological features on the choice of innovations	T-F6	The share of using standard and modular technological solutions in the portfolio of projects that allow for scaling innovation
		T-F7	The degree of loading and wear of the fleet of specialized equipment for the conditions of the Far North, swamps, difficult terrain, etc.
		T-F8	The level of concentration of competencies in critical technologies (welding, automation, energy supply and heavy machinery in remote areas)
		T-F9	The degree of readiness for the use of BIM technologies and digital twins at all objects of the portfolio
Logistics	Constraints and opportunities of logistics for innovation	L-F10	The level of dependence of the project portfolio on the remoteness of facilities from mobilization bases, transport arteries, and the impact of seasonal restrictions
		L-F11	The degree of development of own or partner logistics infrastructure in key construction regions
Economic and financial	Financial opportunities and constraints for the selection, implementation and implementation of innovations	E-F12	The degree of capital intensity and synchronization of financial flows for portfolio projects
		E-F13	The volume and flexibility of the company's reserve funds for testing risky management innovations
		E-F14	The quality of the system for monitoring economic indicators and cost dynamics of projects in the portfolio in real time
		E-F15	The degree of elaboration of methods for assessing the economic impact of the introduction of management innovations
Human resources and social	Human capital for the implementation of innovations	C-F16	The level of accessibility and qualification of personnel for the implementation of innovative projects in the portfolio, including in remote regions
		C-F17	The degree to which the company's management and administration perceive the need for constant managerial innovation and readiness for change
		C-F18	The level of industrial discipline and work experience in conditions of increased industrial safety requirements

aimed at overcoming these deviations through innovation-driven development. The results of diagnostic checks of the production system can also be used by the company's management to make managerial decisions in connection with the development and implementation of investment and innovation projects, the formation of business plans and production programs, the improvement of the organizational structure and reengineering of the corporate model of the enterprise, as well as the comprehensive restructuring of the company.

The implementation of this approach can contribute to improving the effectiveness of both innovation management mechanisms and the strategic planning and management system of a high-tech construction enterprise as a whole based on the justification of rational innovation priorities and optimization of organizational and managerial processes for the formation and management of the enterprise's innovation portfolio.

The use of a set of identified factors is also possible as part of the assessment of innovations in the production systems of high-tech construction enterprises, which can contribute to the unification of approaches and improve the effectiveness of mechanisms for selecting and implementing innovative solutions, and the formation of an effective innovation portfolio of the enterprise.

Thus, within the framework of the performed research, the factor space for the formation of an innovative portfolio of gas transportation construction enterprises has been formed and systematized, as well as the directions of its use in the context of solving the tasks of innovative development of industrial and economic systems of enterprises have been identified. At the same time, there is a significant problem in practice that makes it difficult to apply the results of factor analysis in order to model the organizational and economic mechanisms of forming an innovation portfolio, which is the subject of further research by the author. Overcoming this issue will contribute to solving the urgent and significant task of providing high-tech construction enterprises with the necessary tools to make strategic decisions aimed at improving quality, reducing costs and increasing labor productivity on an innovative basis, and, in turn, creating conditions for sustainable economic growth and strengthening the position of the Russian investment and construction complex.

REFERENCES

1. Belyakov S.I., Lysenkov S.G. The main characteristics used in evaluating innovations in the production systems of high-tech construction enterprises. Sustainability of territorial development in the investment and construction sector : materials of the IV National Scientific and Practical Conference with international participation. Penza, 2025; 92-97. EDN KIJFPS. (rus.).
2. Lysenkov S.G., Belyakov S.I. Planning a strategy for the development of a high-tech construction enterprise based on the formation and implementation of a portfolio of innovations. Real estate: economics, management. 2025; 4:65-68. URL: https://n-eu.iasv.ru/index.php/neu/issue/view/39/50 (rus.).
3. Construction Management. Part One. Organizational Management Models and Contractual Designs of a Capital Construction Project : a Textbook in Two Parts and a Workshop, 4th Edition, Revised and Supplemented. Ed. by Prof. P.G. Grabovyy and Prof. A.A. Lapidus. Moscow, ASV Publishing House, Prosvetitel Publishing House, 2022; 478. URL: https://rusneb.ru/catalog/000200_000018_RU_NLR_BIBL_A_012877488/?ysclid=mn4jejdwgc709908267 (rus.).
4. Construction Management. Part Two. Integrated Development and Developing the Construction Territory : a Textbook in Two Parts and a Workshop (Part 3), 4th Edition, Revised and Supplemented. Under the General Scientific Ed. of Prof. P.G. Grabovyy, Prof. A.A. Lapidus. Moscow, ASV Publishing House, Prosvetitel Publishing House, 2022; 620. EDN OWKBFW. (rus.).
5. Gusakova E.A., Pavlov A.S. Fundamentals of Organization and Management in Construction : Textbook and Workshop for Universities. Moscow, Yurait, 2026; 615. URL: https://urait.ru/bcode/588396 (rus.).
6. Pankratov E.P., Pankratov O.E. The problems of increasing the production capacity of construction companies. Construction Economics. 2015; 3(33):4-17. EDN TTFYLB. (rus.).
7. Lysenkov S.G. To the problem about the specificity of innovation activity. The Bryansk State University Herald. 2012; 3(2):212-215. EDN OIXRYR. (rus.).
8. Lysenkov S.G. Integration and dependence of organizational innovations and approaches to management. Project method. Socioeconomic and legal research: theory, methodology and practice: materials. All-Russian scientific and practical conference. Bryansk, New project, 2016; 29-39. EDN XSROOD. (rus.).
9. Kulakov Yu.N., Meshcheryakova T.S. Innovative management: course of lectures. 2nd ed. Moscow, MISI – MGSU, 2017; 155. URL: https://rucont.ru/efd/703113 (rus.).
10. Ostrovskikh T.I., Yakimova L.A., Vernigor N.F. Innovative activity as the factor of the enterprise strategic development. Bulletin of the KSAU. 2013; 1(76):8-11. EDN PYXHUZ. (rus.).
11. Berdnikova L.F. Methodological foundations for analyzing the resource potential of a construction organization : dissertation candidate of economic sciences. Tolyatti, Saratov state social-economic university, 2009; 227. EDN QEIZNN. (rus.).
12. Prokopenkova V.V. Management of resource potential of associations of subjects of housing construction : dissertation candidate of economic sciences. Bryansk, Moscow state construction university, 2016; 197. EDN BPYFUQ. (rus.).
13. Feklistov I.I. Formation, implementation and development of resource potential of organizations in the construction complex: theoretical and methodological aspects : dissertation doctor of economic sciences. St. Petersburg, St. Petersburg state University of Economics and Finance, 2011; 510. EDN QFVGMJ. (rus.).
14. Barteneva O.A. Project and portfolio methods of innovative management of large-scale investment and construction companies. Russian Journal of Entrepreneurship. 2011; 5(2):147-151. EDN NTUGVZ. (rus.).

Ключевые факторы, оказывающие влияние на механизмы формирования инновационного портфеля предприятий газотранспортного строительства

Высокотехнологичные строительные предприятия сталкиваются с необходимостью постоянного внедрения инновационных решений в целях повышения эффективности производства, снижения затрат и повышения конкурентоспособности. Механизмы выбора и внедрения инновационных решений требуют формирования результативных подходов к объективной оценке их потенциала и сопутствующих рисков. Характерным примером высокотехнологичной подотрасли строительства является сфера газотранспортного строительства, предприятия которой в текущих макроэкономических условиях в полной мере испытывают на себе воздействие эффектов данной проблематики. Субъекты рассматриваемой подотрасли — высокотехнологичные предприятия газотранспортного строительства — в процессе своего функционирования испытывают многоаспектное и разнонаправленное влияние факторов внутренней и внешней среды. Решение научной задачи организационно-экономического моделирования механизмов формирования инновационного портфеля предприятий сопряжено с необходимостью выявления и всеобъемлющего анализа обширного факторного пространства.

В результате проведенного автором многоэтапного экспертного анализа были выявлены и классифицированы ключевые внешние и внутренние факторы, оказывающие влияние на механизмы формирования инновационного портфеля предприятий газотранспортного строительства. Применение комплекса выявленных факторов также возможно в рамках оценки инноваций в производственных системах высокотехнологичных строительных предприятий, что может способствовать унификации подходов и повышению результативности механизмов выбора и внедрения инновационных решений, формирования эффективного портфеля инноваций предприятия.

Ключевые слова: *инновации, инновационный портфель, высокотехнологичное строительство, производственные системы, факторы*

СПИСОК ИСТОЧНИКОВ

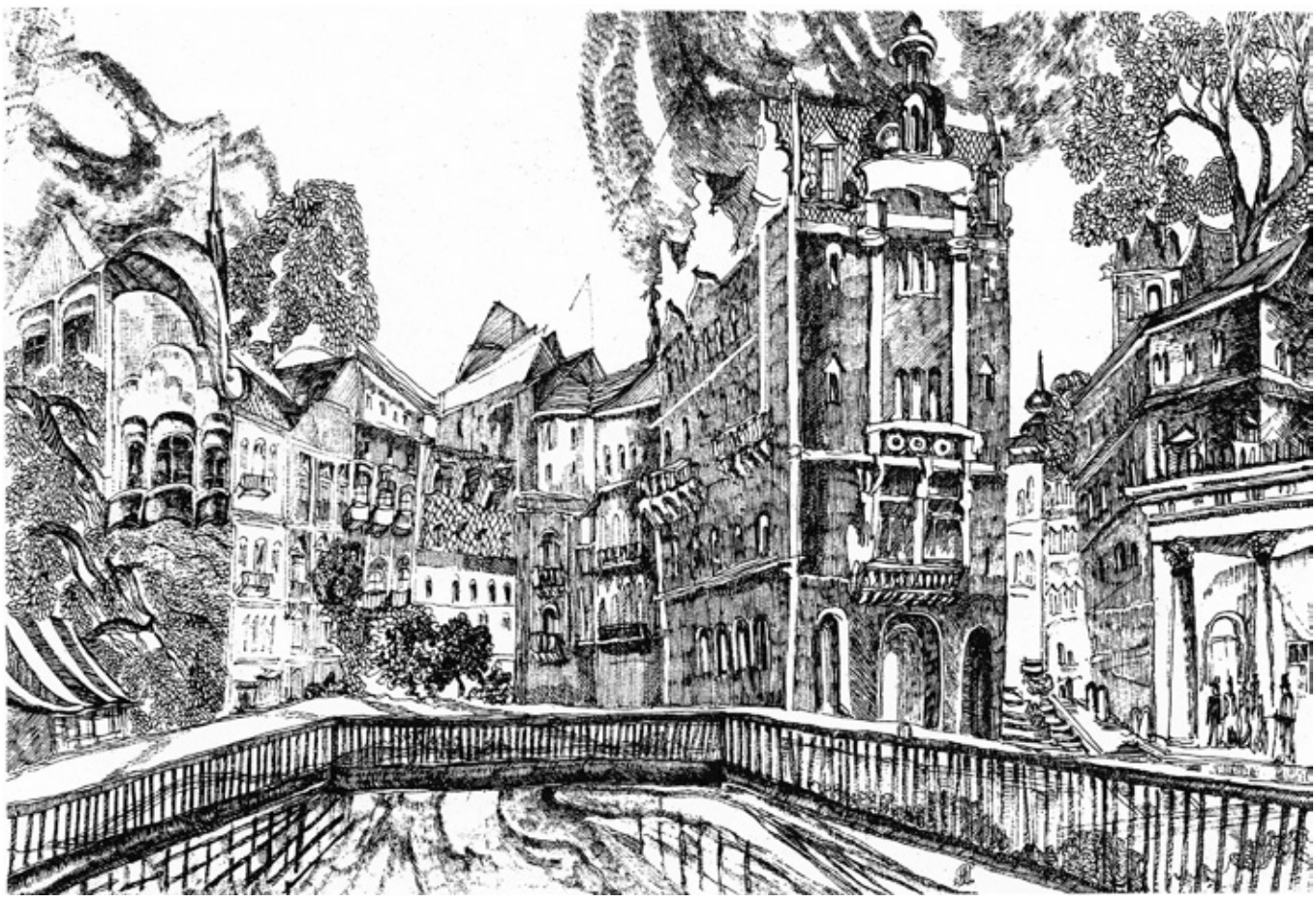
1. Беляков С.И., Лысенков С.Г. Основные характеристики, применяемые при оценке инноваций в производственных системах высокотехнологичных строительных предприятий // Устойчивость развития территорий в инвестиционно-строительной сфере : мат. IV Нац. науч.-практ. конф. с междунар. участием. Пенза, 2025. С. 92–97. EDN KIJFPS.
2. Лысенков С.Г., Беляков С.И. Планирование стратегии развития высокотехнологичного строительного предприятия на основе формирования и реализации портфеля инноваций // Недвижимость: экономика, управление. 2025. № 4. С. 65–68. URL: https://n-eu.iasv.ru/index.php/neu/issue/view/39/50
3. Управление строительством. Ч. 1. Организационные модели управления и контрактные конструкции объекта капитального строительства : уч. в 2-х ч. и практикум, 4-е изд., перераб. и доп. / под общ. науч. ред. проф. П.Г. Грабового, проф. А.А. Лапидуса. М. : Изд-во АСВ, Изд-во Просветитель, 2022. 478 с. URL: https://rusneb.ru/catalog/000200_000018_RU_NLR_BIBL_A_012877488/?ysclid=mn4jejdwgc709908267
4. Управление строительством. Ч. 2. Комплексное освоение и развитие территории застройки : уч. в 2-х ч. и практикум (Ч. 3), 4-е изд., перераб. и доп. / под общ. науч. ред. проф. П.Г. Грабового, проф. А.А. Лапидуса. М. : Изд-во АСВ, Изд-во Просветитель, 2022. 620 с. EDN OWKBFW.
5. Гусакова Е.А., Павлов А.С. Основы организации и управления в строительстве : уч. и практикум для вузов. М. : Юрайт, 2026. 615 с. URL: https://urait.ru/bcode/588396
6. Панкратов Е.П., Панкратов О.Е. Проблемы повышения производственного потенциала предприятий строительного комплекса // Экономика строительства. 2015. № 3 (33). С. 4–17. EDN TTFYLB.

7. Лысенков С.Г. К вопросу о специфике инновационной деятельности // Вестник Брянского государственного университета. 2012. № 3 (2). С. 212–215. EDN OIXRYR.
8. Лысенков С.Г. Интеграция и зависимость организационных инноваций и подходов в управлении. Проектный метод // Социально-экономические и правовые исследования: теория, методология и практика : мат. Всеросс. науч.-практ. конф. Брянск : Новый проект, 2016. С. 29–39. EDN XSROOD.
9. Кулаков Ю.Н., Мещерякова Т.С. Инновационный менеджмент : курс лекций. 2-е изд. М. : МИСИ–МГСУ, 2017. 155 с. URL: https://rucont.ru/efd/703113
10. Островских Т.И., Якимова Л.А., Вернигор Н.Ф. Инновационная активность как фактор стратегического развития предприятия // Вестник КрасГАУ. 2013. № 1 (76). С. 8–11. EDN PYXHUZ.
11. Бердникова Л.Ф. Методические основы анализа ресурсного потенциала строительной организации : дис. ... канд. эконом. наук. Тольятти : Сарат. гос. соц.-эконом. ун-т, 2009. 227 с. EDN QEIZNN.
12. Прокопенкова В.В. Управление ресурсным потенциалом объединений субъектов жилищного строительства : дис. ... канд. эконом. наук. Брянск : Моск. гос. строит. ун-т, 2016. 197 с. EDN BPYFUQ.
13. Феклистов И.И. Формирование, реализация и развитие ресурсного потенциала организаций строительного комплекса: теоретические и методические аспекты : дис. ... д-ра эконом. наук. СПб. : С.-Петерб. гос. ун-т экономики и финансов, 2011. 510 с. EDN QFVGMJ.
14. Бартенева О.А. Проектно-портфельные методы инновационного управления крупными инвестиционно-строительными компаниями // Российское предпринимательство. 2011. № 5 (2). С. 147–151. EDN NTUGVZ.

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The importance of complex modelling of the spatial–territorial system in assessing the implementation of investment and construction projects



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This paper examines an approach to integrated modelling of a spatial-territorial system from the perspective of the interconnections and mutual influences of not just individual factors and components, but rather complex systems that form a natural and artificial spatial system. The fundamental distinction of this approach is that it considers the interactions of systems with the same goal but different resource directions in the formation of a unified system during the implementation of investment and construction projects. The socioeconomic nature of a spatial-territorial system, which takes into account the complex use of land plots with various land uses interconnected with technological process components during the construction of real estate with varying functionality, determines the task of quantifying the balance of the model. The level of capitalization of "undeveloped" ("undeveloped land" — a natural resource at the stage of the beginning of the territory organization process) land resulting from the implementation of investment and construction projects reflects the efficiency of its use, regardless of the functionality of spatial objects. Therefore, this indicator can serve as an integral criterion for the balanced state of a spatial-territorial system. Moreover, the direction of investment impact will be determined by the identified discrepancies in the functioning of individual elements of the system under study during the investment support of project implementation. This article examines a resource decomposition method for a model for all participants in territorial redevelopment, enabling the calculation of benchmark values for the system's economic parameters under the assumption of a balanced structure. These results were achieved through the creation of a comprehensive "territorial genesis" model, based on the interconnected and interdependent production processes of construction projects. Furthermore, the inclusion of humans as a key production factor played a significant role in the model's development. The influence of the human factor is reflected in the model both at the organizational stage and during the adoption and implementation of the investment construction process. Based on the model's decomposition, it was possible to obtain capitalization coefficients for each system element, the entrepreneur's profit level, the contractor's profit level, and the refinancing rate assuming no losses in a balanced system. These values can serve as benchmarks to strive for when developing territories in investment construction projects to ensure the structural balance of the spatial-territorial system, or they can reflect the balance of the real estate market and the state of its individual segments at the time of their assessment.

Keywords: *patterns of territorial functioning, investment activity, investment climate, complex redevelopment project, land capitalization level, capitalization ratio, entrepreneur's profit, key rate*

A territory is a specific concept that is defined by borders, area, properties, resources and is an object of human activity of the population that lives on it [1].

The development of the territory occurs as a result of human activity, which forms both the spatial system and the investment climate, including through the adoption of laws and regulations on the development of territories, structuring the financial system and attracting investment resources [2]. The study of dynamic changes occurring in the territory is not possible without modelling the spatial-territorial system, which includes man and the land as the main natural and intellectual resource for its development [3].

The territory formed in this way is not static. Depending on the development goals, external influences, and changes in the technological base of construction, the territory is transformed and changed.

The dynamics of territorial development can be observed through the analysis of the Spatial Development Strategy of the Russian Federation for the period up to 2030 with a forecast up to 2036[1].

The purpose of the spatial development of the Russian Federation is to form a balanced system of settlement and territorial organization of the economy of the Russian Federation, which will contribute to achieving national goals and ensuring national security.

The planning strategy is a document developed according to the territorial principle within the framework of strategic goal-setting according to the territorial principle. This principle fulfills the task of a key mechanism for implementing the strategy through current territorial planning documents (including the territorial planning schemes of the Russian Federation in various areas, the territorial planning schemes of the subjects of the Russian Federation). This work is carried out according to territorial land management schemes, which primarily provide for the redistribution of lands by combining, dividing and delimiting them based on their effective use under a certain type of land use. In this case, the reconstruction of territories is not considered in isolation, but in the general system of established land use, which significantly increases the possibility of economically efficient use of land [4].

The spatial development strategy is certainly based on innovative technologies that will ensure the breakthrough of modern environmentally oriented industry. Scientific and technological development, in

[1] Strategy for Spatial Development of the Russian Federation through 2030 with a Forecast to 2036 : Order of the Government of the Russian Federation of December 28, 2024, No. 4146-r. URL: http://government.ru/docs/all/157308/ (rus.).

accordance with the strategy, provides for the creation of mechanisms to encourage investors to form infrastructure in territories with preferential regimes, on the basis of which critical and end-to-end technologies are created.

The analysis of the spatial development strategy of the Russian Federation has shown that the inertial scenario, which does not change the existing settlement system and the territorial organization of the economy, does not contribute to the development of the spatial-territorial system and in this case will have to rely only on the implementation of individual local projects. The target scenario, which achieves the goal of developing a spatial-territorial system, is determined by two factors: the equilibrium structure of the self-developing system and the external resource impact that supports the components of the system for structural equilibrium, which is focused on the development of the system [5].

The Strategy defines a digital platform as the basis for making managerial decisions.

However, for urbanized territories, market value and the achievement of quantitative indicators set out in the Strategy prevail as a quantitative characteristic. The methodology used to calculate the market value, for determining which, with the dominant principle of the most efficient use, is purely aimed at the economic exploitation of land, rather than its effective use, ignores the main social and environmental factors and leads to the gradual degradation of territories. And the absence of such an indicator as the level of land use efficiency, which is the main natural resource uniting all branches of the national economy of any country, does not allow us to quantify information about the growth and development of the spatial and territorial system [5]. A digital indicator of the development of a spatial-territorial system should include a set of relationships between all the resources of the spatial-territorial system, starting from land, the main natural resource, and ending with human relations during the construction and operation of real estate.

The task of expressing the state of the spatial-territorial system in digital terms is associated with the issues of the mutual influence of systems of different nature and the multidirectional nature of their resources in the formation of a common integrated system. To achieve this goal, this article examines the application of a complex engineering approach that combines the relationship between subject systems and object systems, regardless of whether these systems are technical or organizational [6]. This approach made it possible to develop a model of the "genesis of territories" [7], decompose it, and switch to economic parameters that characterize each element of the model, provided that the spatial and territorial system is balanced [8]. The paper shows both the role of the behavior of stakeholders in a territorial redevelopment project and the role of the investment climate [9] in shaping the equilibrium structure of the system based on the interests of the project participants. The calculation of the quantitative value of each layer of the model, expressed in economic terms, contributes to the adoption of managerial decisions to create a balanced territorial organization of the economy. The paper shows that based on the equity participation of a particular stakeholder in the capitalization level of undeveloped land, it is possible to determine the conditions for the balance of an integrated system consisting of systems of various nature. Quantification of the capitalization level of "undeveloped land" makes it possible to compare territories with different functional purposes and types of land use, and this supports the digital transformation of the economy.

The basis of the research method published in this article is the model of the "genesis of territories". In this model, man takes the place of the main geological force in the formation of the spatial and territorial system. As a cognitive process of the structural organization and balance of a complex system, it was chosen not the composition of the system based on empirical knowledge, but the method of decomposition of a single, integral balanced system into components. This model fractally repeats the structure of natural self-developing systems. In this case, the nonlinearity of the system change is determined by the proportion of the resource that is transferred to the land by the components included in the model. The resource that is transferred by each element of the "genesis of territories" model to the land as a result of an investment construction project determines the structural balance of the system. The role of the structurally organizing component is performed by the "spatial basis": an integrated system consisting of two systems — "land" and "human", interconnected under the influence of the driving force inherent in these systems, and formed to identify the resources and natural properties of the land to ensure the development of an ecologically sustainable spatial and territorial system.

To develop a comprehensive model of the "genesis of the territory", six prerequisites were adopted, which are specified in the following categories:

- "existence" is an integrally general category;
- "goal" is the most important prerequisite that determines the systematization of rules for the rational use of land in order to create conditions for the sustainable development of the spatial and territorial system by harmonizing the vital activity of human society with the Laws of Nature;
- "multitude of objects", which are understood as the laws of human society that determine the structural and functional organization of the spatial and territorial system;
- "one" — meaning the initial and final reason for the interaction of all elements of the model;
- "unity" — as a result of the structural and functional relationships of individual interdependent elements of the spatial and territorial system;
- "sufficiency", which asserts that no phenomenon can be true without a sufficient reason why this is the case.

These six prerequisites follow from the fundamental concept of the "Genetic energy-informational unity of the World", to which the formed model corresponds.

The structure of the model of the "genesis of the territory" contains a person, while the process of decomposition of the system reveals the mechanism of intellectualization of a person in the process of his activity to create a balanced structure of the system. Based on this, it can be concluded that the model of the "genesis of the territory" used describes a dynamic intellectual system. The model is presented infographically in Fig. 1, compiled by the author, and the choice of its formation is presented in the works [3, 7].

The developed model of the "genesis of the territory" is constructed in such a way that each upper layer determines the necessary functioning of the underlying layer, forming its social usefulness, that is, ultimately, the effective use of land to improve human well-being. The model contains a recurrent relationship between the components of the system (looking from the bottom up: each subsequent element of the system is formed by the interrelation of the two previous elements, and the capabilities of this element determine the activities of the previous ones).

Let's consider the structure of the model based on the resource, properties, characteristics and functional features of each layer of the system.

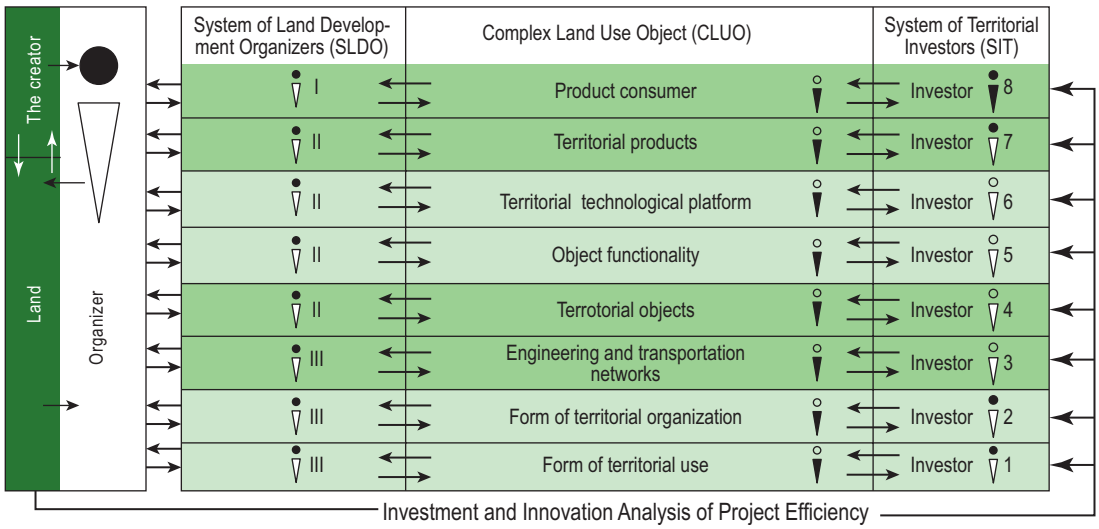


Fig. 1. Infographic representation of the "genesis of the territory" model [3]

Land, as an object in itself, initially has no value, since it is not the result of socially necessary labor and cannot be reproduced by labor, and land management projects created on the land are already the first step towards creating infrastructure and subsequent development of the territory by creating land plots. Human activity in the formation of land plots and land use rules determines the effectiveness of the use of a land resource in its subsequent use. The results of human activity are the subject of socially necessary labor invested for the existing territory and are inseparable from the factors of production and, together with the land, act as the main means of production and the operational basis.

The *form of use of the territory* is an integrated system of the territory, considered in the context of the "natural" environment in full, fixes the necessary requirements and restrictions on the land use of a particular site. The form of use of the territory provides an "infrastructural" resource through the consumption value of the formed land plots with a certain permitted use.

The *form of organization of the territory* is a complex system of the territory, considered in the context of the "natural" environment, to identify the elements of the planning structure, to establish the parameters of their planned development, zones of placement of objects of federal, regional and local importance, and including a land surveying project. The form of organization of the territory provides an "infrastructural" resource through the use value of the formed land plots.

Engineering and transport networks are a complex system of a territory that supplies resources for the implementation of functional support for real estate objects in the studied territory through an increase in the use value of formed land plots of a certain functionality.

The *technological platform of a territory* is a complex system of a territory that includes a set of technologies used in the construction of real estate, ranging from investment design to managing the execution of an investment project and supplying a resource by generating the consumer value necessary for the rational use of the formed land.

The *functionality of the facility* is an integrated system of the territory that ensures the implementation of functions to create the necessary efficiency of improvements on the land by creating real estate objects with public utility.

Territorial objects are a complex system of a territory, on the condition of which depends the implementation and provision of the necessary functions to ensure the vital activity of the population through the formation of a specific labor market for the creation of an object.

The *product of a territory* is a complex system of a territory that reflects the quality of a socially useful building or structure on a formed land plot due to the technologies used and the level of spiritual, scientific and technical development of a human resource when creating a traditional and innovative product.

A *consumer of a product* is a complex system of a territory that includes participants in the operational stage of the life cycle of real estate objects that ensure the reproduction of production capital by involving the resource of the land plot and improvements located on it in the economic sphere of the spatial and territorial system in accordance with the state of supply and demand in the market of the product being created.

This model reflects the technological chain of the investment process and the interconnection of construction participants. The model itself is a "complex system", and each layer of this model, in turn, is essentially the same "complex system". The unity of the model elements determines the functionality of various "platforms" of the territorial development cycle model [10], united by a single goal for the evolution of the system and capable of change.

The model of the "genesis of the territory" can be easily transformed into systems of a certain type of land use with specification of the functionality of each element. The proposed model takes into account the interrelationships and interdependencies of the elements: principles that correspond to models of natural systems and reflect the social significance of the land.

The components of the model essentially represent complex systems of organizers, users and investors, which consist of two system layers (elements). The first layer performs a creative and stimulating function (SLDO system), the second a creative one (SIT and CLUO systems).

From the consideration of the system's fractal integrity to natural systems and the human brain, the system decomposition method was applied. The system was divided into separate elements by converting the resources of the components of the system, described by physical constants, based on the postulates of the Evolutionary model of the Universe by B.A. Astafiev [11]. Calculations

Table 1. Sequence of layers of the "genesis of the territory" model (compiled by the author)

The conditioned layer of the "genesis of the territory" model	A number of equity participation components of the "genesis of territories" model for urbanized territories
Land Form of use of the territory + The consumer of the products	0.076393 + 0.123607 = 0.200000
Form of organization of the territory Engineering and transportation networks + Form of use of the territory	0.076393 + 0.076393 = 0.152786
Engineering and transportation networks Technological platform of the territory + Form of organization of the territory	0.123607 + 0.123607 = 0.247214
Objects of the territory Products of the territory + Functionality of the facility	0.076393 + 0.076393 = 0.152786
Products of the territory Consumer of products + Objects of the territory	0.123607 + 0.123607 = 0.247214
Total	1.00000

made on the basis of stakeholders' shared resource participation in the transformation of territories allowed us to move to "dimensionless quantities reflecting the economic efficiency of land use" [12]. The result of the decomposition of the model for urbanized territories is presented in Table 1.

The restructuring of the components of the "genesis of the territory" model by setting goals for them by the "organizer" determines not only the final result of the participants' activities in the development of territories, but also forms the vision of the "SLDO system of organizers" and "SIT investors". This transforms the understanding of the project participants about the interrelationship of individual elements of the integrated system, which contributes to the transformation of the biosphere into the noosphere, which will ensure the effective and creative implementation of complex design and investment construction works in the relevant territories [13].

The behavior of stakeholders in the territorial development project is subordinated to various goals. The system of investors (SIT) and performers of work in (CLUO) is focused on making a profit, ensuring their expanded reproduction. The consumer is focused on the operational process of real estate and their purchasing power. In a balanced system, these multidirectional goals are formed and ensured by the investment climate [14], which should create conditions for the development of territories through the activities of the State, the State Bank, the "organizer" and the system of territory organizers (SLDO).

In this process, the determining role is played by the "technological platform" of the model, which plays a connecting role between the "land platform": the operational base and the components that ensure the construction of buildings and structures.

The complex model of the "genesis of territories" helps to determine this relationship. Since the model describes the organizational, socio-technical mechanism of territorial development, it allows us to consider the target function of the integrated system "technological platform". The function of the "technology platform" is to integrate organizational and technological innovations into the resource development of territories. The purpose, or rather, the mission of the "technology platform" is to ensure and support the process of capitalization of territories, primarily land, including the process of "intellectual" capitalization of participants in an investment construction project.

The content of the "technology platform" layer influences other layers of the model in the process of innovative construction methods that are based on the principles of sustainable development, i.e. "green" buildings. The concept of a "green" building is a building that equally meets the three principles of sustainable development related to the fields of ecology, economics and sociology. Such a building can be built only through the constant interaction of all project participants at all stages of its life cycle, including design, construction, operation, and disposal. This is the only way to achieve optimal solutions in terms of reliability, efficiency, rationality, functionality and style.

Let's consider the influence of the "territory technology platform" layer on other layers of the "territory genesis" model.

It should be noted that the reconstruction of the "technological platform" layer of the "genesis of the territory" model entails a change in the equipment used, affects the construction of engineering and transport networks and communication systems, and, as a result, determines the possibilities of obtaining innovative products that determine the level of capitalization of the land. Moreover, this relationship is present in all models of the "genesis of territories", regardless of the type of land use.

The organizational restructuring of the functioning of enterprises in the territories, formed as innovative changes in their work, was investigated in a series of papers [15–17] related to the identification of the mechanism of economic innovative development of enterprises. As a result of modelling in this area of the economy, direct projections of the "technology platform" layer onto all layers of the "genesis of the territory" model were obtained. The resulting scheme of the complex object of innovative reconstruction of the territory is shown in Fig. 2. The arrows in the figure show the directions of the spread of innovative technologies from the "technology platform" layer to other layers of the model.

The integrated technology platform system includes not only "technical" but also social technologies that have been developed to date. According to [18]: "... Technology platforms are a new communication platform for discussing the most important technological development projects, for developing and implementing long-term priorities across the country's economy based on a common vision of modernizing existing and forming new sectors of the economy, as well as tools to influence the speed of the spread of promising technologies in all spheres of society". Technology platforms combine the capabilities of science and business, applied throughout the development and production cycle of innovative products. Technological platforms are also becoming the basis for the formation of thematic areas within which the government will determine

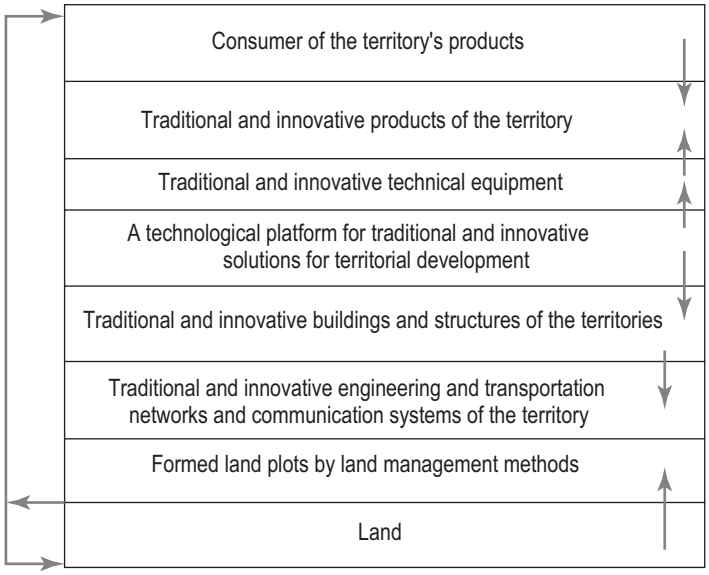


Fig. 2. Scheme of the complex object of innovative development of the territory

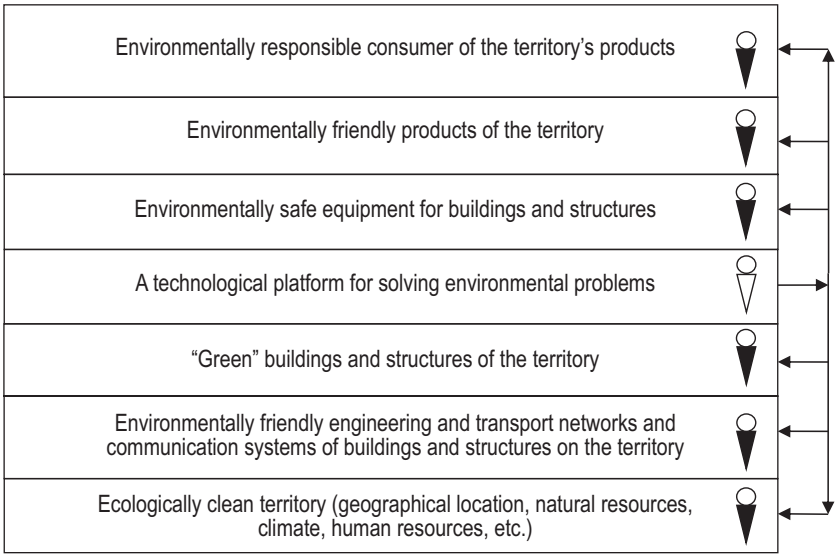


Fig. 3. An infographic view of the model of the "genesis of territories" in the ecological reconstruction of territories

priorities for various research activities, the results of which are planned to be introduced into production [18].

This makes it possible to consider the technology platform as a means of territorial development using cross-disciplinary approaches to the formation of reconstruction technologies. Note that when the "technology platform" layer is projected onto the "land" layer, the latter acquires the focus of innovative development. Moreover, the direction of modern zoning of the country's territories, which consists in choosing territories for priority reconstruction (accelerated development zones, sustainable development zones, support zones), involves the integrated development of the territories of the regions in which these zones have been created, will be created or are in the process of formation.

If the technological platform of the territory is focused on solving the environmental problems of the territory, then the "genesis of the territory" model takes the form of an integrated object of "environmental management of territories", shown in Fig. 3. The peculiarity of this model is the restructuring of the targets of the activities of specialists involved in the reconstruction of the layers of the model, to comply with environmental standards in the process of territory reconstruction.

The technological platform, as a means of solving environmental problems of the territory, is also becoming the basis for the formation of thematic areas within which the state will determine priorities for various research activities, the results of which are planned to be introduced into production, including in the form of the best available technologies.

It is the social component of the "genesis of the territory" model that, due to the spirituality of the performers of the territorial development project, unites the capabilities of science and business applied throughout the cycle of development, production and consumption of environmental products of the territory, forms the corresponding organizational projects of this territory.

The peculiarity of the developed model of the "genesis of the territory" is the restructuring of the targets of the activities of specialists involved in the development of territories aimed at land use efficiency.

Table 2. Results of calculations of the capitalization coefficients of the elements and their share of a single real estate object in accordance with the model of the "genesis of the territory" for urbanized lands (compiled by the author)

Components		The fraction of energy transferred by an element to the Land	The capitalization coefficient of the element	The share of an element in an integrated system	The energy of the element fraction (4/3)	The share of the rental value of a component in the cost of a single object (column 5 × line 12)
Number	1	2	3	4	5	6
1	Type of land use	0.001194637	0.012244882	0.0763932	6.238786303	0.095657711
2	The consumer of the products	0.001766967	0.018111193	0.123607	6.824895349	0.104644371
3	Type of land use	0.001194637	0.012244882	0.0763932	6.238786303	0.095657711
4	Engineering and transport infrastructure	0.001162686	0.011917388	0.0763932	6.410230236	0.098286417
5	Facility of the territory	0.001881266	0.019282744	0.123607	6.410239095	0.098286552
6	The generated land plot	0.001932964	0.019812642	0.123607	6.238794339	0.095657834
7	Product of the territory	0.001092046	0.011193337	0.0763932	6.824881875	0.104644164
8	Functionality of the territory	0.001128539	0.011567385	0.0763932	6.604189091	0.101260338
9	The consumer of the products	0.001766967	0.018111193	0.123607	6.824895349	0.104644371
10	Technology platform	0.001826014	0.018716418	0.123607	6.604201754	0.101260532
11	Total	0.014946723	–	1.00000	–	1
12	Weight ratio 1/Total	66.90429735	–	–	0.015332744	–

The indicator of the level of capitalization of land, reflecting the effectiveness of its use in the implementation of an investment construction project, is determined by an investment and innovation analysis with the criterion of equilibrium of the model elements. A management decision is made based on the value of this indicator. The result of the decomposition of the "genesis of territories" model made it possible to calculate the capitalization coefficients of individual elements of the model [9], schematically these results are presented in Table 2.

Based on the data obtained, it is easy to determine the share of stakeholders in the cost of a single property. So, the main components used in estimating the value of real estate for an equilibrium system are equal:

- the capitalization coefficient of the land plot: 0.012244882 + + 0.018111193 + 0.019812642 = 0.050168717;
- the share of a land plot in a single real estate object: 0.095657711 + + 0.104644371 + 0.095657834 = 0.295959915;
- capitalization ratio for improvements = 0.103033347;
- percentage of improvements — 0.704040085;
- total capitalization ratio according to the investment group method: 0.050168717 · 0.295959915 + 0.103033347 · 0.704040085 = = 0.087387536.

The amount of an entrepreneur's profit is determined by the sum of capitalization coefficients reflecting human activity (capitalization coefficient of improvements), the total capitalization coefficient and the equilibrium refinancing rate: 0.103033347 + 0.087387536 + + 0.0407 = 0.231166007, this practically corresponds to an increase in the share of the "Organizer" after the completion of the land development project — 0.231165946.

The results of calculating the equity participation of a land plot in the total value of a real estate object were compared based on the decomposition of the "genesis of territories" model with data from the commercial real estate market. A comparison of the results is presented in Table 3.

The comparison shows that the value of the residual value of the land plot according to market data practically coincides in the upper part of the confidence interval with the results of the decomposition. The large variation in the value of the confidence interval, due to its lower part, indicates an unbalanced structure of the created real estate in the commercial segment. This allows us to conclude that the land capitalization coefficient is overestimated, leading to a decrease in the residual value of the land plot.

The obtained results of the analysis of the significance of complex modelling of the spatial — territorial system allow us to draw the following conclusions:

The use of information modelling methods in increasing the capitalization of the city territory is considered using the example of using an integrated approach to building an information model of a real estate object. This approach takes into account all the tangible and intangible resources that an object exchanges with its surroundings during the investment design process.

Information modelling is a technology for information support of the product creation process. This type of modelling makes it possible to clarify the impact of changes and risks in an object (including geodynamic risks) at all stages of the object's life cycle.

Table 3. Comparison of the results of the share of the formed land plot in value and income during decomposition and market data of the "commercial" real estate segment (compiled by the author)

Data source	Class A, B offices	Class C offices	Shopping malls	Free-use facilities
Decomposition result	0.296	0.296	0.296	0.296
Average market data	0.2	0.22	0.19	0.19
Confidence interval	0.11–0.29	0.13–0.3	0.1–0.28	0.11–0.27

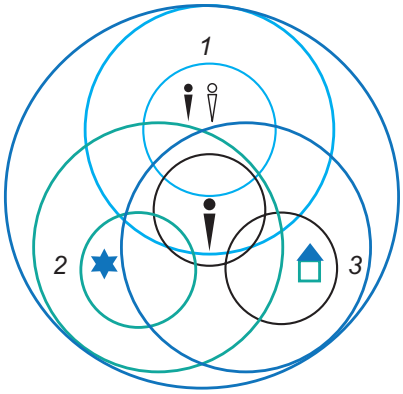


Fig. 4. An infographic model of the interaction of three systems, implemented in the model of the "genesis of the territory": 1 — "Society – Human" system; 2 — "Nature – Human" system; 3 — "Human – Artificial world" system

The use of an integrated approach makes it possible to describe the object of research, taking into account the practice of its implementation in several fields of activity, at the intersection of which the object is located, which, in turn, allows you to obtain a set of relevance and a set of points of novelty for a wide range of practical applications. At the same time, object representation models developed in a related field of research can be used to solve problems in the main field of research. In this case, the function of the "technology platform" is to ensure and support the investment process in construction, and the role played is the integration of organizational and technological innovation resources into the management of the development of the territory.

The integrated development of territories requires the development of a co-organization of three integrated systems. The systems "Nature – Human", "Society – Human", "Human – Artificial world".

The science of Ecology deals with the "Nature – Human" system. Social sciences study the "Society – Human" system, while economics studies the "Human – Artificial World" system. We get the task of a cross-disciplinary solution.

The developed model of the "genesis of the territory", by determining the interconnectedness and interdependence of the model elements, made it possible to determine the conditions for the co-organization of these three systems. At the same time, at the center of the complex system is a person on whose spiritual, intellectual level and creative activity the development of the spatial and territorial system on land depends. The interaction of these systems is shown infographically in Fig. 4.

Only by defining the interaction of these three systems can we approach the issue of the level of capitalization of territories and the sustainability of the spatial-territorial system.

The elements of the three systems create a common complex system with different attitudes to the use of resources and the Land and the humanity living on it. The unified formation of elements of a common system with various resources determines an integrated approach to the implementation of the spatial and territorial system. This view of the spatial and territorial system allows us to consider ways to implement the principles of sustainable development defined by the United Nations[2].

[2] Best Practices for Achieving Sustainable Development Goals in Russia and Globally. News Digest. Scientific and Educational Center for Sustainable Development. No. 1. 2020. URL: https://web.archive.org/web/20220108001328/https://www.ranepa.ru/documents/digests-ifur/digest-ifur-1.pdf (rus.).

REFERENCES

1. Volkov S.N. Land management : Textbooks and teaching aids for students of higher educational institutions. Moscow, GUZ, 2013; 992. EDN UBSDHF. (rus.).
2. Alekseev V.N. The evolution of the concept of "Investment climate" in the transitional economy of Russia. Economic Problems and Legal Practice. 2022; 18(1):173-179. EDN QPPVPD. (rus.).
3. Svetlakov V.I. Choosing an approach to modelling a spatial-territorial system. Bulletin of the Russian Academy of Natural Sciences. 2022; 22(1):67-75. DOI: 10.52531/1682-1696-2022-22-1-67-75. EDN DOBXPB. (rus.).
4. Tatarinov K.A. Workshop on Land Management Economics : Textbook. Irkutsk, BSU Publishing House, 2018; 141. URL: http://sgal.bgu.ru/pub.aspx?id=23594 (rus.).
5. Svetlakov V.I. Territorial planning — a mechanism for implementing the spatial development strategy. Modern problems of project management in the investment sphere and environmental management. Contemporary Project Management Issues in Investment and Environmental Management : Proceedings of the XVI International Scientific and Practical Conf. Moscow, Plekhanov Russian University of Economics, 2025; 187-193. EDN HRMTMB.
6. Mokhov A.I. Modelling studies in the natural sciences on the basis of complexotechnics. Bulletin of the Russian Academy of Natural Sciences. 2015; 15(1):25-30. EDN TTVLLN. (rus.).
7. Svetlakov V.I. Simulation in modern land management design. Moscow Economic Journal. 2022; 7(2):133-145. DOI: 10.55186/2413046X_2022_7_2_115. EDN UYBAKV. (rus.).
8. Svetlakov V.I. Calculation of the land capitalization coefficient with structural homogeneity of the spatial-territorial system. International agricultural journal. 2024; 7(4):1300-1313. EDN NNWJOQ. URL: https://iacj.ru/ru/nauka/article/102606/view (rus.).
9. Alekseev V.N., Mokhov A.I., Svetlakov V.I. Complex object of territorial redevelopment as a model of the structure of activities in the biosphere. Russian Engineer 2025 : Collection. URL: https://s3-oris.bmstu.ru/cms.bmstu.ru/rusengineer_new/sbornik_tezisov_russkiy_inzhener_2025_compressed.pdf (rus.).
10. Svetlakov V.I., Mokhov A.I. A model of cycle of complex development of the territory. Naukovedenie. 2014; 6(25):68. DOI: 10.15862/68EVN614. EDN TTHKHH. (rus.).
11. Astafiev B.A. The Universe: discoveries, theories, hypotheses. Moscow, Nauka, 2015; 612. URL: https://search.rsl.ru/ru/record/01008059557 (rus.).
12. Svetlakov V.I. On the choice of a criterion for the development of a spatial-territorial system. International agricultural journal. 2024; 4:1284-1299. DOI: 10.55186/25880209_2024_8_4_10. EDN QQYIJP. URL: https://qje.su/ru/storage/download/218906 (rus.).
13. Svetlakov V.I., Mokhov A.I., Mokhova L.A., Borovoy E.A. The Models of Integrated Area Renovation. International Journal of Psychosocial Rehabilitation. 2020; 24(3):2883-2904. DOI: 10.37200/IJPR/V24I3/PR2020323. EDN SCCVNZ. URL: https://www.psychosocial.com/index.php/ijpr/article/view/3496 (rus.).
14. Alekseev V.N., Ermilov V.G. Investment climate of Moscow: individual aspects. Finance and Credit. 2010; 13(397):2-6. EDN LARMNV. (rus.).
15. Mokhov A.I., Minaev V.A., Faddeev A.O. System integration of BIM technologies and geodynamic risk models in the construction sector. Territory Development. 2016; 1:54-58. EDN YUXQEO. (rus.).
16. Siluyanov A.V., Latyshev G.V., Latyshev K.V., Mokhov A.I. Complex technology for the reconstruction of automation systems of an "intelligent building". Electrical and data processing facilities and systems. 2012; 8(1):10-13. EDN OPFDHZ. (rus.).
17. Mokhov A.I., Teodorovich N.N., Latyshev G.V., Vikulin D.Yu. Redevelopment of intelligent buildings. Management of investment, construction, housing and communal services complexes : International collection of scientific papers. Ed. by Doctor of Engineering Sciences, Prof. V.O. Chulkov. Moscow, MG AKKHIS, 2010; 277-285. (rus.).
18. Bystrov A.V., Svetlakov V.I., Boikova I.V. Resources technological platform composed of complex object reconstruction site. Modern problems of project management in the investment and construction sphere and environmental management : Proceedings of the VII International Scientific and Practical conference. Moscow, Plekhanov Russian University of Economics, 2017; 287-291. EDN YMTSQP. (rus.).

Значимость комплексного моделирования пространственно-территориальной системы при оценке выполнения инвестиционно-строительных проектов

Рассматривается подход к комплексному моделированию пространственно-территориальной системы с точки зрения взаимосвязи и взаимовлияния не отдельных факторов и компонентов, а комплексных систем, которые формируют естественную и искусственную пространственную систему. Принципиальное отличие такого подхода состоит в том, что в нем рассматриваются взаимодействия систем с одинаковым целеполаганием, но разнонаправленным ресурсом при формировании единой системы в процессе выполнения инвестиционно-строительных проектов. Социально-экономический характер пространственно-территориальной системы, учитывающий комплекс использования земельных участков с различным видом землепользования, взаимосвязанных с компонентами технологического процесса при строительстве объектов недвижимости различной функциональности, детерминирует задачу количественного определения баланса модели. Уровень капитализации «чистой» («чистая земля» — природный ресурс на этапе начала процесса организации территории) земли в результате выполнения инвестиционно-строительных проектов отражает эффективность ее использования в независимости от функциональности пространственных объектов. Поэтому этот показатель может выступать в качестве интегрального критерия сбалансированного состояния пространственно-территориальной системы. При этом направленность инвестиционного воздействия определится выявленным несоответствием функционирования отдельных элементов исследуемой системы в процессе инвестиционного обеспечения выполнения проектов. В статье рассматривается метод ресурсной декомпозиции модели для всех участников переустройства территории, позволивший рассчитать эталонные величины экономических параметров системы при условии ее сбалансированной структуры. Полученные результаты стали возможны после создания комплексной модели «генезиса территорий», которая сформирована исходя из взаимосвязанных и взаимообусловленных производственных процессов выполнения проектов строительства. Кроме этого, существенную роль в формировании модели оказало включение в нее человека в качестве основного производственного фактора. Влияние человеческого фактора реализовано в модели как на этапе организационных мероприятий, так и на этапе принятия и осуществления инвестиционного процесса строительства. По результатам декомпозиции модели удалось получить величины коэффициентов капитализации для каждого элемента системы, уровня прибыли предпринимателя, уровня прибыли исполнителей, величину ставки рефинансирования при условии отсутствия потерь в сбалансированной системе. Данные величины могут выступать в качестве эталонных, к которым следует стремиться при освоении территорий в инвестиционных строительных проектах для структурной сбалансированности пространственно-территориальной системы либо отражать сбалансированность рынка недвижимости и состояние отдельных его сегментов на момент их оценки.

Ключевые слова: *закономерности функционирования территории, инвестиционная деятельность, инвестиционный климат, комплексный объект переустройства, уровень капитализации земли, коэффициент капитализации, прибыль предпринимателя, ключевая ставка*

СПИСОК ИСТОЧНИКОВ

1. Волков С.Н. Землеустройство : уч. и уч. пособие для студентов высших учебных заведений. М. : ГУЗ, 2013. 992 с. EDN UBSDHF.
2. Алексеев В.Н. Эволюция понятия «Инвестиционный климат» в переходной экономике России // Проблемы экономики и юридической практики. 2022. № 18 (1). С. 173–180. EDN QPPVPD.
3. Светлаков В.И. Выбор подхода к моделированию пространственно-территориальной системы // Вестник РАЕН. 2022. № 22 (1). С. 67–75. DOI: 10.52531/1682-1696-2022-22-1-67-75. EDN DOBXPB.
4. Татаринов К.А. Практикум по экономике землеустройства : уч. Иркутск : Изд-во БГУ, 2018. 141 с. URL: http://sgal.bgu.ru/pub.aspx?id=23594
5. Светлаков В.И. Территориальное планирование — механизм реализации стратегии пространственного развития // Современные проблемы управления проектами в инвестиционной сфере и природопользовании : мат. XVI Междунар. науч.-практ. конф. М. : ФГБОУ ВО «РЭУ им. Г.В. Плеханова», 2025. С. 187–192. EDN HRMTMB.
6. Мохов А.И. Моделирование исследований в естественных науках на основе комплексотехники // Вестник РАЕН. 2015. № 15 (1). С. 25–30. EDN TTVLLN.
7. Светлаков В.И. Моделирование в современном землеустроительном проектировании // Московский экономический журнал. 2022. № 7 (2). С. 133–145. DOI: 10.55186/2413046X_2022_7_2_115. EDN UYBAKV.
8. Светлаков В.И. Расчет коэффициента капитализации земли при структурной однородности пространственно-территориальной системы // International Agricultural Journal. 2024. № 7 (4). С. 1300–1313. EDN NNWJOQ. URL: https://iacj.ru/ru/nauka/article/102606/view
9. Алексеев В.Н., Мохов А.И., Светлаков В.И. Комплексный объект переустройства территории как модель структуры деятельностей в составе биосферы // Русский инженер-2025 : сборник. URL: https://s3-oris.bmstu.ru/cms.bmstu.ru/rusengineer_new/sbornik_tezisov_russkiy_inzhener_2025_compressed.pdf
10. Светлаков В.И., Мохов А.И. Модель цикла комплексного развития территории // Науковедение. 2014. № 6 (25). С. 68. DOI: 10.15862/68EVN614. EDN TTHKHH.
11. Астафьев Б.А. Мироздание: открытия, теории, гипотезы М. : Наука, 2015. 612 с. URL: https://search.rsl.ru/ru/record/01008059557
12. Светлаков В.И. О выборе критерия развития пространственно-территориальной системы // International Agricultural Journal. 2024. № 67 (4). С. 1284–1299. DOI: 10.55186/25880209_2024_8_4_10. EDN QQYIJP. URL: https://qje.su/ru/storage/download/218906
13. Svetlakov V.I., Mokhov A.I., Mokhova L.A., Borovoy E.A. The Models of Integrated Area Renovation // International Journal of Psychosocial Rehabilitation. 2020. No. 24 (3). Pp. 2883–2904. DOI: 10.37200/IJPR/V24I3/PR2020323. EDN SCCVNZ. URL: https://www.psychosocial.com/index.php/ijpr/article/view/3496
14. Алексеев В.Н., Ермилов В.Г. Инвестиционный климат Москвы: отдельные аспекты // Финансы и кредит. 2010. № 13 (397). С. 2–6. EDN LARMNV.
15. Мохов А.И., Минаев В.А., Фаддеев А.О. Системная интеграция BIM-технологий и моделей геодинамических рисков в строительной сфере // Управление развитием территории. 2016. № 1. С. 54–58. EDN YUXQEO.
16. Силуянов А.В., Латышев Г.В., Латышев К.В., Мохов А.И. Комплексотехника переустройства систем автоматизации «интеллектуального здания» // Электротехнические и информационные комплексы и системы. 2012. № 8 (1). С. 10–13. EDN OPFDHZ.
17. Мохов А.И., Теодорович Н.Н., Латышев Г.В., Викулин Д.Ю. Переустройство интеллектуальных зданий // Управление инвестиционно-строительным и жилищно-коммунальным

комплексами : Междунар. сб. науч. тр. / под ред. д-ра техн. наук, проф. В.О. Чулкова. М. : МГ АКХИС, 2010. С. 277–285.
18. Быстров А.В., Светлаков В.И., Бойкова И.В. Ресурсы технологической платформы в составе комплексного объекта переустройства территорий // Современные проблемы управления проектами в инвестиционно-строительной сфере и природопользовании : мат. VII Междунар. науч.-практ. конф. М. : ФГБОУ ВО «РЭУ им. Г.В. Плеханова», 2017. С. 287–291. EDN YMTSQP.

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Selection of rational technical solutions for the repair of residential buildings

The unsatisfactory technical condition of the majority of apartment buildings is explained by the fact that most of them were constructed during the period of rapid housing development (from the early 1960s to the late 1970s of the 20th century), the main objective of which was to erect buildings in the shortest possible time with minimal financial and material resources. This inevitably affected the quality of buildings, since inexpensive, low-quality, and short-lived materials were used in their construction. Moreover, the wide range of normative (design) service lives of the main structures, elements, and systems implies the need for their almost continuous repair or replacement. At present, virtually all apartment buildings erected during the period of mass industrial housing construction are included in regional programmes for the capital repair of common property in apartment buildings. In this context, the selection of technical solutions for capital repairs is of critical importance, particularly those that involve the use of materials and products with design service lives corresponding to the residual service lives of non-replaceable elements. The paper presents a methodology developed by the authors for determining the residual resource (residual service life) of structures, elements, and systems of residential buildings.
Keywords: *normative service life, residual resource, gamma-percent residual resource, capital repair, apartment buildings*

One of the key factors determining the unsatisfactory technical condition of a significant part of the housing stock in the Russian Federation is the heterogeneity of structural reliability, caused by the different normative service lives of individual structures, elements, and engineering systems that together form a building as an integrated object. During operation, these components are subjected to unequal loads and environmental impacts, which leads to uneven wear and premature deterioration of the performance characteristics of certain parts of the building.

Current regulatory and technical documents establish design (normative) service lives for the main structural elements and engineering systems of residential buildings. At the same time, the values of normative durability vary significantly depending on the functional purpose of the elements, the materials used, and operating conditions. The discrepancy between the actual service lives of individual systems and their normative values often necessitates repair works of varying levels of complexity.

Information on the normative service lives of structures, elements, and engineering systems of residential buildings, as regulated by current standards, is partially presented in Table [1–3].

In practice, the established normative service lives often differ significantly from the actual service lives [4]. This is due to the fact that normative durability indicators are usually determined under laboratory conditions during the development and preparation of new materials and products for industrial production. In the course of such tests, real operating conditions of buildings are not always fully taken into account, including the effects of climatic factors, operational loads, installation specifics, and the level of technical maintenance. This leads to discrepancies between design and actual durability indicators. As a rule, these values are obtained using accelerated aging methods. In this case, testing is carried out under ideal conditions in climatic chambers, excluding the influence of external factors characteristic of real operation, where the actual service lives of the same material or product may differ even within a single building [5].

Such a variation in the normative service lives of structures, elements, and systems is explained by two main factors: the intention to reduce construction costs during the period of mass housing development and the lack of technological capabilities at domestic construction industry enterprises to

Normative (Design) Service Lives of Selected Structures, Elements, and Systems of Residential Buildings of Capital Group II

Name of the structure (element, system)	Normative (Design) Service Life, years
Precast and cast-in-place reinforced concrete foundations	200
Reinforced concrete exterior walls	125
Precast reinforced concrete interstory floors	150
Floors: • parquet; • linoleum	 50 10...15
Roofs: • roll roofing made of roofing felt; • roofing steel (carbon steel); • galvanized roofing steel	 10…12 20 50
Heating systems (piping and heating devices)	40
Water supply systems (excluding shut-off and mixing valves)	15
Ceramic sanitary fixtures	20
Interior plaster	40



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produce high-quality and durable materials and products [6]. At the same time, it is well known that the main direction for improving technical solutions is the minimization of the dispersion of normative service lives of individual structures, elements, and systems, that is, when:

$$\sigma_{sl} = \sqrt{\sum_i \left(S_i - T_{sl}\right)^2 d_i} \rightarrow \min, \quad (1)$$

where S_i — is the normative averaged service life of the i-th element (structure or system); T_{sl} — is the average service life of the element (structure or system) based on statistical observation data; d_i — the share of the replacement cost of the i-th element (structure or system) in the total replacement cost of the building [7]:

$$T_{sl} = \sum_i S_i d_i. \quad (2)$$

Apartment buildings included in the current regional programmes for the capital repair of common property, with a total area estimated at approximately 2 billion m^2, were in the vast majority of cases constructed without taking into account modern requirements for the durability of structures and the coordination of service lives of individual elements and engineering systems [8]. During the period of their construction, priority was generally given to reducing construction time and costs, which subsequently led to accelerated wear of certain structural and engineering components and the need for capital repairs.

However, when carrying out capital repairs, materials, elements, and structures are used whose range today is virtually unlimited, often without due consideration of the requirement for equal durability and without mandatory accounting for the residual resource of elements, structures, and systems that are not replaced during capital repair. It is evident that when elements (structures or systems) with a normative service life shorter than the residual resource (service life) of non-replaceable elements are used (which usually occurs in order to reduce repair costs), the effectiveness of the repair is significantly reduced. Conversely, the use of elements (structures or systems) with normative service lives exceeding the residual resource of non-replaceable elements leads to unproductive expenditures that unjustifiably increase the estimated cost of repairs.

This circumstance acquires particular significance in the context of implementing state policy in the field of capital repairs, since the overwhelming majority of regional programmes for the capital repair of common property in apartment buildings were developed and approved without proper consideration of the actual technical condition of the buildings included in these programmes. Such an approach initially reduces the validity of the planned repair measures and does not allow full consideration of the real needs of the housing stock for restoration and modernization.

It should be noted that current legislation on capital repairs provides for mandatory monitoring of the technical condition of apartment buildings, the results of which are intended to serve as the basis for the formation, revision, and updating of regional programmes. However, in practice, this mechanism is largely declarative in nature and does not ensure the acquisition of objective and reliable information regarding the actual condition of structural elements and engineering systems of buildings.

According to data from the Internet portal “Housing and Utilities Reform”, in 2014 — at the time when most regional capital repair programmes began to be implemented — comprehensive technical monitoring of apartment buildings was carried out in full in only 56 constituent entities of the Russian Federation. In most regions, however, reporting on monitoring activities was based not on comprehensive technical inspections of the actual condition of buildings, but on data from technical inventory authorities. Such information, as a rule, does not reflect the real level of physical deterioration of structures and engineering systems and therefore cannot be considered a reliable basis for managerial decision-making.

As a result, regional programmes for the capital repair of common property in apartment buildings developed in the absence of state technical accounting data and instrumental inspections inherently contain a high risk of inefficient use of budgetary and extrabudgetary funds allocated for capital repairs. This manifests itself both in the performance of excessive works not justified by the actual condition of buildings and in the underestimation of the need for timely repair of certain structural and engineering elements.

It should be emphasized that only three regional programmes — those of Perm Krai, Belgorod Region, and Chelyabinsk Region — explicitly state that the lists of works (services) for the capital repair of common property in apartment buildings must be determined based on the results of comprehensive inspections of the housing stock, with defect reports prepared for each individual building. In our view, this approach is the most justified and consistent with the objectives of ensuring the reliability and durability of buildings.

Thus, it follows that one of the key conditions for improving the effectiveness of regional capital repair programmes is an orientation toward the normative (design) service lives of structures, elements, engineering systems, and equipment of apartment buildings subject to capital repair, with mandatory consideration of their actual and residual service life. Only by adhering to this approach can rational allocation of capital repair funds and achievement of the required level of reliability of the housing stock be ensured.

The authors propose a methodology for selecting technical solutions for the capital repair of buildings that takes into account the residual resource of structures, elements, and systems that are not replaced during repair and construction works [9].

The residual resource of a building element (structure or engineering system) is understood as the portion of its operational life corresponding to the period from the moment of operation time τ to the transition to a limit state under normative operating conditions [10, 11]. This indicator reflects the potential duration of further reliable operation of the element after a certain period of use.

If the total operating time of an element (structure or system) from the start of operation to failure or transition to a limit state is denoted by ξ, then the value of the residual resource ξ_τ after an operating time τ can be determined as the difference between the total operating time and the actual time in service: $\xi_\tau = \xi - \tau$, provided that $\xi \geq \tau$.

For the quantitative assessment of the residual resource of building elements, special probabilistic indicators are used in reliability theory. In particular, it is recommended to apply the indicator of the mean residual resource $T(\tau)$, which represents the mathematical expectation of the residual resource value of an element after its operation for a time period τ[1] [12]. This indicator makes it possible to estimate the expected duration of further failure-free operation of the element.

[1] On determining the requirements for the procedure for determining the residual resource (service life) of the object of examination : Letter of Rostekhnadzor dated December 23, 2021 No. 11-00-15/15945. URL: https://www.consultant.ru/document/cons_doc_LAW_405324 (rus.).

Along with this, the indicator of the γ-percent residual resource $T_\gamma(\tau)$ is used. It is defined as the time interval counted from the moment τ during which an element that has operated without failure up to time τ retains its operable condition with probability γ [13]. The value of the γ-percent residual resource is determined from the following relationship:

$$\frac{P[\tau + T_\gamma(\tau)]}{P(\tau)} = \gamma, \quad (3)$$

where $P(\tau)$ is the probability of failure-free operation up to time τ.

If it is assumed that $P_\tau(t) = P(\tau + t)/P_\tau$ is the probability of failure-free operation of an element (structure or system) within the time interval $[\tau, \tau + t]$, then the mean residual resource can be expressed as:

$$T(\tau) = \int_\infty^0 P_\tau(t)dt \quad \text{or} \quad T(\tau) = \frac{1}{P_\tau(t)}\int_\infty^0 P_\tau(t)dt, \quad (4)$$

and the residual resource is determined as the root of the equation $P_\tau(t) = \gamma$ with respect to t (i.e., $t = T_\gamma(\tau)$) for a predetermined value of γ, which corresponds to the normative (design) service life.

The value of the mean residual resource of an element (structure or system) in this case is determined using the following expression, taking into account the reliability function $P(t) = e^{-2\sqrt{t}}$[2]:

$$T(\tau) = e^{-2\sqrt{t}}\int_0^\infty e^{-2\sqrt{t}}\,dt. \quad (5)$$

Since:

$$\int_0^\infty e^{-2\sqrt{t}}\,dt = \frac{1}{2}e^{-2\sqrt{t}}\left(1 + 2\sqrt{\tau}\right), \quad (6)$$

then

$$T(\tau) = \frac{1}{2}\left(t + 2\sqrt{\tau}\right). \quad (7)$$

The procedure for determining the γ-percent residual resource can be illustrated by the following example. Let us assume that γ = 90 % after a certain period of normative operation of a waterproofing layer made of asphalt mastic on a flat roof with a reinforced concrete base, that is, the value of the reliability function of the waterproofing layer is γ = 0.9. The normative (design) service life of the waterproofing layer is approximately 7 years (2,500 days).

In this case, the failure-free operating time of the coating is determined from the expression:

$$P_\tau(t) \equiv e^{-\sqrt{\tau+1}-\sqrt{\tau}} = 0.9.$$

It follows that for a given normative (design) service life of the waterproofing layer and a given reliability level $\sqrt{\tau+1}-\sqrt{\tau} = 0.10536$, solving the equation with respect to t yields the value $T_{90}(t) = 11.5$.

Thus, the residual resource and the γ-percent residual resource can be determined using the following relationships:

$$T(\tau) \geq \frac{T - \tau}{P_\tau}; \quad (8)$$

$$T_\gamma(\tau) \geq T_\gamma - \tau. \quad (9)$$

After determining the residual resource of all elements, structures, and systems that are not replaced during capital repair, materials and products are selected for replacement such that their normative (design) service life does not exceed the residual resource of the non-replaceable elements, structures, and systems, while ensuring a guaranteed reliability level of the renovated building[3].

REFERENCES

1. Kolotilkin B.M. Durability of Residential Buildings. Moscow, Stroyizdat, 1965; 250. URL: https://search.rsl.ru/ru/record/01006314103 (rus.).
2. Pogorelov S.N., Semenyak G.S., Ulrikh D.V. Technical Operation of Buildings and Structures : a tutorial. Chelyabinsk, South Ural State University Publishing Centre, 2019; 126. URL: https://rusneb.ru/catalog/000199_000009_010319964 (rus.).
3. Kasimov R.G. Defects and damage to building structures, methods and devices for their quantitative and qualitative assessment : a tutorial. Orenburg, OSU, 2016; 109. URL: https://elib.osu.ru/handle/123456789/13160 (rus.).
4. Roytman A.G. Reliability of structures of operated buildings. Moscow, Stroyizdat, 1985; 175. URL: https://search.rsl.ru/ru/record/01001285199 (rus.).
5. Shmelev G.D., Ishkov A.N., Vorobyova Yu.A. Technical examination of civil engineering structures : Study guide. Voronezh, Voronezh State University of Architecture and Civil Engineering, 2011; 66. EDN VTNNGZ. (rus.).
6. Oleinik S.P. Scientific Foundations of Construction Waste Management : diss. Doc. of Engineering Sciences. Moscow, 2006; 384. URL: https://rusneb.ru/catalog/010003_000061_36a5dedbc4c5c9de4c834ebec6ff839d/ (rus.).
7. Roitman A.G., Smolenskaya N.G. Repair and reconstruction of residential and public buildings. Moscow, Stroyizdat, 1978; 319. URL: https://rusneb.ru/catalog/000200_000018_rc_2218386 (rus.).
8. Shreiber K.K. Major repairs of common property in apartment buildings — problems and solutions : monograph. Moscow, ASV, 2021; 399. URL: https://search.rsl.ru/ru/record/01011160347 (rus.).
9. Shreiber K.A. Construction and operation of buildings and structures: conceptual approaches : monograph. Moscow, ASV, 2023; 119. URL: https://rusneb.ru/catalog/000199_000009_011818137 (rus.).
10. Kanunnikov A.V., Buzalo N.A. The concept of residual service life of the buildings at the examination of industrial safety. Construction and Architecture. 2019; 7(4):19-24. DOI: 10.29039/2308-0191-2019-7-4-19-24. EDN QMWBCZ. (rus.).
11. Gavrilyev I.M., Korolkov D.I., Gravit M.V. Modified method for calculating residual resource using exponential distribution. The Eurasian Science Journal. 2019; 11(2):61. EDN LTUESO. (rus.).
12. Pravikov Yu.M., Muslina G.R. Fundamentals of the Theory of Reliability of Technical Processes in Mechanical Engineering : a tutorial. Ulyanovsk, UlSTU, 2015; 122. EDN CONBJD. (rus.).
13. Pelenko V.V., Verkholantsev A.A., Nechitailov V.V. Reliability of electric and thermal energy production systems : textbook. St. Petersburg, Higher School of Electrical Engineering, St. Petersburg State University of Industrial Technologies, 2023; 75.

[2] GOST R 27.002–2009. National Standard of the Russian Federation. Dependability in Engineering. Terms and Definitions. URL: National Standard of the Russian Federation (rus.).

[3] GOST R 54257–2010. National Standard of the Russian Federation. Reliability of Building Structures and Foundations. Basic Provisions and Requirements. URL: https://docs.cntd.ru/document/1200083899 (rus.).

Выбор рациональных технических решений при ремонте жилых зданий

Неудовлетворительное техническое состояние большинства многоквартирных домов объясняется тем, что большая их часть была построена в период скоростного жилищного строительства (начало 60-х – конец 70-х гг. XX в.), основными задачами которого было возводить здания в кратчайшие сроки с минимальными затратами финансовых и материально-технических ресурсов. Это не могло не сказаться на качестве зданий, поскольку для их возведения использовались дешевые, низкокачественные и недолговечные материалы, а разброс значений нормативных (расчетных) сроков службы основных конструкций, элементов и систем настолько велик, что предполагает практически постоянный их ремонт или замену. В настоящее время практически все многоквартирные дома, возведенные в период массового индустриального жилищного строительства, включены в региональные программы капитального ремонта общего имущества в многоквартирных домах, и принципиальное значение имеет выбор при проведении капитального ремонта таких технических решений, которые предусматривали бы применение материалов и изделий с расчетными сроками службы, адекватными остаточным срокам службы несменяемых элементов. В статье излагается разработанная авторами методика определения остаточного ресурса (остаточного срока службы) конструкций, элементов и систем жилых зданий.

Ключевые слова: *нормативный срок службы, остаточный ресурс, гамма-процентный остаточный ресурс, капитальный ремонт, многоквартирные дома*

СПИСОК ИСТОЧНИКОВ

1. Колотилкин Б.М. Долговечность жилых зданий. М. : Стройиздат, 1965. 254 с. URL: https://search.rsl.ru/ru/record/01006314103
2. Погорелов С.Н., Семеняк Г.С., Ульрих Д.В. Техническая эксплуатация зданий и сооружений : уч. пос. Челябинск : Издательский центр ЮУрГУ, 2019. 126 с. URL: https://rusneb.ru/catalog/000199_000009_010319964
3. Касимов Р.Г. Дефекты и повреждения строительных конструкций, методы и приборы для их количественной и качественной оценки : уч. пос. Оренбург : ОГУ, 2016. 109 с. URL: https://elib.osu.ru/handle/123456789/13160
4. Ройтман А.Г. Надежность конструкций эксплуатируемых зданий. М. : Стройиздат, 1985. 175 с. URL: https://search.rsl.ru/ru/record/01001285199
5. Шмелёв Г.Д., Ишков А.Н., Воробьёва Ю.А. Техническая экспертиза строительных конструкций гражданских зданий : уч. пос. Воронеж : Воронежский ГАСУ, 2011. 66 с. EDN VTNNGZ.
6. Олейник С.П. Научные основы управления строительными отходами. М., 2006. 384 с. URL: https://rusneb.ru/catalog/010003_000061_36a5dedbc4c5c9de4c834ebec6ff839d/
7. Ройтман А.Г., Смоленская Н.Г. Ремонт и реконструкция жилых и общественных зданий. М. : Стройиздат, 1978. 319 с. URL: https://rusneb.ru/catalog/000200_000018_rc_2218386/
8. Шрейбер К.К. Капитальный ремонт общего имущества в многоквартирных домах: проблемы и решения : монография. М. : АСВ, 2021. 399 с. URL: https://search.rsl.ru/ru/record/01011160347
9. Шрейбер К.А. Возведение и эксплуатация зданий и сооружений: концептуальные подходы : монография. М. : АСВ, 2023. 119 с. URL: https://rusneb.ru/catalog/000199_000009_011818137/
10. Канунников А.В., Бузало Н.А. Понятие остаточного срока службы зданий при проведении экспертизы промышленной безопасности // Строительство и архитектура. 2019. № 7 (4). С. 19–24. DOI: 10.29039/2308-0191-2019-7-4-19-24. EDN QMWBCZ.
11. Гаврильев И.М., Корольков Д.И., Гравит М.В. Модифицированная методика расчета остаточного ресурса с использованием экспоненциального распределения // Вестник Евразийской науки. 2019. № 11 (2). С. 61. EDN LTUESO.
12. Правиков Ю.М., Муслина Г.Р. Основы теории надежности технических процессов в машиностроении : уч. пос. Ульяновск : УлГТУ, 2015. 122 с. EDN CONBJD.
13. Пеленко В.В., Верхоланцев А.А., Нечитайлов В.В. Надежность систем производства электрической и тепловой энергии : уч. пос. СПб. : ВШТЭ СПбГУПТД, 2023. 75 с.

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Formation of initial data for functional models of university campus dormitories

The role of dormitories in modern university campuses is constantly increasing. The requirements for them are expanding and becoming more complex not only as a living environment but also as a functional environment. In this regard, the problem of assessing the quality of the functional structure of dormitories is no less relevant in comparison with other university campuses. Modern student dormitories in the structure of university campuses cease to perform exclusively the function of accommodation and become part of the educational, research and social ecosystem. However, the evaluation of their design solutions is still carried out mainly at the stage of formed spatial planning solutions and is based on technical and economic indicators and regulatory verification. In this article, the authors continue to consider the functional approach to the formation and evaluation of university campuses, in particular dormitories, as their mandatory elements. Within the framework of the functional approach, dormitory buildings are considered as systems of functional modules (living cell, kitchen, public spaces, floor, etc.) having calculable parameters and criteria. As a tool for identifying lists of such parameters and their values, the use of a qualimetric methodology based on user satisfaction criteria in the range from 0 to 100 is proposed. The proposed approach makes it possible to evaluate the functional models being developed at the pre-design stage and form spatial planning solutions based on an integral satisfaction indicator, and not just regulatory compliance. The methodology can be integrated into digital information models of dormitory buildings and used in the development of campus programmes and strategies for the development of university infrastructure.
Keywords: *functional model, qualimetric analysis, university dormitories, campuses, material and spatial environment, satisfaction level*



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INTRODUCTION

University campuses, which are being created and developing in the face of modern challenges, are increasingly coming to the need to combine several leading functions in a single space. University dormitories are no exception here. First of all, they become an extension of the educational environment. When it comes to dormitories for graduate students, doctoral students and teachers, it is often also a continuation of the environment of scientific activity. The number of students and teachers involved in startups and technology entrepreneurship projects is growing. And some of the work from them is also transferred to the walls of dormitories.

All universities strive to be a platform for the student, scientific and cultural community. They cultivate the desire for sports and creativity. And for several years they want to be not only a cozy and safe, but also a functional home for several thousand people, most of whom are undergoing personality development during this period. To do this, campus dormitories, among others, must have an extremely well-developed and balanced functional model that allows them to link diverse and diverse functional processes in one material and spatial environment (hereinafter referred to as MSE) and ensure their further development. The existing fund of student dormitories in Russia is represented quite widely and in various ways, however, even newly opened dormitories are often designed according to the model of the last century, which is characterized by a low level of individualization, low functionality of residential cells, lack of common spaces for communication and project areas, etc. It should also be noted that both the spaces and the technical capabilities of existing dormitories often do not provide sufficient opportunities for working with electronic resources, working in a digital environment, teamwork, viewing educational content and online communication. Dormitories for students and workers are often built according to the same standard designs, and do not take into account the specifics of modern scientific and educational work. All of the factors above negatively affect campus infrastructure satisfaction in general and reduce student engagement in education and science. The lowest indicators of Russian universities are safety, pollution levels and the desire to study in the city [1].

As part of the research on student campuses, significant unproductive time spent by university residents on transitions related to the remote location of various groups of rooms and disadvantages of zoning, low functionality and poor adaptability of most spaces have been identified. We must not forget that the regulatory and legal context of the creation of campuses is still represented by a number of contradictions. The contradiction between the current regulatory requirements and the innovative nature of the settlement[1]. The contradiction between technical requirements and modern technological achievements, which were supposed to be implemented, etc. It is obvious that it is functional modeling and subsequent consideration of the characteristics of functional processes in dormitories that will further form a modern approach to their creation and

[1] City University or Country Campus: Prospects, Limitations, and Consequences for Russian Universities Using the Example of St. Petersburg State University. URL: https://www.pltf.ru/issledovaniya/gorodskoj-universitet-ili-zagorodnyj-kampus-perspektivy-ogranicheniya-i-posledstviya-dlya-rossijskih-universitetov-na-primere-sankt-peterburgskogo-gosudarstvennogo-universiteta (rus.).

development through a proper approach to their design, construction and operation [2].

THE FUNCTIONAL MODEL OF THE DORMITORY

Today, the dormitories of major foreign and Russian universities, such as FEFU, KGEU, MIT, Tietgen Dormitory and others, are characterized by a variety of public spaces in the infrastructure of dormitory buildings, as well as an active social life. As part of their development and modernization, they strive to provide for the effectiveness and variability of the placement of functional zones of periodic and episodic implementation, taking into account their specifics, and to organize an integrated spatial organization of the territory in a special way.

But fundamentally, the functional composition of any dormitory consists of four interrelated types of spaces (Fig. 1). All four types of spaces are present in every dormitory, regardless of size, only their composition and area change. The presence, parameters and interaction of these spaces ensures the full functioning of the dormitory [3].

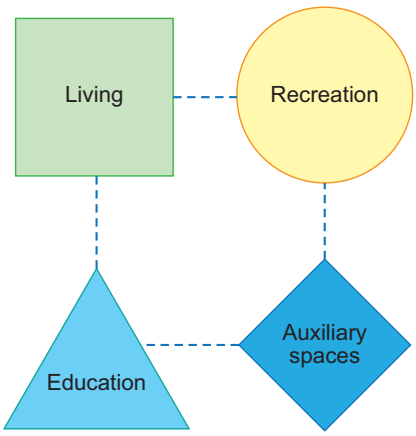


Fig. 1. The dormitory functional composition

Accommodation is the basic function of the dormitory. These are spaces that provide a comfortable sleep and lifestyle for students, graduate students, teachers, and staff living on campus. Their components are: household maintenance, storage, hygiene, cooking, nutrition, interactions, household activities, etc. Education is a space where students carry out independent learning tasks, project and team activities, participation in start — ups and scientific research, individual and collective work with multimedia, computing and other equipment. Leisure is a space that provides an opportunity for active and passive recreation, sports, as well as friendly communication. The leisure function can be implemented both at the level of a residential cell and in the public spaces of a dormitory. Administrative and service spaces are areas closed to public access and are necessary for: dormitory management, cleaning, security, inventory storage, and technical operation. The first three groups, as implementing basic functions, can be classified according to the degree of individualization into the following functional zones:

1. Residential blocks: characterized by the permanent residence of a specific group of students, combine the functional areas necessary for living, welfare and education.

2. Residential floors: combine several residential blocks with public spaces (depending on the spatial layout of the building). They can combine common areas for household maintenance, leisure and education, accessible to all residents of the floor, as well as rooms for the management and operation of the dormitory.

3. Common areas of the dormitory, accessible to all residents (usually the ground floors). The service areas of everyday life, storage, leisure activities, self-training, and dormitory management are combined.

Combinations and parameters of functional areas should correspond to the category of residents. In order to increase satisfaction with dormitory spaces, it is advisable to take into account the variability of residents' requests and ensure versatility when forming a functional model of the campus and in the subsequent design of dormitory spaces. For example, for bachelors, it is recommended to combine living rooms into blocks with a common kitchen and dining area, a social area or a living room [4]. And it is advisable to place a coworking space on each residential floor or even in a block if the block unites more than 3 residential cells. A higher level of individualization is recommended for undergraduates and postgraduates, when a kitchen-niche and an independent communication area are provided in a residential cell. In all cases, it can be considered effective to place different types of categories of students on the same floor to create conditions for the transfer of experience and the formation of inter-faculty startups and joint projects of students and graduate students [5].

It follows from the above that the formation of an effective functional model of a dormitory is influenced by the category of residents, the sets of zones and spaces, the level of technological equipment, the parameters of engineering and low-current systems. Of course, we must not forget about the parameters of the microclimate (natural lighting, humidity conditions, air exchange, acoustics, sound insulation) and the level of decoration. But in this approach, the functional model has an “as is” format and is based on architectural, construction and engineering solutions. The correct format of the model is the “as it should be” format, reflecting the condition, capabilities and effectiveness of dormitories in the future. And if such a “correct format” for the university's research and educational environment is best represented by its management and leading staff, then for dormitories, such a format is better represented by its users. Architectural, construction, engineering, engineering, technological and other requirements for subsequent design solutions should be focused on their functional tasks. With their help, the conditions for ensuring the parameters of the material and spatial environment of the campus are determined [6].

THE METHODOLOGY OF QUALIMETRIC ASSESSMENT

To solve a number of tasks related to the search and systematization of criteria and their combinations that have the greatest impact on user satisfaction in university dormitories, the authors applied qualimetric analysis. It is a method of quantifying the quality of objects and processes based on a system of criteria (properties) and their weight significance. It allows you to express quality as an integral quantity (index), taking into account both quantitative and qualitative parameters [7]. In this article, the authors have displayed the methodology and results of applying qualimetric analysis to assess the satisfaction of the student dormitory environment. This allows us to take into account such criteria that establish a link with satisfaction as: subjective perception of privacy; level of social comfort; convenience of logistics; quality of recreational spaces; balance of individual and public areas. The necessary and reasonable parameters of a dormitory can be formed as part of the preparation of its functional model and the campus model. And the architect will

begin the process of functional zoning and preparation of spatial planning solutions with clear tasks, and maybe even checklists, in which the university, as a functional customer, will characterize the environment he needs. But today, to evaluate the design solutions of buildings, first of all, technical and economic indicators are used, which help to draw a conclusion about the rational use of the volumes and areas of the future facility. However, in this format, as research shows[2], future users of the building — students, teachers — cannot evaluate the quality indicators of the MSE, such as the presence of certain zones, ease of navigation, and the relative location of spaces. Some of these indicators can be described quantitatively, but for most criteria a categorical assessment is applicable (for example, "yes/no"). According to the Standard of innovative educational environment (campuses): "The level of satisfaction with the quality of services provided by dormitories is at least 75 % of user satisfaction"[3]. The criteria for evaluating the IPU at the design decision stage, including compactness, functionality, ergonomics, and safety, can be expressed through satisfaction with the design solution on a scale from 1 to 100 points.

Accordingly, the task of the assessment will be to select the optimal functional model and design solution based on the satisfaction assessment.

This complex indicator depends on a number of properties that need to be determined. Each property has its own weighting coefficients, which are used to determine the relative values of properties. Their sum gives an overall assessment of the integral indicator of satisfaction with the housing and communal services of dormitories.

The numerical value of the weighting coefficient can be obtained by two methods: analytical and expert. Despite the fact that according to the rule of qualimetry, it is necessary to give preference to the analytical method [8], in the absence of statistical data, the expert method of weight assessment was chosen in the work.

The expert assessment is based on the analysis of data on student satisfaction with the university infrastructure: these are research data, student reviews in open sources (on the Internet).

In the proposed approach: the dormitory is represented as a set of functional modules; each module is described by a system of parameters; for each parameter, regulatory requirements are fixed according to Russian normative documentation[4].

Next, a list of properties that affect satisfaction is formed, which are classified into the following property groups:

- area and interconnection of functional modules;
- functional zoning and spatial structure;
- accessibility and privacy, comfort;
- equipment and flexibility of use.

The weighting coefficient G_i is determined by the expert method for each group of properties. Within the framework of this study, the specific area of functional zones, in terms of one student, has the greatest weight (45 %). Since it is precisely the lack of space that often leads to a low assessment of student satisfaction with MSE. The next most important group of properties (40 %) is the qualitative zoning of the dormitory, which determines the presence, number

[2] University Campuses and the City: Cooperation for Competitiveness. Center for Strategic Research. URL: https://www.csr.ru/ru/research/universitetskie-kampusy-i-gorod-kooperatsiya-radi-konkurentosposobnosti (rus.).

[3] Standard of innovative educational environment (campuses). URL: https://прокампус.рф/documents/download?id=43 (rus.).

[4] SR 118.13330.2022. Public Buildings and Structures. SNiP 31-06–2009. URL: https://www.minstroyrf.gov.ru/docs/223331; SR 379.1325800.2020. Buildings of dormitories. Rules of design Rules. URL: https://docs.cntd.ru/document/603252625 (rus.).

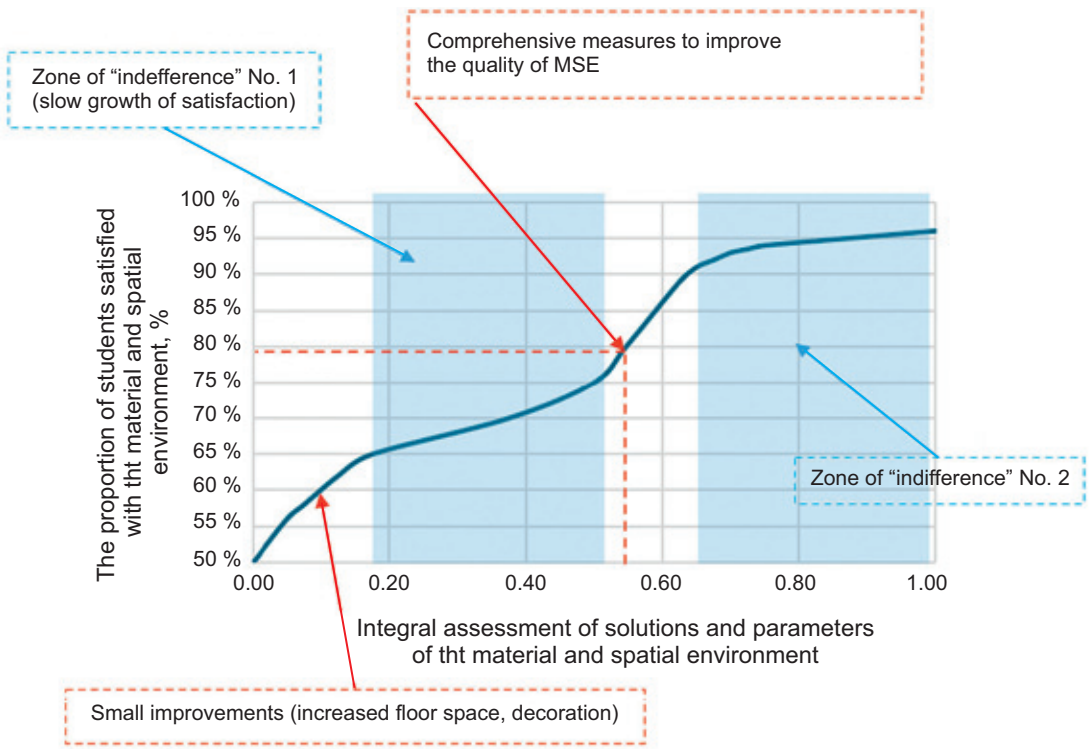


Fig. 2. The dependence of the growth of student satisfaction with the material and spatial environment of the campus on the integral assessment of satisfaction by qualimetric calculation

and proportion of various zones in the functional model of the dormitory. It is proposed to focus the remaining 15 % of the weight on accessibility of the environment for people with disabilities, as well as taking into account the needs of various groups of residents (junior/senior students, graduate students, teachers, couples with children, international students) [9], as well as on the quality of equipment (furniture, equipment, sockets, Internet, etc.) MSE.

The next step to evaluate the objects of qualimetric analysis according to the proposed quality assessment methodology is to determine the minimum allowable or "defective" values. For properties q, these indicators are denoted by q_{def}. There are two methods for determining these values: documentary and expert. The first one is based on the indicators of existing regulatory documents. The expert method is used when it is inappropriate or impossible to use the documentary method [8]. Based on open data on student satisfaction with modern student dormitories in Russia and abroad, the authors have derived the recommended values of the MSE parameters, which correspond to a high satisfaction value. Based on these data, a functional dormitory model with optimal values of q_{i1} properties was formed. For each property, the relative property index K_{i1} was determined using the formula 1:

$$K_i = \frac{q_i - q_{def}}{q_i}. \quad (1)$$

The values were compared with the relative property index K_{i2}, corresponding to the second functional model (functional model No. 2) of the dormitory, formed according to the relevant regulatory and technical requirements and recommendations.

Then, for each property, the satisfaction value was determined using the formula 2:

$$U_i = K_i \cdot G_i. \quad (2)$$

The integral satisfaction index of the student dormitory for each functional model was determined by the formula 3:

$$U = \Sigma U_i = \Sigma K_i \cdot G_i. \quad (3).$$

Within the framework of the conducted research, the factors and conditions determining the dependence of the growth of student satisfaction with the material and spatial environment of the campus on the integral assessment of satisfaction (Fig. 2) have been established. It was also found that the assessment of the satisfaction of MSE with properties corresponding to the high assessment of students exceeded the value obtained for functional model 2 by 53 %.

A preliminary analysis of the dependence obtained makes it possible to make an assumption that increasing the satisfaction of dormitory users by improving the parameters of the housing and communal services on an ongoing basis is ineffective, since, for example, there are some "zones of indifference" when improving properties does not bring a significant increase in satisfaction. Thus, a slight improvement in the relatively minimal possible conditions is significant, further improvement is accompanied by a slow increase in satisfaction, and when certain high-quality indicators of MSE are achieved, satisfaction practically ceases to grow. This observation needs further research, as it allows us to identify the optimal values of the MSE parameters.

CONCLUSIONS

The traditional assessment of dormitories is based on: availability of space, optimal capacity, level of sanitary conditions, and other values. As such studies and student surveys show, compliance with regulatory requirements does not always ensure high satisfaction with the environment. Against this background, the qualimetric analysis made it possible to take into account the spatial structure of dormitories, the interrelation of functional modules, accessibility, comfort, socialization opportunities, flexibility of use, and psychological perception of the environment. The satisfaction indicator can and should be determined at the stage of functional modeling, when comparing alternative models to select the optimal MSE for the future dormitory. Then, this will make it possible to form spatial planning solutions based on an assessment of the quality of the functional structure, and not just regulatory requirements.

REFERENCES

1. Remizova T.S., Alaev A.A. World-class university campuses as a new form of organization of educational spaces in the territory of the Russian Federation. Journal University Management: Practice and Analysis. 2023; 27(2):101-115. DOI: 10.15826/umpa.2023.02.016. EDN UJTFED. (rus.).
2. Zheblienok N.N., Likhacheva L.A., Malinina S.V. Cooperation of the city and the campus in the space of the existing and new urban areas. Architecture and Modern Information Technologies. 2024; 4(69):223-238. DOI: 10.24412/1998-4839-2024-4-223-238. EDN BSZBWX. (rus.).
3. Popov A.V. The Concept of Architectural Development of University Campuses in Russia : Dissertation for the Degree of Doctor of Architecture. Nizhny Novgorod, 2022; 622. EDN EQZLUD. (rus.).
4. Wanqi L., Bolotova E.L. Assessment of future teachers' satisfaction with the conditions for the implementation of Russian-Chinese joint educational programs. Perspectives of Science and Education. 2021; 5(53):110-124. EDN IXURZU. (rus.).
5. Zvonov I.A., Kashirina N.V., Molchina N.A. Educational and technological conditions as a factor of university environment development. Real Estate: Economics, Management. 2024; 1:63-66. DOI: 10.22337/2073-8412-2024-1-63-66. EDN CDZOTD.
6. Zvonov I.A. Prospects for the application of functional requirements models in the creation of university campuses. Real Estate: Economics, Management. 2025; 4:148-153. URL: https://n-eu.iasv.ru/index.php/neu/issue/view/39/50
7. Azgaldov G.G. Qualimetry in architectural and construction design. Moscow, Stroyizdat, 1989; 264. EDN PNRQPN. (rus.).
8. Zhuzhnevsky D.L., Dvortsova A.S. Formation of a methodology for assessing design solutions for higher education facilities using the example of an educational center in Kogalym. Days of Student Science : Collection of reports from the scientific and technical conference based on the results of research at the Institute of Economics and Management of the National Research University Moscow State University of Civil Engineering. Moscow, National Research University Moscow State University of Civil Engineering, 2024; 666-669. EDN CPSNIQ. (rus.).
9. Popov A.V., Golubeva A.A., Sergeeva I.A., Starkova A.A. Transformation of requirements for the design of university campuses in modern conditions. Housing construction. 2024; 5:35-41. DOI: 10.31659/0044-4472-2024-5-35-41. EDN THXCCW. (rus.).
10. Molchina N.A. Evaluation of indoorlighting environment based on satisfaction criteria: parameters of daylighting for functional and visual comfort. Light & Engineering. 2025; 33(6):54-60. DOI: 10.33383/2025-053. EDN QFKTQR.

Формирование исходных данных для функциональных моделей общежитий университетских кампусов

Роль общежитий в современных университетских кампусах постоянно возрастает. Дополняются и усложняются требования к ним уже не как к среде проживания, а как к среде функционирования. В связи с этим проблема оценки качества функциональной структуры общежитий не менее актуальна в сравнении с другими объектами университетских кампусов. Современные студенческие общежития в структуре университетских кампусов перестают выполнять исключительно функцию проживания и становятся частью образовательной, научно-исследовательской и социальной экосистемы. Однако оценка их проектных решений по-прежнему осуществляется преимущественно на стадии сформированных объемно-планировочных решений и основывается на технико-экономических показателях и нормативной проверке. В настоящей статье авторами продолжено рассмотрение функционального подхода к формированию и оценке объектов университетских кампусов, в частности общежитий, как их обязательных элементов. В рамках функционального подхода здания общежитий рассматриваются как системы функциональных модулей (жилая ячейка, кухня, общественные пространства, этаж и др.), имеющих исчисляемые параметры и критерии. Как инструмент выявления перечней таких параметров и их величин предлагается применение квалиметрической методики, основанной на критериях удовлетворенности пользователей в диапазоне от 0 до 100. Предложенный подход позволяет оценивать разрабатываемые функциональные модели на предпроектной стадии и формировать объемно-планировочные решения на основе интегрального показателя удовлетворенности, а не только нормативного соответствия. Методика может быть интегрирована в цифровые информационные модели зданий общежитий и использоваться при разработке кампусных программ и стратегий развития университетской инфраструктуры.

Ключевые слова: *функциональная модель, квалиметрический анализ, университетские общежития, кампусы, материально-пространственная среда, уровень удовлетворенности*

СПИСОК ИСТОЧНИКОВ

1. Ремизова Т.С., Алаев А.А. Университетские кампусы мирового уровня как новая форма организации образовательных пространств на территории Российской Федерации // Университетское управление: практика и анализ. 2023. № 27 (2). С. 101–115. DOI: 10.15826/umpa.2023.02.016. EDN UJTFED.
2. Жеблиенок Н.Н., Лихачева Л.А., Малинина С.В. Кооперация города и кампуса в пространстве существующего и нового города // Архитектура и современные информационные технологии. 2024. № 4 (69). С. 223–238. DOI: 10.24412/1998-4839-2024-4-223-238. EDN BSZBWX.
3. Попов А.В. Концепция архитектурного формирования кампусов вузов в России : дис. … д-ра арх. Нижний Новгород, 2022. 622 с. EDN EQZLUD.
4. Ваньци Л., Болотова Е.Л. Оценка удовлетворенности будущих педагогов условиями реализации российско-китайских совместных образовательных программ // Перспективы науки и образования. 2021. № 5 (53). С. 110–124. DOI: 10.32744/pse.2021.5.8. EDN IXURZU.
5. Звонов И.А., Каширина Н.В., Молчина Н.А. Образовательно-технологические условия как фактор развития университетской среды // Недвижимость: экономика, управление. 2024. № 1. С. 63–66. DOI: 10.22337/2073-8412-2024-1-63-66. EDN CDZOTD.
6. Звонов И.А. Перспективы применения моделей функциональных требований при создании университетских кампусов // Недвижимость: экономика, управление. 2025. № 4. С. 148–153. URL: https://n-eu.iasv.ru/index.php/neu/issue/view/39/50
7. Азгальдов Г.Г. Квалиметрия в архитектурно-строительном проектировании. М. : Стройиздат, 1989. 264 с. EDN PNRQPN.
8. Жужневский Д.Л., Дворцова А.С. Формирование методики оценки проектных решений объектов высшего образования на примере образовательного центра в г. Когалыме // Дни студенческой науки : сб. докл. науч.-техн. конф. по итогам НИРС ИЭУКСН НИУ МГСУ, Москва, 26 февраля 2024 года. М. : НИУ МГСУ, 2024. С. 666–669. EDN CPSNIQ.
9. Попов А.В., Голубева А.А., Сергеева И.А., Старкова А.А. Трансформация требований к проектированию университетских кампусов в современных условиях // Жилищное строительство. 2024. № 5. С. 35–41. DOI: 10.31659/0044-4472-2024-5-35-41. EDN THXCCW.
10. Molchina N.A. Evaluation of indoor lighting environment based on satisfaction criteria: parameters of daylighting for functional and visual comfort // Light & Engineering. 2025. No. 33 (6). Pp. 54–60. DOI: 10.33383/2025-053. EDN QFKTQR.

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Positive emergent effect in post-collapse building restoration systems

The paper examines the phenomenon of positive emergence within the synergistic system of construction and restoration works following building collapses caused by significant natural or man-made impacts. Emergence is defined as the manifestation of qualitatively new, previously unpredictable system properties leading to the enhanced performance of the object. The post-earthquake restoration of the Italian village of Venzone (1976) serves as a case study, demonstrating how a disaster can catalyze improvements in architectural integrity, functionality, and socio-economic value through adaptive reconstruction. A probabilistic-statistical model for predicting the Positive Emergence Effect (PEE) is developed, incorporating key influencing factors: project team competence, flexibility of design solutions, sufficiency of resources, and the architectural improvement potential of the project. Under favourable conditions, the baseline probability of PEE is estimated to exceed 17 %. The model is then refined by introducing the critical important risk factor of latent defects undetected during the initial technical survey. Accounting for this factor significantly reduces the predicted PEE probability, highlighting the paramount importance of comprehensive pre-project examination and uncertainty management. The practical value of the research lies in justifying adaptive project design and flexible management approaches to realize the emergent potential in post-collapse restoration. The proposed framework provides a basis for developing compensatory measures against unforeseen complications. The research concludes that a positive emergent effect should be considered a valuable target in reconstruction planning, capable of transforming a recovery process into an opportunity for holistic systemic enhancement of the building across technical, economic, and sociocultural dimensions.

Keywords: *emergence, post-collapse restoration works, synergy, probabilistic forecasting, flexibility of design solutions, hidden defects*



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INTRODUCTION

The execution of construction and restoration works (CRW) on buildings after sustained damage relies on clear planning, regulations, and standards. The issue of reviving cities after devastating military conflicts and natural disasters has been studied by P.P. Oleinik, A. Maaruf, E.V. Shcherbina, A. Belal and M. Hrasnica. Based on the results of the research work by B.F. Shirshikov and V.V. Akulich, it can be unequivocally concluded that CRW encompasses all types of general construction and specialized works and can have the character of either major repairs or reconstruction, depending on the degree of damage sustained. Some features of restoration works can be distinguished [1]:

- specific types of works with their own non-standard technology;
- the composition and scope of works depend on the spatial planning solutions of buildings and structures, the degree of their damage, the sequence of restoration works, and the concentration of restoration works on the object and within a group;
- the structure of CRW, its non-repeatability;
- the possibility of forming and operating specialized mobile mechanized columns for performing individual types of works by integrated teams;
- changes in the work structure, the ratio of specific weights of various types of works in the total volume of construction and installation works. The restoration of any building is sharply different from the work ratios in its new construction;
- the absence of standard and ready-made solutions, as well as all necessary regulations for CRW.

Under conditions of uncertainty arising from emergencies involving real estate objects, there is a need for rapid forecasting of the probability of possible scenarios, namely further consequences, both positive and negative, in terms of their impact on the object under consideration. Probabilistic forecasting is defined by the post-nonclassical scientific paradigm, which has become most relevant in modern society [2].

Construction and restoration work (CRW) collectively constitute a complex construction system, comprising various defined and variable parameters. The CRW organization system after a collapse is a typical synergistic system, characterized by its components such as a high degree of uncertainty, internal and external interactions, and the capacity for adaptation and self-organization. The application of synergy principles allows for more flexible and effective management of this complex process (Fig. 1).

Emergence in this context is understood as a qualitatively new property of a system arising from the interaction of its components, not initially embedded in the design. We will consider this effect from the perspective of old construction objects' systems acquiring, as a result of forced changes and modernization, new aggregate qualities.

Let's consider a vivid example of European experience in restoring an entire village after a natural disaster.

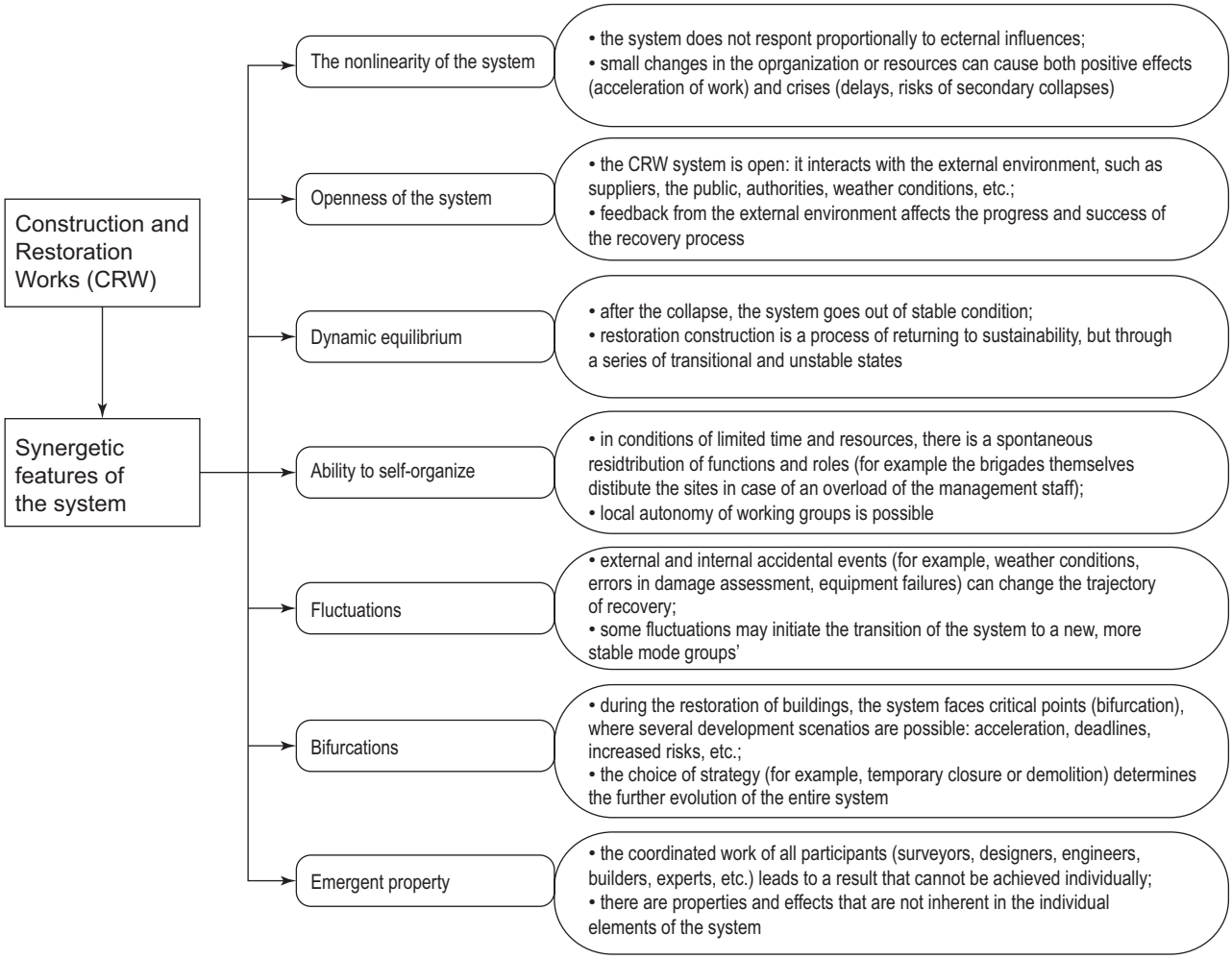


Fig. 1. Main features of synergy in the CRW organization system

THE VILLAGE OF VENZONE IN THE ITALIAN PROVINCE OF UDINE (HISTORICAL MUSEUM OF MUMMIES)

On May 6, 1976, a devastating earthquake occurred in the Friuli-Venezia Giulia region in northeastern Italy, completely destroying the village of Venzone in the province of Udine [3]. Large-scale restoration works of the village's historical buildings and architectural monuments began shortly thereafter. The city committee decided to reuse suitable stone fragments from the destroyed buildings in the restoration and construction. During the meticulous process of collecting and sorting stones, over 10,000 stones from the destroyed buildings were preserved, stored, and cataloged for reuse in reconstruction. The reconstruction of Venzone was completed in 1990. Today, it is hardly noticeable that most buildings were rebuilt in the last few decades [3].

The restoration of the historical buildings led to Venzone being recognized as the most beautiful village in Italy in 2017 based on the results of the national television competition "Il Borgo dei Borghi", surpassing 19 rival contenders. The winner received special recognition from the judges as the best example of architectural and artistic restoration after an earthquake[1].

In the reconstruction of Venzone, one can note the acquired positive emergent effect in the form of widespread global publicity after winning the competition, a significant increase in tourism levels, and the strengthening of the local economy (Fig. 2, 3)[2].

Unlike new construction design, the organization system, for example, for reconstruction after destruction, must possess properties of flexibility, creativity, and adaptation "on the go", which determines its viability. It is precisely under these conditions that the potential for positive emergence arises. The forecast of obtaining a positive effect can be calculated using statistical mathematical analysis.

The concept of emergence pertains to systems theory, defined by the rule "the holistic property of a system is greater than the sum of the properties of all its individual elements". The presence of generated properties specific to the system and not derivable from the known properties of the system's elements and the ways they are combined into subsystems is emergence [4, 5].

Experience in organizing construction works shows the emergent structure of relationships between elements and subsystems of each system. Subsystems cannot function autonomously; they interact in such a way that the properties of a subsystem depend on

[1] Venzone vince l'edizione 2017 Concorso "Borghi". Corriere della Sera. 17 aprile 2017. URL: https://www.corriere.it/cronache/17_aprile_17/venzone-vince-l-edizione-2017-concorso-borgo-borghi-032ab05c-236e-11e7-9fca-ec0025fa502c.shtml

[2] URL: https://new.unarussainitalia.ru/srednevekovyy-vencone-i-ego-muzey-mum.html



Fig. 2. Fountain in the square



Fig. 3. The main cathedral of Venzone

Table 1. Positive consequences of the emergent effect

Aspect	Before reconstruction	After reconstruction	Effect
Functionality	Outdated planning solutions	New public spaces, atrium, translucent structures	• the flexibility of the system of planning solutions and space, increasing the safety margin of building structures can significantly expand the possibilities of application and purpose of the building; • reduced load on heating and air conditioning systems contributes to a significant reduction in the size of engineering systems, consequently freeing up usable volume, and the systems themselves are easier to conceal; • the system of integrating modern materials into the historical foundation and design, considering current societal needs, allows achieving a high level of social significance
Energy Efficiency	Low	Enhanced by the use of the latest materials with an increased coefficient of heat transfer resistance	
Architectural expressiveness	Standardized historical	Integration of new materials and architectural solutions into the historical framework. A unique blend of old and new	
Structural strength	Heterogeneous, partially weakened	Reinforced with innovative materials	
Social significance and identity	Low level of importance, appearance is repulsive	The updated visual appearance acquires a unique symbiosis of qualities already historically familiar with the updated and modern, the level of social attractiveness is high	

the totality of interconnections with other elements and the quantitative measure of these interconnections. The actual operational parameters of an engineering structure (service life, maintenance costs, etc.) often diverge significantly from their design values, which were forecasted based on calculation schemes of individual subsystems and elements prior to their integration. The emergence of a system does not allow limiting oneself to studying its elements and the connections between them but also requires conducting a holistic analysis of the complex system. The patterns of generated (emergent) properties are the most complex to observe, qualify, quantify, and forecast, requiring constant monitoring of the system's lifecycle, analysis of all available information about the object, and the development of situational support for the system's development [4].

Key characteristics of the emergent effect:

- unpredictability: the inability to foresee at the design stage all positive and negative consequences for the implementation object;
- wholeness: the overall property of the system surpasses the sum of its components;
- contextuality: it depends on specific conditions (social, technical, environmental).

Also, it is necessary to highlight the possible positive consequences of the effect, indicated in Table 1.

We have defined the goals of such projects aimed at obtaining positive emergent effects, and to achieve any goal, specific tasks must be set. Regarding construction and restoration works, it is first necessary to consider the tasks that will be set at the stages of inspection and design [6].

The experience of post-disaster recovery, described in other studies, confirms and specifies the key conditions for the emergence of positive emergence in construction and restoration works (CRW). Analysis of works dedicated to damage assessment and reconstruction strategies shows that unpredictability and the necessity for adaptation are not obstacles, but potential sources of systemic improvements.

In the context of damage and hidden defect assessment, the study by M. Hrasnica (2019) emphasizes the unique complexity of inspecting historical masonry after wars and natural disasters, where a significant portion of critical damage may initially remain hidden [7]. In turn, the results of the work by Nestor M. et al. (2022), using the example of reinforced concrete columns damaged by explosions, show how combined impacts lead to complex, non-linear damages poorly amenable to standard assessment methods [8]. This illustrates the principle of wholeness and unpredictability of

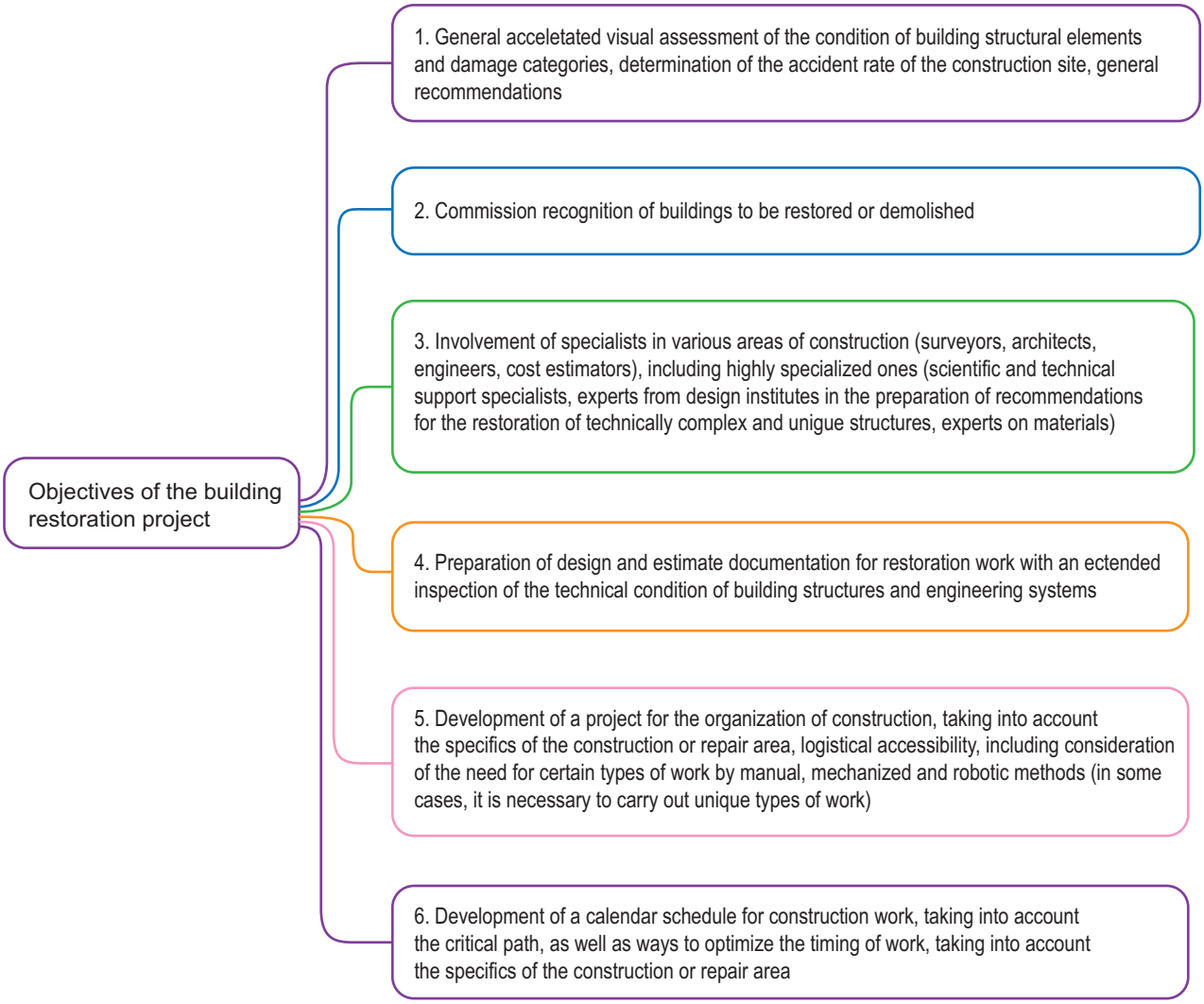


Fig. 4. Flowchart of main CRW (construction and restoration work) tasks

emergent systems, where the behavior of a damaged structure as a whole cannot be reduced to the simple sum of damages to its individual elements. This conclusion confirms the necessity for flexible design and the presence of a broad base of innovative solutions to adequately respond to the actual, and not just the projected, picture of destruction.

Speaking of the aspects of recovery planning and social adaptation, one cannot fail to mention the dissertation research by S. Kassouha (2020), which analyzes the application of post-war housing recovery methods from West Germany to contemporary Syria [9]. Its key finding is the impossibility of mechanically copying solutions without deep adaptation to local social, economic, and cultural conditions. This directly corresponds to the contextuality of the emergent effect and underscores the role of socio-technical interactions. Successful reconstruction leading to positive emergent results (as in the case of the village of Venzone) must consider the object not only as a physical structure but also as an element of a social system. Its restoration can become a catalyst for broader positive changes, taking into account the emergent historical specificities and identity of the CRW area [10, 11].

Thus, contemporary research in the field of damage assessment and recovery emphasizes three interconnected aspects critically important for realizing positive emergence in CRW:

- deep and iterative condition assessment, revealing hidden potential and risks;
- holistic engineering approach, accounting for non-linear interactions within the system of damages;
- adaptive socio-technical strategy, flexibly adjusting to varying situations.

The integration of these principles into the CRW organization system creates an environment where unforeseen circumstances are transformed from threats into opportunities for the evolutionary improvement of the object.

A post-collapse restoration project poses complex and unique tasks (Fig. 4).

These circumstances create an environment conducive to the emergent appearance of new architectural and engineering solutions. We can calculate the approximate probability of obtaining a positive result using mathematical models from statistics. By adapting statistical models to our case of CRW, we will introduce the necessary variables, calculate the probability of a positive emergent effect, and consider measures to compensate for such a non-primary factor as the presence of hidden defects not detected during the technical inspection.

CALCULATION OF THE PROBABILITY OF A POSITIVE EMERGENT EFFECT IN CONSTRUCTION USING THE EXAMPLE OF POST-COLLAPSE RECONSTRUCTION

We will build a probabilistic-statistical model that accounts for key parameters influencing the outcome of reconstruction [12, 13].

1. Problem Statement

Let P_{+e} — be the desired probability of a positive emergent effect (PEE), i.e., the probability that the outcome of post-collapse reconstruction will lead to improved architectural, technical-economic, or functional characteristics of the building.

We proceed from a model of conditional probability considering independent variables (factors):

$$P_{+e} = P(E_1 \cap E_2 \cap E_3 \cap E_4), \quad (1)$$

where E_1 — presence of high competence of the design team in reconstruction projects;

E_2 — presence of an organizational knowledge base with a sufficient number of optimal and innovative technical solutions, enhancing the flexibility of applying design solutions;

E_3 — availability of sufficient resources (time, budget) for the timely implementation of changes in reconstruction projects;

E_4 — degree of elaboration of the architectural-functional improvement potential embedded in the project.

These events are assumed to be statistically independent for the sake of a first approximation (dependencies can be accounted for later if necessary).

2. Defining Probability Components

In Table 2, we adopt conditional probabilities (based on surveys and practice of design organizations, using a typical specimen of 50 reconstruction projects of various types of capital construction objects).

3. Calculation of Final Probability

Assuming factor independence:

$$P_{+e} = P(E_1) \cdot P(E_2) \cdot P(E_3) \cdot P(E_4), \quad (2)$$

where $P(E_i)$ — is the probability of each individual event.

Let's perform the calculation using the formula:

$$P_{+e} = 0.85 \cdot 0.6 \cdot 0.5 \cdot 0.7 = 0.1785.$$

4. Result Interpretation

The probability of a positive emergent effect in post-collapse reconstruction, according to this model, is ~17.85 %.

What this means:

- approximately in every fifth or sixth case, reconstruction yields improvement in architectural-functional characteristics due to emergent solutions;
- this is a relatively high probability, considering it involves deviation from planned, standard solutions under conditions of large-scale destruction.

5. Conclusion

The calculation shows that under favourable conditions, the probability of positive emergence reaches ~18 %, confirming the advisability of supporting design flexibility and allowing innovative approaches in post-collapse reconstruction conditions.

Table 2. Adopted probabilities for each factor

Factor	Conditional event E_i	Probability estimation $P(E_i)$
Team Qualification	E_1	0.85 (85 %)
Flexibility of Design	E_2	0.6 (60 %)
Sufficiency of Budget/Time	E_3	0.5 (50 %)
Architectural Potential	E_4	0.7 (70 %)

PROBABILITY OF A POSITIVE EMERGENT EFFECT (PEE) ACCOUNTING FOR THE RISK OF HIDDEN DEFECTS NOT IDENTIFIED DURING THE POST-COLLAPSE INSPECTION

We will introduce an additional random variable — the presence of defects in structures not accounted for by the inspection (hidden defects) (D) — and forecast its overall impact on the system.

Important clarification:

- this variable is non-normative in terms of assessment[3];
- defects D are not a consequence of contractor errors;
- defects D are not related to poor workmanship but are caused by undetected (hidden) damages discovered only after the start of reconstruction.

Impact of undetected defects on the overall outcome:

- emergence of unplanned work volumes (additional reinforcement, dismantling, demolition, etc.);
- diversion of resources and time previously allocated for implementing innovative or architectural-functional improvements;
- shift in priorities: the design team may be forced to shift focus from optimization to threat mitigation;
- budget constraints, as the risk reserve budget may be fully utilized without replenishment;
- legal or contractual constraints: some decisions require recalculations, approvals, and deferred solutions.

General Extended Probability Model

We denote:

- P_{+e}: probability of a positive emergent effect;
- D: the event that the building has hidden defects not detected during the inspection;
- $\neg D$: there are no hidden defects or their presence has no significant impact on the result;
- $P(D)$: probability of the presence of undetected (hidden) defects;
- $P_{+e|D}$: probability of a positive effect given the presence of hidden defects;
- $P_{+e|\neg D}$: probability of a positive effect given full identification of the structure's condition during the inspection stage (the influence of hidden defects is not significant).

General formula:

$$P_{+e} = P(D) \cdot P_{+e|D} + (1 - P(D)) \cdot P_{+e|\neg D}. \quad (3)$$

Let us consider a case accounting for the previously considered model components (E_1, E_2, E_3, E_4).

[3] GOST 31937–2024. Buildings and Structures. Rules for Surveying and Monitoring Technical Condition: effective date 01-05-2024. Official ed. Moscow, RIS, 2024; 64. URL: https://docs.cntd.ru/document/1305691614 (rus.).

Then our formula takes the general form:

$$P_{+e} = P(E_1|D \cap E_2|D \cap E_3|D \cap E_4|D); \quad (4)$$

$$P_{+e} = P(E_1|D \cap E_2|D \cap E_3|D \cap E_4|D) = \\ = P(E_1|D) \cdot P(E_2|D) \cdot P(E_3|D) \cdot P(E_4|D), \quad (5)$$

where $E_1|D$ — presence of high competence of the design team in reconstruction projects where unaccounted-for hidden defects were identified during the installation process;

$E_2|D$ — presence of an organizational knowledge base with a sufficient number of optimal and innovative technical solutions, enhancing the flexibility of applying design solutions in case hidden structural damages are identified;

$E_3|D$ — availability of sufficient resources (time, budget) for timely implementation of changes in reconstruction projects where unaccounted-for hidden defects were identified during the installation process;

$E_4|D$ — degree of elaboration of the architectural-functional improvement potential embedded in the project.

Thus, the extended probability model:

$$P_{+e} = P(D) \cdot P(E_1 \cap E_2 \cap E_3 \cap E_4|D) + \\ + P(\neg D) \cdot P(E_1 \cap E_2 \cap E_3 \cap E_4| \neg D); \quad (6)$$

$$P_{+e} = P(D) \cdot P(E_1 \cap E_2 \cap E_3 \cap E_4|D) + (1 - P(D)) \cdot P_{+e|\neg D}. \quad (7)$$

Parameter Estimation

Probability of hidden defects $P(D)$.

According to data from technical audits and engineering inspections of buildings after accidents, as well as conducted surveys of construction organizations, in 30–40 % of cases, not all significant defects can be detected at the inspection stage. Let us adopt an averaged probability value $P(D) = 0.35$.

Input parameters:

$P(D) = 0.35$ — probability of the presence of significant hidden defects;

$P(\neg D) = 1 - P(D) = 0.65$ — probability of the absence of hidden defects with significant influence.

Let us introduce a coefficient for reducing efficiency in the presence of defects — α_i, then:

- $P(E_i|\neg D)$ — effectiveness of the factor under normal conditions;
- $P(E_i|D) = \alpha_i \cdot P(E_i|\neg D)$, where $\alpha \in (0, 1)$ — is the efficiency reduction coefficient in the presence of defects (e.g., 0.6 means a 40 % drop).

Also, we consider the important condition that α_i is not a result of poor workmanship but a forced adaptation of the project to new conditions. Consequently:

- α_i values inevitably decrease even with high competence and a knowledge base;
- however, projects do not become failures; the overall emergent effect merely diminishes.

$$P(E_i) = \alpha_i \cdot P(E_i|\neg D) \cdot P(D) + P(E_i|\neg D) \cdot (1 - P(D)); \quad (8)$$

$$P(E_i) = P(E_i|\neg D) \cdot [\alpha_i \cdot P(D) + (1 - P(D))] = \\ = P(E_i|\neg D) \cdot [1 - P(D)(1 - \alpha_i)], \quad (9)$$

where $\alpha_i = 1$: unaccounted defects do not affect efficiency → $P(E_i) = P(E_i|\neg D)$;

$\alpha_i < 1$: he smaller α_i and the larger $P(D)$, the more the overall probability $P(E_i)$ decreases.

Table 3 presents data from surveys conducted among construction organizations and state institutions from 2021 to 2025, indicating averaged values of coefficient α_i and calculated $P(E_i|D)$ (probabilities considering defects).

Substituting the found values into our model for determining P_{+e}:

$$P_{+e} = P(D) \cdot P(E_1 \cap E_2 \cap E_3 \cap E_4|D) + (1 - P(D)) \cdot P_{+e|\neg D} = \\ = 0.35 \cdot (0.79 \cdot 0.54 \cdot 0.43 \cdot 0.68) + 0.65 \cdot 0.1785 = \\ = 0.35 \cdot 0.1247 + 0.65 \cdot 0.1785 = 0.1597 \ (\sim 15.97\ \%).$$

Result interpretation:

- accounting for the risk of hidden defects, the probability of a positive emergent effect decreases from ~17.85 to ~15.97 %;
- this is a reduction of ~2 percentage points (~10.5 % relative to the previous estimate);
- thus, timely and thorough inspection of structures before the start of reconstruction can significantly influence the probability of success.

BAYESIAN REVISION: *P(D|E)*

Suppose that after observing a positive emergent effect, we want to clarify the probability that hidden defects were nevertheless present:

$$P(D|E) = \frac{P(E|D) \cdot P(D)}{P(E)}. \quad (10)$$

Table 3. Data obtained from surveys conducted from 2021 to 2025

Factor	Mechanism of defect influence	Probability value α_i	Probability estimate $P(E_i|\neg D)$	Probability estimate $P(E_i|D)$, considering α_i
Team Qualification E_1	Efficiency remains unchanged, but the pace of work will decrease	0.75–0.85 (average 0.80)	0.85 (85 %)	0.79 (79 %)
Flexibility of Design E_2	The developed design solutions are subject to adjustments based on the actual situation	0.65–0.75 (average 0.70)	0.6 (60 %)	0.54 (54 %)
Sufficiency of Budget/Time E_3	A significant part of the budget/time is spent on correcting unforeseen design errors	0.55–0.65 (average 0.60)	0.5 (50 %)	0.43 (43 %)
Architectural Potential E_4	Forced adjustments to the project already during implementation may hinder the implementation of the architectural ideas originally laid down	0.85–0.95 (average 0.90)	0.7 (70 %)	0.68 (68 %)

Using the values obtained above from the calculation:

$P(D) = 0.35$ — probability of the presence of hidden defects;

$P(E|D) = P(E_1 \cap E_2 \cap E_3 \cap E_4|D) = 0.1247$ (calculated above);

$P(E) = P_{+e} = 0.1597$ — total probability of a positive effect (calculated earlier by the total probability formula).

Then we obtain:

$$P(D|E) = \frac{P(E|D) \cdot P(D)}{P(E)} = \frac{0.1247 \cdot 0.35}{0.1597} =$$

$$= \frac{0.0436}{0.1597} = 0.2733\ (\sim 27.3\,\%).$$

Conclusion: even with a positive effect, the probability that hidden defects were still present is about 27.3 %. This indicates that the system can adapt to shortcomings — emergence acts as a compensatory capability.

This implies:

- the possibility of achieving positive results even in the presence of unforeseen problems;
- but it also points to the necessity of a systems approach to design that accounts for potential uncertainty.

System interpretation (Systems Theory)

The model is based on 4 independent factors (E_1–E_4), each influencing the system's readiness for adaptation:

- E_1 *и* E_2 — the cognitive-design loop (knowledge and competencies);
- E_3 — the resource loop (time, budget);
- E_4 — the architectural-functional potential (system reserve).

In terms of systems engineering:

1. The probability of PEE is the reliability of the system's functional reserve, realized under a certain configuration of factors.

2. The presence of hidden defects is a structural defect causing a potential “deviation from the norm”.

The model's robustness is manifested in that even with the deterioration of one factor (e.g., the appearance of D), a positive outcome is still possible if strong compensating factors (E_1, E_2) are present.

The graph shows the dependence of the final probability of a positive emergent effect P_{+e}, accounting for hidden structural defects $P(D) = 0.35$, on the parameters:

- $P(E_1)$ — probability of having a competent design team;
- $P(E_2)$ — probability of flexibility of design solutions.

Key conclusions determined by the graph:

- with $P(D) = 0.35$, the effect of hidden defects reduces overall success but does not nullify it;
- the higher the values of E_1 and E_2, the higher the final probability P_{+e}, but even with high values of E_1 and E_2, the presence of hidden defects reduces the probability of a positive effect, albeit insignificantly;
- the presence of hidden defects lowers the overall probability level;
- the effect of improving E_1 and E_2 is more pronounced in the range of high values (from 0.6 and above), but with a low level of any factor, a sharp drop in P_{+e} is observed.

COMPENSATORY MEASURES TO REDUCE THE NEGATIVE IMPACT OF HIDDEN DEFECTS

To compensate for the negative impact of hidden defects ($P(D)$) on the probability of a positive emergent effect in post-collapse reconstruction projects, it is recommended to take measures to increase the resilience of the project system to uncertainty [14, 15]. Fig. 6 presents directions and practical measures.

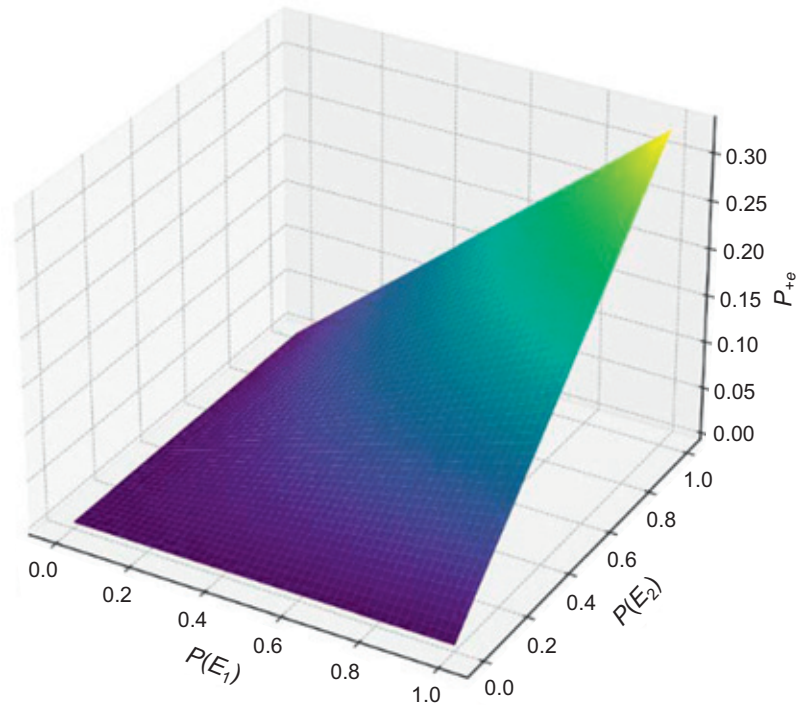


Fig. 5. Three-dimensional graph of result dependence on parameters E_1 and E_2 (dependence of P_{+e} on parameters E_1 and E_2, taking into account hidden defects)

1. Professional development of the project team (E_1)	The graph showed that the highly qualified designers significantly offset the negative impact of hidden defects. Measures: • involvement of specialists with experience in emergency facilities and reconstruction; • regular professional development of survey specialists, especially in terms of diagnostics of structures, reinforcements, adaptive solutions; • the formation of an "emergency expert team" within the organization, with an eye to responding quickly when hidden defects are detected
2. Knowledge base development and project flexibility (E_2)	The flexibility of design solutions is crucial for adapting a project to unforeseen circumstances. Measures: • implementation of digital libraries of design solutions, including examples of reinforcement implementation, defect elimination, and backup structural elements for reinforcement; • development of standard modules and nodes that can be easily adapted to the actual conditions; • development of a database of protocols and regulations in case of detection of various kinds of hidden defects at all stages of the CRW
3. Increase the time and budget reserve (E_3)	If there are hidden defects, an additional resource of time and money can be crucial to achieve a positive result. Measures: • establish a "budget buffer reserve" for at least 10–20 % of the total estimated cost of reconstruction; • create extended work schedules with the ability to adapt when changing design assumptions; • to conclude CRW contracts with a flexible financing model that provides for adjustments in case of unforeseen circumstances
4. Preliminary detection of defects and refinement of the examination (reduction of $P(D)$)	Reducing the underlying risk of hidden defects directly increases the chance of a successful emergent effect. Measures: • the use of "enhanced examination methods" (ultrasound, thermal imaging, tomography, autopsy of individual hidden nodes); • conducting an additional survey by an outside organization; • the use of structural diagnostic methods based on the destruction data (behavioral analysis by modeling the structure according to the shape of the collapse)
5. The strategy of "adaptive design"	IDEA: The project should initially assume several implementation scenarios, taking into account possible risks, including hidden defects. Measures: • to form variable design solutions with the possibility of quick replacement; • to model critical nodes in advance, taking into account all the features in which problems may arise during disassembly or reinforcement; • develop a protocol for "switching to a backup strategy" when identifying hidden problems

Fig. 6. Compensatory measures to reduce the negative impact of hidden defects

Conclusion from the statistical calculation

Even with $P(D)$ = 0.35 (35 %), due to the professional level of the team and flexibility of solutions, the probability of a positive outcome can be doubled. Therefore, the main attention should be paid to:

- proactive uncertainty management;
- accumulation and transfer of knowledge;
- and the implementation of adaptive design as a mandatory stage in the reconstruction of emergency objects.

CONCLUSIONS

The process of conducting construction and restoration works on damaged buildings, despite the inherently negative fact of damage, can become a catalyst for such positive effects of synergistic construction systems as emergence. The analysis of a specific case showed that flexibility, collective intelligence, and adaptation to unforeseen circumstances can not only restore but also improve a building in a number of parameters. The proposed statistical

model for forecasting the probability of obtaining a positive emergent effect, considering various types of damages not identified during inspection, allows for assessing the shortcomings of the construction-restoration system and increasing its effectiveness.

Thus, the positive emergent effect should be considered not as a side effect but as a potentially valuable objective in reconstruction and architectural design.

REFERENCES

1. Shirshchikov B.F., Akulich V.V. Features of the development of organizational and technological solutions when performing construction and restoration work in emergency conditions. Moscow, National Research University Moscow State University of Civil Engineering, 2015; 116. EDN VOCQWT. (rus.).
2. Belal A.A. Features of urban restoration of the historical centers of cities in the SAR damaged during the war : dissertation for the degree of candidate of technical sciences. Moscow, 2022; 136. EDN SCBJNW. (rus.).
3. Jeleński T. Practices of Built Heritage Post-Disaster Reconstruction for Resilient Cities. Buildings. 2018; 8(4):53. DOI: 10.3390/buildings8040053
4. Gusakova E.A. Systems engineering of organizational and technological cycles of construction projects : dissertation for the degree of Doctor of Technical Sciences. Moscow, 2004; 370. EDN NHZXVF. (rus.).
5. Gusakov A.A. Systems Engineering in Construction. Moscow, Stroyizdat, 1983; 440. URL: https://search.rsl.ru/ru/record/ 01001161266 (rus.).
6. Gusakova E.A., Pavlov A.S. Fundamentals of Organization and Management in Construction : Textbook and Workshop for Secondary Vocational Education. Moscow, Yurait, 2025; 615. URL: https://rusneb.ru/catalog/000200_000018_RU_NLR_BIBL_A_011289934 (rus.).
7. Hrasnica M. Damage assessment for masonry and historic buildings in Bosnia and Herzegovina. Damage Assessment and Reconstruction After War or Natural Disaster. 2019; 333-356. DOI: 10.1007/978-90-481-2386-5_13
8. Mejía N., Peralta R., Tapia R., Durán R., Sarango A. Damage assessment of RC columns under the combined effects of contact explosion and axial loads by experimental and numerical investigations. Engineering Structures. 2022; 254:113776. DOI: 10.1016/j.engstruct.2021.113776. EDN SWYXTO.
9. Kassouha S. Transferring experiences of post-war west Germany in social housing to reconstruction strategies after the war in Syria : dissertation. Stuttgart, Germany, 2020; 482. DOI: 10.18419/opus-10826
10. Ho J.Ts.W. Emergent place-identity: place activation through the architectural restoration of a small Hakka household in the Hong Kong countryside. Built Heritage. 2024; 8(1):7. DOI: 10.1186/s43238-024-00117-4. EDN WVDAXG.
11. Bunin A.V., Savarenskaya T.F. History of urban planning art : in 2 volumes. Vol. 2. Urban planning of the twentieth century in the countries of the capitalist world. Moscow, Stroyizdat, 1979; 411. URL: https://search.rsl.ru/ru/record/01007592487 (rus.).
12. Semenov V.A. Probability Theory and Mathematical Statistics : a Textbook for Bachelors and Specialists. St. Petersburg, Piter, 2013; 192. URL: https://search.rsl.ru/ru/record/01006510355 (rus.).
13. Kremer N.Sh. Probability Theory and Mathematical Statistics. Moscow, Unity-Dana, 2003; 573. EDN QJMCDH. (rus.).
14. Maaruf A., Oleinik P.P. Measures to preparate the territories damaged by the war for the restoration of the housing stock. Engineering Journal of Don. 2023; 10(106):330-342. EDN PRIUPO. (rus.).
15. Borisov A.M., Vertakova Yu.V. Strategic management of organizational viability based on the application of a balanced scorecard system. Moscow, INFRA-M, 2019; 238.

Положительный эффект эмерджентности в системе строительно-восстановительных работ после обрушения зданий

Рассматривается феномен позитивной эмерджентности в синергетической системе строительно-восстановительных работ (СВР), возникающей после обрушения зданий вследствие значительных природных или техногенных воздействий. Эмерджентность понимается как появление качественно новых, непредусмотренных изначально свойств системы, ведущих к улучшению объекта. На примере восстановления итальянской деревни Венцоне после землетрясения 1976 г. показано, как катастрофа может стать катализатором эволюции, приводящей к росту архитектурной выразительности, функциональности, туристической привлекательности и социально-экономической значимости восстанавливаемого объекта. Отдельное внимание уделено социотехническим взаимодействиям, роли интуитивных и креативных решений, и гибкости проектных команд, позволивших использовать катастрофу как возможность для эволюции архитектурного объекта в условиях неопределенности. На основе анализа реальных случаев и теоретической базы предлагается вероятностно-статистическая модель для прогнозирования положительного эффекта эмерджентности (ПЭЭ). Модель учитывает ключевые факторы: компетентность команды, гибкость проектных решений, достаточность ресурсов и архитектурный потенциал. Расчет показывает, что при благоприятных условиях вероятность ПЭЭ достигает больше 17 %. При этом вводится важный корректирующий фактор — риск наличия скрытых дефектов, не выявленных при обследовании. Учет этого фактора в модели вносит важные уточнения и снижает вероятность ПЭЭ, тем самым подчеркивая критическую важность тщательного предпроектного анализа. Практическая значимость работы заключается в обосновании ценности адаптивного проектирования и управления неопределенностью для реализации эмерджентного потенциала в строительно-восстановительных проектах. Предложенная модель и выводы служат основой для разработки компенсирующих мероприятий, направленных на минимизацию негативного влияния непредвиденных факторов. Заключительно делается вывод, что положительный эмерджентный эффект следует рассматривать как целевой, а не побочный элемент реконструкции, способный превратить процесс ликвидации повреждений в возможность системного улучшения восстанавливаемого объекта по широкому спектру параметров — от технико-экономических до социокультурных.

Ключевые слова: *эмерджентность, строительно-восстановительные работы, синергетика, вероятностное прогнозирование, гибкость проектных решений, скрытые дефекты*

СПИСОК ИСТОЧНИКОВ

1. Ширшиков Б.Ф., Акулич В.В. Особенности разработки организационно-технологических решений при выполнении строительно-восстановительных работ в чрезвычайных условиях : монография. М. : НИУ МГСУ, 2015. 116 с. EDN VOCQWT.
2. Белал А.А. Особенности градостроительного восстановления исторических центров городов САР, пострадавших в ходе войны : дис. … канд. техн. наук. М., 2022. 136 с. EDN SCBJNW.

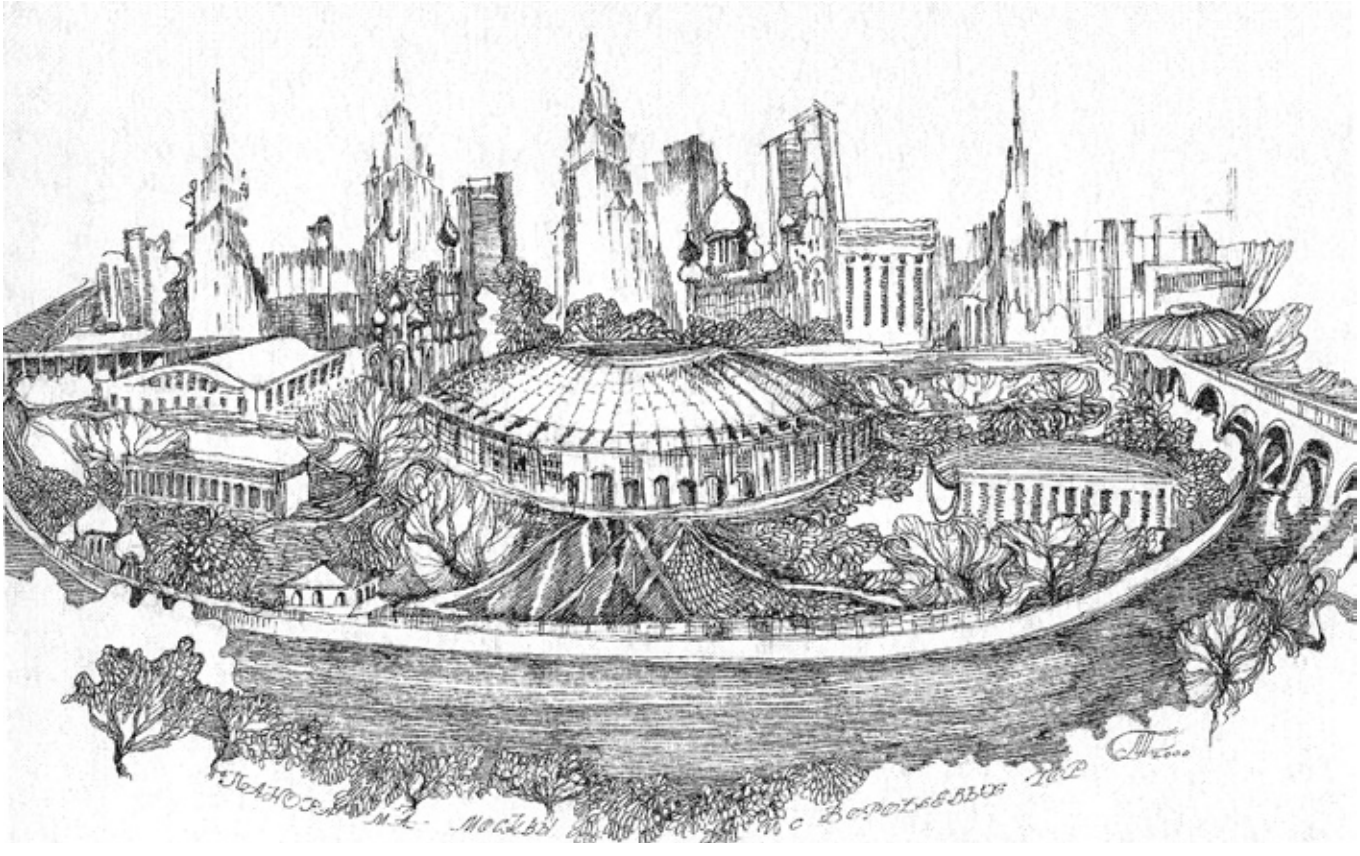
3. Jeleński T. Practices of Built Heritage Post-Disaster Reconstruction for Resilient Cities // Buildings. 2018. No. 8 (4). P. 53. DOI: 10.3390/buildings8040053
4. Гусакова Е.А. Системотехника организационно-технологических циклов объектов строительства : дис. … д-ра техн. наук. М., 2004. 370 с. EDN NHZXVF.
5. Гусаков А.А. Системотехника строительства. М. : Стройиздат, 1983. 440 с. URL: https://search.rsl.ru/ru/record/01001161266
6. Гусакова Е.А., Павлов А.С. Основы организации и управления в строительстве : уч. и практикум для среднего профессионального образования. М. : Юрайт, 2025. 615 с. URL: https://rusneb.ru/catalog/000200_000018_RU_NLR_BIBL_A_011289934
7. Hrasnica M. Damage assessment for masonry and historic buildings in Bosnia and Herzegovina // Damage Assessment and Reconstruction After War or Natural Disaster. 2019. Pp. 333–356. DOI: 10.1007/978-90-481-2386-5_13
8. Mejía N., Peralta R., Tapia R., Durán R., Sarango A. Damage assessment of RC columns under the combined effects of contact explosion and axial loads by experimental and numerical investigations // Engineering Structures. 2022. No. 254. P. 113776. DOI: 10.1016/j.engstruct.2021.113776. EDN SWYXTO.
9. Kassouha S. Transferring experiences of post-war west Germany in social housing to reconstruction strategies after the war in Syria : dissertation. Stuttgart, Germany, 2020. P. 482. DOI: 10.18419/opus-10826
10. Ho J.Ts.W. Emergent place-identity: place activation through the architectural restoration of a small Hakka household in the Hong Kong countryside // Built Heritage. 2024. No. 8 (1). P. 7. DOI: 10.1186/s43238-024-00117-4. EDN WVDAXG.
11. Бунин А.В., Саваренская Т.Ф. История градостроительного искусства : в 2-х т. Т. 2. Градостроительство XX в. в странах капиталистического мира. М. : Стройиздат, 1979. 411 с. URL: https://search.rsl.ru/ru/record/01007592487
12. Семёнов В.А. Теория вероятностей и математическая статистика : уч. пос. для бакалавров и специалистов. СПб. : Питер, 2013. 192 с. URL: https://search.rsl.ru/ru/record/01006510355
13. Кремер Н.Ш. Теория вероятности и математическая статистика М. : Юнити-Дана, 2003. 573 с. EDN QJMCDH.
14. Мааруф А.Г., Олейник П.П. Мероприятия по подготовке территорий, поврежденных войной, к восстановлению жилищного фонда // Инженерный вестник Дона. 2023. № 10 (106). С. 330–342. EDN PRIUPO.
15. Борисов А.М., Вертакова Ю.В. Стратегическое управление жизнеспособностью организации на основе применения системы сбалансированных показателей : монография М. : ИНФРА-М, 2019. 238 с.

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Engineering and Technical Survey of Cultural Heritage Object in the Project for Its Restoration and Adaptation for Modern Use

The paper presents the results of an engineering and technical survey of building structures in a project to restore and adapt a cultural heritage site for modern use. The aim of this study is to develop and implement an integrated methodology for diagnosing the technical condition of building structures, taking into account the specific nature of cultural heritage sites, as well as to justify reinforcement and restoration measures aimed at extending the resource potential and adapting the site to its modern functional purpose. The initial permitting documentation for the surveyed site was studied and a survey programme was developed during the survey. The building space-planning solutions were established, the building's load-bearing elements design was determined. The building's structure measurements were taken, floor plans, facades, and characteristic sections were drawn up. A detailed inspection of the building's load-bearing structures was conducted, identifying their design features. Photographic recording was completed. The technical condition of the building's load-bearing and enclosing structures was determined. A technical report was prepared based on the survey results. Visual and visual-instrumental methods were used during the survey. Structural defects were visually identified, including cracks, deformations, load-bearing elements displacement relative to design positions, and others. Visual and instrumental methods were used to refine the geometric dimensions, and the actual physical and mechanical properties were examined. The building's technical condition was determined, and conclusions regarding its future operation were formulated based on the comprehensive engineering and technical survey results, in-place and laboratory tests, verification calculations, and an archival materials study. Verification calculations were performed for the building's metal roof truss, vertical displacements and *N* forces in the truss were determined, and designated cross-sections were checked for the first and second limit states, as well as for local truss stability. A seismoacoustic pile survey was also conducted to determine the pile depth. Furthermore, as the technical survey part of the cultural heritage site, a mycological test of the wooden dome roof structure was performed to detect infestation by biodegradable fungi (biological damage), and the possible causes of the infestation were determined. Specimens from the wooden supporting roof structures were examined using cultural and morphological methods.

Keywords: *comprehensive engineering and technical survey, cultural heritage object, reconstruction, seismoacoustic sounding, mycological research, verification calculations, strength assessment*



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The cultural heritage preservation worldwide remains a pressing issue, as many countries possess vast numbers of historic monuments requiring protection and restoration. This article examines technical inspection methods applied to cultural heritage object in Russia. Mandatory comprehensive engineering and technical inspection is a key component of international heritage preservation programmes. This process involves detailed evaluation of structural characteristics, current condition, and related risks. The results form a scientific basis for effective restoration and adaptation strategies, incorporating advanced diagnostic technologies to improve accuracy and reduce damage risks during work [1–3].

The work objective presented in this article is to determine the building structural design, its technical condition, and the structures overall load-bearing capacity, identify hazardous damage, perform surveys with the architectural drawings and initial data for design, perform verification calculations, apply instrumental assessment methods, conduct laboratory tests taking into account the cultural heritage site objects and justify measures for strengthening and restoration aimed at extending the resource potential and adapting the site to its modern functional purpose. Engineering surveys types include engineering and technical inspection (building inspection, pit excavation, laboratory and office work). The survey was carried out in accordance with the requirements of Russian National Standard: GOST 31937–2024[1], Code of Practice: CP 13-102–2003[2], CP 70.13330.2012[3], CP 31-110–2003[4] [4–7].

The building discussed in this article is a regional cultural heritage site. The building was not in use prior to the survey and during the research. The building has a complex configuration, four stories high, with a basement, two mezzanines, superstructures, and a cinema on the second, third, and fourth floors. It was constructed between 1928 and 1931. Reconstruction was completed in 1972. The building is a special design object. Its structural design is mixed, with some parts being frameless and others being a partial frame. The column foundations are pile grillages connected by concrete slab with pile clusters. The wall foundations are composite strip foundations made of cut limestone rubble in a cement-sand mortar, concrete, and ceramic brick. The exterior walls are constructed of brickwork in a cement-sand mortar, plastered, and painted. The interior walls are

[1] GOST 31937–2024. Buildings and constructions. Rules of inspection and monitoring of the technical condition.

[2] CP 13-102–2003. Rules for inspection of load-bearing structural elements of buildings and structures.

[3] CP 70.13330.2012. Load-bearing and separating constructions.

[4] CP 31-110–2003. Design and erection of electrical equipment in residential and public buildings.

self-supporting, made of ceramic brick in a cement-sand mortar, and cinder concrete. The floor slabs are monolithic reinforced concrete, also made of precast reinforced concrete slabs on metal beams. The spandrel beams are reinforced concrete. The roof structures are complex in configuration, with flat and domed sections. The roof covering is galvanized steel sheet over wooden framings, with soft roofing made of rolled waterproofing membrane over reinforced concrete roof slabs. Water removal is controlled, while the external water removal is uncontrolled. The building's spatial rigidity is adequate, ensured by rigid joints connecting the beams to the columns and the floor slabs. The courtyard area is levelled. The adjacent asphalt pavement serves as a blind area in the courtyard, while paving slabs serve as a blind area on the main facades. Balconies are made of reinforced concrete slabs, cantilevered into the building's exterior wall. They are located on the main and courtyard facades at the second-story level. The building's facades are plastered and painted. Two- and three-flight staircases are made of monolithic reinforced concrete on a monolithic reinforced concrete slab, on steel stringers, with reinforced concrete landings and landings supported by reinforced concrete and steel beams and stairwell walls. Partitions are made of brick and cinder block. The building facade fragment is shown in Fig. 1.

The technical survey included a series of measures aimed at establishing the building materials strength characteristics in load-bearing structures using non-destructive testing methods. The concrete strength class was determined in compliance with the regulatory requirements set forth in Russian National Standard GOST 31937–2024[1]. The building's structural strength was assessed using the non-destructive, rapid impact pulse method using the Beton PRO Condtrol instrument in accordance with Russian National Standard GOST 22690–2015[5]. According to the test results, the average concrete strength of monolithic reinforced concrete columns was 31.8 MPa, the average concrete strength of monolithic reinforced concrete beams was 32.1 MPa, the average concrete strength of monolithic reinforced concrete floor slabs was 32.0 MPa, the average strength of ceramic bricks in the external walls of the 1st floor and basement was 9.3 MPa. Concrete strength was assessed using the ultrasonic device UK1401. Nondestructive testing results show that concrete strength in monolithic foundation slabs under blocks



Fig. 1. The building facade fragment

1–5 matches class B25, as does strength in cast-in-place columns embedded in soil.

Verification calculations. Calculation relevance stems from ensuring reliability of metal roof trusses in a cultural heritage building under service loads. Work aims to verify vertical displacements and forces *N*, check assigned sections for ultimate limit states 1 and 2, and local stability per CP 16.13330.2017[6] and CP 20.13330.2016[7]. Tasks include load calculation, truss element strength and stability assessment, and local buckling analysis. Results confirm compliance of metal truss designs with standards and enhance operational reliability [8–15].

The designated sections were verified for the first and second limit states, as well as for local stability along the truss based on the verification calculations results (Fig. 2–4).

The maximum utilization coefficient of steel sections for the first limit state is 0.544 ($k_u = 0.544 < k_u^{max} = 1$). The maximum utilization coefficient of steel sections for the 2nd limit state is 0.550 ($k_u = 0.550 < k_u^{max} = 1$). The maximum utilization coefficient of steel sections for local stability is 0.702 ($k_u = 0.702 < k_u^{max} = 1$).

Calculation results confirm that the design cross-sections ensure required strength, stiffness, and stability of structures under

[5] GOST 22690–2015. Concretes. Determination of strength by mechanical methods of nondestructive testing.

[6] CP 16.13330.2017. Steel structures.

[7] CP 20.13330.2016. Loads and actions.

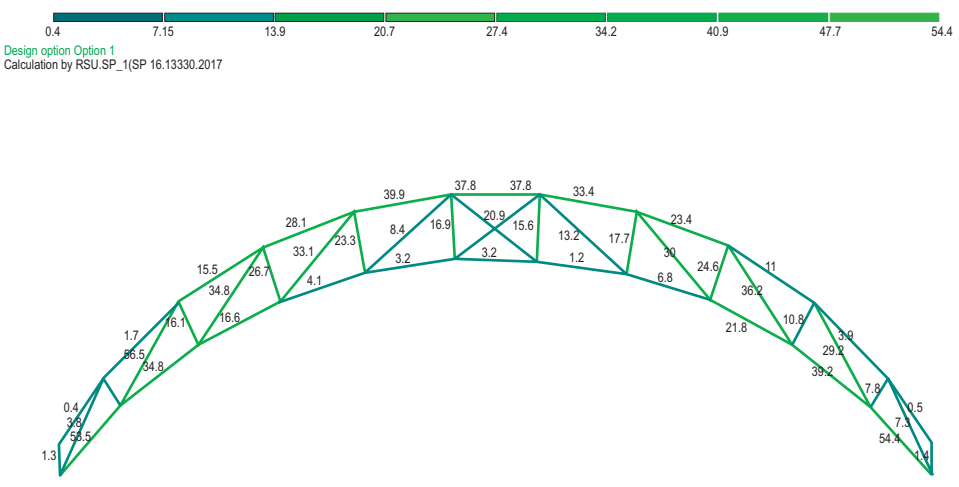


Fig. 2. Result of checking the assigned sections for the 1st limit state in the truss

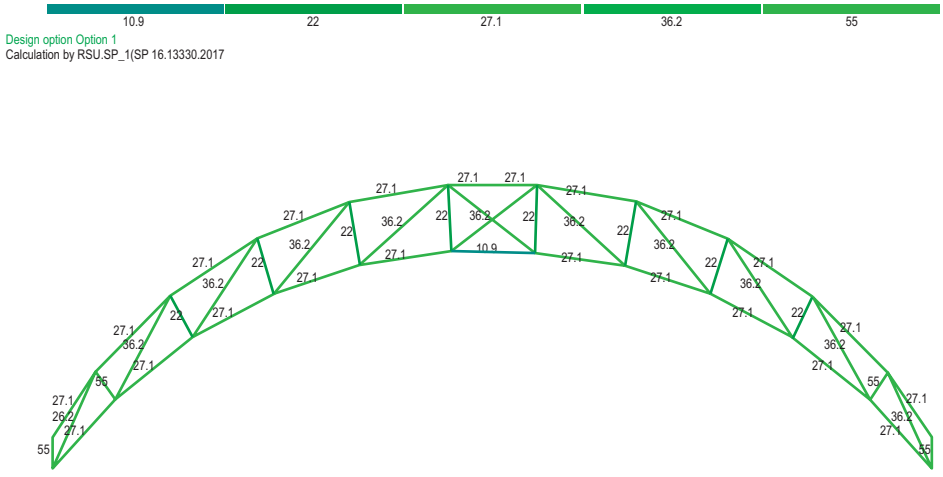


Fig. 3. Result of checking the assigned sections for the 2nd limit state in the truss

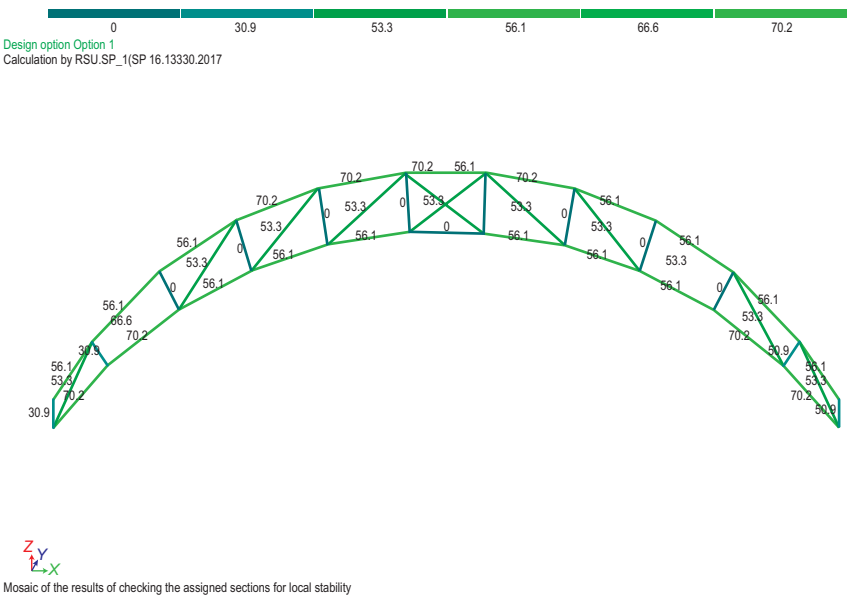


Fig. 4. Result of checking the assigned sections for local stability along the truss

design loads, thereby guaranteeing operational reliability of the building roof.

A seismoacoustic pile survey was also conducted to determine the pile emplacement depth. A pile extensiometer (IDS-1) was used to accomplish this task. 30 measurements were taken on the three piles under study at the survey site. The pile 1 length, according to data processing, was 5.7 m (±10 %, method error) based on the pile survey results. The pile 2 length, according to data processing, was 5.9 m (±10 %, method error). The pile 3 length, according to data processing, was 5.6 m (±10 %, method error).

Additionally, as part of the technical inspection in the cultural heritage object, the wooden dome roof structures mycological examination was performed to detect infestation by biodegradable fungi (biological damage) and to determine the damage possible causes. Specimens were collected nondestructively. Material fragments were taken from sites of natural failure or via surface mycological methods that preserve structural integrity. Specimens went into sterile containers. Specimens from the building's wooden supporting roof structures were examined using cultural and morphological methods. Localized areas of the wooden structures biodeterioration, in the form of small foci of rot at leak sites, were discovered on the inspected rafter system. Overall, the structures condition is acceptable: the wood is strong, the protective coating is functioning properly, and the structures exhibit only minor superficial biodeterioration. The building's wooden structures biodeterioration is assessed according to CP 28.13330.2017[8] as grade I, with localized areas of grade II–III damage requiring replacement or replacement. All preserved structures must undergo comprehensive antiseptic treatment.

The soil survey results. The soils assessment underlying the footing of the building's foundations was conducted based on the eighteen test pits results. The pits excavation was carried out from the basement level to a depth of approximately 0.5 m below the existing foundations footing. Soil specimens were collected beneath the foundation footings during the excavation and subjected to laboratory analysis in a stationary soil laboratory. Specimens were collected using sampling rings. It was determined that the immediate foundation soil for the building is a heavy, stiff loam containing plant residues based on the laboratory test results and

[8] CP 28.13330.2017. Protection against corrosion of construction.

an archival data analysis. The design bearing capacity of the foundation soils, R_0, for the existing foundation structure was calculated in accordance with formula 5.7 from CP 22.13330.2016[9].

This work presents results for strength and deformation characteristics of soil sampled during pit 3 excavation. Sampling interval is 1.35–1.55 m. Soil structure is not disturbed. Specimens are at natural moisture. Soil: heavy silty clay, stiff plastic with medium-deformed plant residue inclusions. Ring height is 25 mm (compression), 35 mm (shear). Ring diameter is 87.5 mm (compression), 72 mm (shear) per GOST 12248.1–2020[10]. The oedometric deformation modulus $E_{0.10\text{-}0.20}$ is 9.09 MPa. The compressive deformation modulus $E_{0.10\text{-}0.20}$ is 5.45 MPa. The deformation modulus taking into account m_{oed} $E_{0.10\text{-}0.20}$ is 13.2 MPa. The internal friction angle is 14.57°. The cohesion is 0.025 MPa.

The building foundation survey results. A lack of waterproofing material for the foundation structures was revealed during the foundations and base soils inspection.

Wall survey results. Basement walls, plinth, and exterior finishes, violations of masonry technology were identified, including missing bond, substandard joint sizes, mixed masonry (using ceramic and sand-lime bricks), and using bricks of varying strengths. Additionally, sections were identified where window and door openings have been narrowed or filled with masonry of various materials, use of irregular bricks and broken bricks, presence of decommissioned engineering communications embedded within wall thicknesses, areas with blocked niches and technological channels intended for pipe and utility passage, weathering of mortar joints in the masonry walls; localized damage to brickwork, patches of "chaotic" brickwork appearance, and numerous signs of water leakage on the wall surfaces were discovered. The finishing structures layers were dismantled.

The columns survey results. Chips in the protective layer of concrete, local exposure of longitudinal and transverse reinforcement, damage or absence of the concrete protective layer, transverse and longitudinal reinforcement corrosion, non-vibrated sections of monolithic structures, potholes and cavities on the concrete structures were found.

Floor slabs survey results. Water leakage traces on the slab surfaces, deterioration areas in the concrete slabs protective layer with reinforcing bars exposure, the slab reinforcement corrosion, localized damage to the protective concrete layer on the 1st, 2nd, and 3rd floors slabs, localized loss of the protective concrete cover with exposure and reinforcement bars surface corrosion in the basement slab, unplanned technological openings for utilities made during the building's operation, including openings created by breaking through structural elements, which compromised the concrete slabs reinforcement, non-vibrated areas in the monolithic slab structures, the protective concrete layer of monolithic reinforced concrete beams localized destruction, water leakage, and non-vibrated zones in the monolithic beam structures were identified as a floor slab and roof structures survey result. Taking into account that no significant defects or damage affecting the floors and roof load-bearing capacity were detected, the floors and roof load-bearing capacity is sufficient to withstand the actual loads.

Roof and roofing inspection results. The roof and covering structures survey revealed water leaks from the roof onto the covering, technological openings for utilities (ventilation) made during building operation — including openings created by perforating structures that compromised reinforcement in concrete slabs — damage to double joists between slabs due to natural wear, leaks including rot, lack of fire and bio protection for wood, compacted slag not meeting current thermal protection standards, mechanical damage to monolithic reinforced concrete beams, chips, exposed reinforcing bars, localized deterioration of the concrete protective layer on monolithic reinforced concrete beams, surface corrosion of reinforcement in monolithic beams, leakage traces, non-vibrated areas or formwork marks on monolithic structures, absence of fire and bio protection on wooden structures, damage to wooden elements from moisture and roof leaks (humidity, rot), missing components in wooden truss structures, peeling or missing paint on metal structures, localized surface corrosion at joints, localized missing bolts in connections, destruction of the upper layers of roll roofing (cracking, warping), clogged drainage funnels, areas of biological damage on the roofing, blisters and pimples in the roll roofing, localized roof leaks, deformation, mechanical damage, corrosion, and loosening of metal sheet fastenings on the dome roof. The drainage system's condition is unsatisfactory, with mechanical damage and surface corrosion on protective caps of drainage funnels. Water inlets are in poor condition due to deformation, surface corrosion, and clogging.

Fig. 5 shows the general view of the first-floor premises, the floor slabs and beams with repaired concrete protective layers, and column strengthening via injection grouting. Fig. 6 illustrates the dome on



Fig. 5. The general view of the first-floor premises

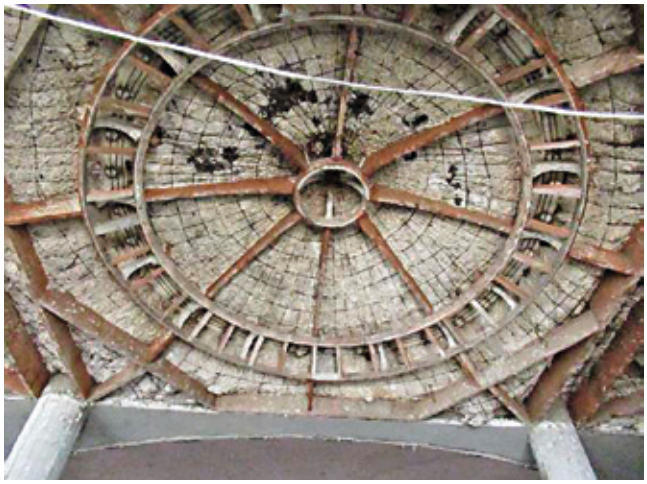


Fig. 6. The general view of the dome on a wooden frame located on the first floor

[9] CP 22.13330.2016. Soil bases of buildings and structures.

[10] GOST 12248.1–2020. Soils. Determination of strength parameters by shear strength testing.



Fig. 7. The masonry mortar weathering, local damage to the brickwork of the walls on the first floor



Fig. 8. Deformation, mechanical damages, corrosion, reduced tightness of metal sheet seam fasteners on the building's dome roofing

a wooden frame in the first-floor premises, including concrete deterioration with exposed and corroded reinforcement mesh. Fig. 7 documents mortar weathering, localized brick masonry damage in the walls of the first-floor premises, and wall strengthening through injection grouting. Fig. 8 reveals deformation, mechanical damage, corrosion, and loose fastening of metal roofing sheets on the dome roof.

Following a comprehensive survey, the structural elements technical condition in the building classified as a regional cultural heritage site was evaluated. It included the following types of work: detailed visual examination of all structural components with visible defects and damages identification, test pits excavation at key points to assess the foundations and soil condition, performing exploratory openings of finishing and structural layers to evaluate the actual state of concealed structural elements, instrumental measurements of geometric parameters and deformations in load-bearing structures, materials sampling for laboratory testing to determine their physical and mechanical properties, and the load-bearing capacity calculations considering identified defects, actual material properties, and applicable regulatory requirements — exhaustive data on the current technical condition were obtained.

The building's foundations, columns, walls, floor and roof structures, balconies and loggias, staircases, and timber and window assemblies are in working condition and capable of supporting existing loads. The identified defects and damage were the building's long service life result. There is no information on major repairs.

Thus, the survey conducted allowed to objectively assess the technical condition of the cultural heritage building, identify critical defects, and determine measures necessary for its preservation and further operation in accordance with regulatory requirements. Comprehensive technical survey using state-of-the-art technologies and standardized methods provide the basis for informed decision-making in preserving cultural heritage objects in international practice.

REFERENCES

1. Rimshin V., Roshchina S., Lukin M., Ketsko E. Scientific Basis of Studying the Pile Foundations Bearing Capacity During Building Reconstruction. Proceedings of MPCPE 2024. Lecture Notes in Civil Engineering. 2024; 576:282-294. DOI: 10.1007/978-3-031-81635-2_28

2. Telichenko V., Rimshin V., Ketsko E. Engineering structures stability against progressive collapse. E3S Web of Conferences. 2023; 410:02037. DOI: 10.1051/e3sconf/202341002037. EDN TYYYAK.

3. Rimshin V.I., Truntov P.S., Kuzina I.S., Roshchina S.I., Ketsko E.S. Engineering calculations of acidifier retaining walls during water treatment facilities designing. Lecture Notes in Civil Engineering. 2022; 182:55-73. DOI: 10.1007/978-3-030-85236-8_5. EDN YFEXGC.

4. Neverov A.N., Ketsko E.S., Truntov P.S., Rimshin V.I. Calculating the strengthening of construction structures before the reconstruction of the building. Lecture Notes in Civil Engineering. 2022; 182:173-179. DOI: 10.1007/978-3-030-85236-8_14. EDN GHCLDA.

5. Fadeev R., Lisyatnikov M., Rimshin V., Roshchina S. Investigation of the Strength Characteristics of Hydraulic Concrete Under Various Methods of Its Testing. Proceedings of MPCPE 2024. Lecture Notes in Civil Engineering. 2024; 576:113-125. DOI: 10.1007/978-3-031-81635-2_12

6. Kuzina E., Rimshin V., Neverov A. Residual resource of power resistance during building structures deformation. E3S Web of Conferences. 2019; 135:03009. DOI: 10.1051/e3sconf/201913503009. EDN UMYIGZ.

7. Krishan A.L., Rimshin V.I., Astafeva M.A. Deformability of a volume-compressed concrete. IOP conference series: materials science and engineering. 2018; 463(2):022063. DOI: 10.1088/1757-899X/463/2/022063. EDN WULQHB.

8. Telichenko V., Rimshin V., Ketsko E. Digital robotic systems for non-destructive reinforced concrete structures testing. E3S Web of Conferences. 2024; 533:02045. DOI: 10.1051/e3sconf/202453302045. EDN SRSXHS.

9. Rimshin V.I., Suleymanova L.A., Amelin P.A. Strength of Normal Sections of Flexural Reinforced Concrete Elements Damaged by Corrosion and Strengthened with External Composite Reinforcement. Structural Mechanics of Engineering Constructions and Buildings. 2024; 20(4):331-341. DOI: 10.22363/1815-5235-2024-20-4-331-341. EDN TZOMCJ.

10. Telichenko V., Rimshin V., Ketsko E. Promising directions for the artificial intelligence development in the housing and utilities sector. E3S Web of Conferences. 2024; 535:05001. DOI: 10.1051/e3sconf/202453505001. EDN OFARFI.

11. Krishan A.L., Astafeva M.A., Rimshin V.I., Shubin I.L., Stupak A.A. Compressed Reinforced Concrete Elements Bearing Capacity of Various Flexibility. Lecture Notes in Civil Engineering. 2022; 182:283-291. DOI: 10.1007/978-3-030-85236-8_26. EDN JPNURD.

12. Karpenko N.I., Rimshin V.I., Eryshev V.A., Shubin L.I. Deformation Models of Concrete Strength Calculation in the Edition of Russian and Foreign Norms. IOP Conference Series Materials Science and Engineering. 2020; 753(5):052043. DOI: 10.1088/1757-899X/753/5/052043. EDN TYMKCF.

13. Wang Sh., Jiang Y., Xu Y., Zhang L., Li X., Zhu L. Sustainability of Historical Heritage: The Conservation of the Xi'an City Wall. Sustainability. 2019; 11(3):740. DOI: 10.3390/su11030740

14. Penica M., Golovina S., Morgul V. Revitalization of Historic Buildings as an Approach to Preserve Cultural and Historical Heritage. International Scientific Conference Urban Civil Engineering and Municipal Facilities (SPBUCEMF-2015). Procedia Engineering. 2015; 117:883-890. DOI: 10.1016/j.proeng.2015.08.165. EDN UYZRDP.

15. Wang J., Zakaria S.A. Morphological Characteristics and Sustainable Adaptive Reuse Strategies of Regional Cultural Architecture: A Case Study of Fenghuang Ancient Town, Xiangxi, China. Buildings. 2025; 15(1):119. DOI: 10.3390/buildings15010119. EDN YPZSGO.

Инженерно-техническое обследование строительных конструкций в проекте реставрации и приспособления для современного использования объекта культурного наследия

В статье представлены результаты инженерно-технического обследования строительных конструкций в проекте реставрации и приспособления для современного использования объекта культурного наследия. Целью данного исследования является разработка и внедрение интегрированной методики диагностики технического состояния строительных конструкций с учетом специфики объекта культурного наследия, а также обоснование мероприятий по усилению и реставрации, направленных на продление ресурсного потенциала и адаптацию объекта к современному функциональному назначению. В ходе обследования изучена исходно-разрешительная документация по объекту обследования и составлена программа проведения обследования. Установлены объемно-планировочные решения здания, определено конструктивное исполнение несущих элементов здания. Выполнены обмеры строительных конструкций здания, оформлены планы этажей, фасады, характерные разрезы. Проведен детальный осмотр несущих конструкций здания с выявлением их конструктивных особенностей. Выполнена фотофиксация элементов конструкций здания. Определено техническое состояние несущих и ограждающих конструкций здания. Составлено техническое заключение по итогам обследования. При обследовании использовались визуальный и визуально-инструментальный методы. Визуально выявлялись видимые дефекты строительных конструкций: трещины, деформации, смещения несущих элементов относительно проектных положений и другое. Визуально-инструментальными методами уточнялись геометрические размеры строительных конструкций и отдельных элементов, исследовались фактические физико-механические характеристики материалов конструкций здания. По результатам комплексного инженерно-технического обследования, натурных и лабораторных исследований, поверочных расчетов и изучения архивных материалов определяется техническое состояние здания, сформулированы выводы о его дальнейшей эксплуатации. Выполнены поверочные расчеты металлической фермы покрытия здания, определены вертикальные перемещения и усилия *N* в ферме, выполнена проверка назначенных сечений по первому и второму предельным состояниям, местной устойчивости по ферме. Также было выполнено обследование методом сейсмоакустического зондирования свай с целью определения глубины их заложения. Кроме того, в рамках технического обследования объекта культурного наследия было выполнено микологическое исследование деревянных конструкций крыши здания купольного типа на предмет заражения грибами-биодеструкторами (поражения биологического характера), установление возможных причин поражения. Были исследованы пробы с деревянных несущих конструкций крыши здания культуральными и морфологическими методами.

Ключевые слова: *комплексное инженерно-техническое обследование, объект культурного наследия, реконструкция, сейсмоакустическое зондирование, микологическое исследование, поверочные расчеты, оценка прочности*

СПИСОК ИСТОЧНИКОВ

1. Rimshin V., Roshchina S., Lukin M., Ketsko E. Scientific Basis of Studying the Pile Foundations Bearing Capacity During Building Reconstruction // Proceedings of MPCPE 2024. Lecture Notes in Civil Engineering. 2024. No. 576. Pp. 282–294. DOI: 10.1007/978-3-031-81635-2_28

2. Telichenko V., Rimshin V., Ketsko E. Engineering structures stability against progressive collapse // E3S Web of Conferences. 2023. No. 410. P. 02037. DOI: 10.1051/e3sconf/202341002037. EDN TYYYAK.

3. Rimshin V.I., Truntov P.S., Kuzina I.S., Roshchina S.I., Ketsko E.S. Engineering calculations of acidifier retaining walls during water treatment facilities designing // Lecture Notes in Civil Engineering. 2022. No. 182. Pp. 55–73. DOI: 10.1007/978-3-030-85236-8_5. EDN YFEXGC.

4. Neverov A.N., Ketsko E.S., Truntov P.S., Rimshin V.I. Calculating the strengthening of construction structures before the reconstruction of the building // Lecture Notes in Civil Engineering. 2022. No. 182. Pp. 173–179. DOI: 10.1007/978-3-030-85236-8_14. EDN GHCLDA.

5. Fadeev R., Lisyatnikov M., Rimshin V., Roshchina S. Investigation of the Strength Characteristics of Hydraulic Concrete Under Various Methods of Its Testing // Proceedings of MPCPE 2024. Lecture Notes in Civil Engineering. 2024. No. 576. Pp. 113–125. DOI: 10.1007/978-3-031-81635-2_12

6. Kuzina E., Rimshin V., Neverov A. Residual resource of power resistance during building structures deformation // E3S Web of Conferences. 2019. No. 135. P. 03009. DOI: 10.1051/e3sconf/201913503009. EDN UMYIGZ.

7. Krishan A.L., Rimshin V.I., Astafeva M.A. Deformability of a volume–compressed concrete // IOP conference series: materials science and engineering. 2018. No. 463 (2). P. 022063. DOI: 10.1088/1757-899X/463/2/022063. EDN WULQHB.

8. Telichenko V., Rimshin V., Ketsko E. Digital robotic systems for non–destructive reinforced concrete structures testing // E3S Web of Conferences. 2024. No. 533. P. 02045. DOI: 10.1051/e3sconf/202453302045. EDN SRSXHS.

9. Rimshin V.I., Suleymanova L.A., Amelin P.A. Strength of Normal Sections of Flexural Reinforced Concrete Elements Damaged by Corrosion and Strengthened with External Composite Reinforcement // Structural Mechanics of Engineering Constructions and Buildings. 2024. No. 20 (4). Pp. 331–341. DOI: 10.22363/1815-5235-2024-20-4-331-341. EDN TZOMCJ.

10. Telichenko V., Rimshin V., Ketsko E. Promising directions for the artificial intelligence development in the housing and utilities sector // E3S Web of Conferences. 2024. No. 535. P. 05001. DOI: 10.1051/e3sconf/202453505001. EDN OFARFI.

11. Krishan A.L., Astafeva M.A., Rimshin V.I., Shubin I.L., Stupak A.A. Compressed Reinforced Concrete Elements Bearing Capacity of Various Flexibility // Lecture Notes in Civil Engineering. 2022. No. 182. Pp. 283–291. DOI: 10.1007/978-3-030-85236-8_26. EDN JPNURD.

12. Karpenko N.I., Rimshin V.I., Eryshev V.A., Shubin L.I. Deformation Models of Concrete Strength Calculation in the Edition of Russian and Foreign Norms // IOP Conference Series Materials Science and Engineering. 2020. No. 753 (5). P. 052043. DOI: 10.1088/1757-899X/753/5/052043. EDN TYMKCF.

13. Wang Sh., Jiang Y., Xu Y., Zhang L., Li X., Zhu L. Sustainability of Historical Heritage: The Conservation of the Xi'an City Wall // Sustainability. 2019. No. 11 (3). P. 740. DOI: 10.3390/su11030740

14. Penica M., Golovina S., Morgul V. Revitalization of Historic Buildings as an Approach to Preserve Cultural and Historical Heritage // International Scientific Conference Urban Civil Engineering and Municipal Facilities (SPBUCEMF-2015). Procedia

Engineering. 2015. No. 117. Pp. 883–890. DOI: 10.1016/j.proeng.2015.08.165. EDN UYZRDP.
15. Wang J., Zakaria S.A. Morphological Characteristics and Sustainable Adaptive Reuse Strategies of Regional Cultural Architecture: A Case Study of Fenghuang Ancient Town, Xiangxi, China // Buildings. 2025. No. 15 (1). P. 119. DOI: 10.3390/buildings15010119. EDN YPZSGO.

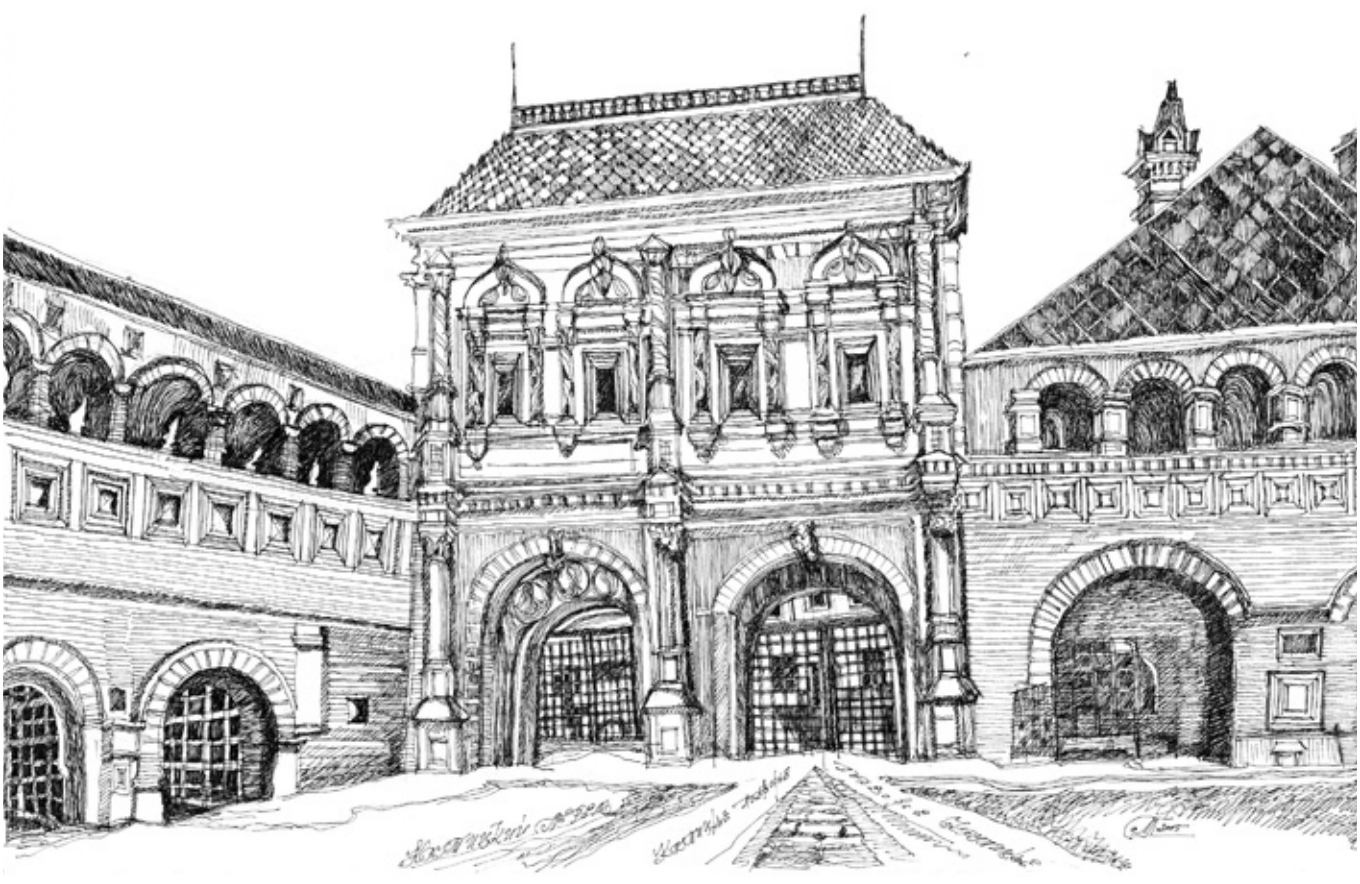
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Organizational and technological solutions for installing polymer membrane roofs in subzero temperature conditions

In conditions of sharp cold spells, typical for Arctic and similar regions, the installation of roofing requires the use of special materials and technologies capable of maintaining their operational properties at sub-zero temperatures. This paper examines organizational and technological solutions related to the use of polymer membrane roofing systems, including PVC (polyvinyl chloride), TPO (thermoplastic polyolefin), and EPDM (ethylene propylene diene monomer) membranes. A comprehensive analysis is provided of the physical and mechanical properties of these materials, with emphasis on their frost resistance, elasticity, long-term watertightness, and durability under mechanical stress. Special attention is paid to the practical aspects of installation during the winter season, including weld temperature ranges, base surface preparation, storage and transportation conditions, and measures for ensuring installation quality under strong winds, precipitation, and limited daylight hours. The article identifies key challenges encountered during cold-climate roofing operations, such as reduced seam strength due to temperature deviations, increased defect rates from poorly prepared substrates, logistical complexities, and labor shortages. Technological procedures and process maps are presented that help mitigate these risks, including preheating methods, use of protective coverings, precise control of welding equipment settings, and targeted worker training. The article emphasizes the importance of an integrated approach to project design, logistics, and work organization to ensure the high reliability and long-term performance of polymer roofing membranes in freezing climates. The study concludes with a rationale for optimal solutions that align material properties with construction process requirements.

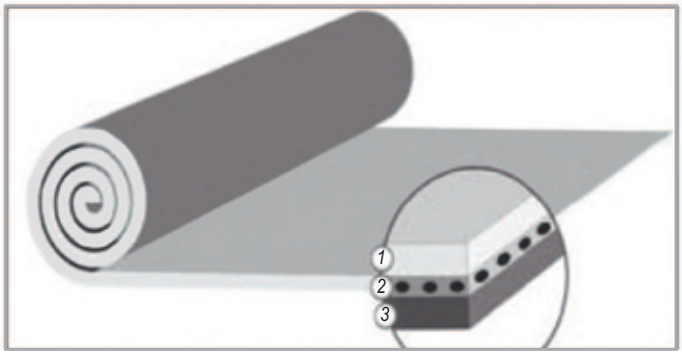
Keywords: *polymer membranes, PVC, TPO, EPDM, cold climate, roofing technology, seam sealing, mechanical fastening, hot-air welding*



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Under the sharply continental climate of Siberia, characterized by prolonged frost periods, significant temperature fluctuations, and intense wind loads, the installation and operation of polymer roofing membranes require a reassessment of both design solutions and organizational and technological approaches. When calculating structural joints, it is necessary to consider substantial temperature variations ranging from –40 °C in winter to +30 °C in summer, which cause thermal expansion and contraction of the membrane, leading to stress concentrations at fastening points and welded seams [1]. An analysis of damage observed at specific facilities in Novosibirsk, Tomsk, and Krasnoyarsk indicates that the most vulnerable zones remain junctions with parapets, pipes, and expansion joints, where violations of seam welding technology or inadequate sealing layers result in delamination, cracking, and detachment of the membrane. Roofing installation technology under cold-weather conditions requires strict control of temperature regimes during storage, transportation, and installation of roll materials: at temperatures below –15 °C, flexibility deteriorates, brittleness increases, and tensile strength decreases. Construction practice shows that improper adaptation of technology to weather conditions leads to loss of membrane watertightness already within the first years of operation. All of this forms the task of developing adaptive roofing installation technologies that include temperature-independent materials, modified seam welding methods, and a technical quality control system adapted to the conditions of Siberia and the Far North.

Polymer membrane roofing systems, especially those based on ethylene-propylene-diene rubber (EPDM), thermoplastic polyolefins (TPO), and polyvinyl chloride (PVC), are distinguished by a combination of high strength, durability, and installation efficiency [2]. EPDM membranes, manufactured as roll materials with a thickness ranging from 1.1 to 1.5 mm, demonstrate resistance to ultraviolet radiation and ozone, withstand temperature fluctuations from –40 to +120 °C, and have a service life reaching 30–35 years. TPO membranes are characterized by high reflectivity, which reduces thermal loads on the roof, and exhibit excellent resistance to ultraviolet aging [3, 4]. Standardized tests confirm welded seam strength of up to 500 N/50 mm. Installation of such roofing systems is possible at negative temperatures (down to –10 °C) using hot-air welding and special freeze-resistant sealants [5]. Modern polymer membranes have a mass of 1.2–1.5 kg/m^2, which reduces loads on load-bearing structures and simplifies installation. In addition to high installation rates (up to 600 m^2 per shift), these roofing systems demonstrate a low water absorption coefficient (less than 0.1 %), resistance to chemical substances, and resistance to biological degradation. In practice, this leads to reduced operating costs and an extended maintenance interval. Comprehensive studies confirm that the use of membrane systems makes it possible to achieve energy efficiency, minimize heat losses, and adapt roofing structures to severe climatic conditions. Laboratory aging data for PVC membranes also indicate [6] that at a temperature of –20 °C, after 100 cooling-heating cycles, up to 12 % of welded joint strength



1 — reinforcing mesh; *2* — lower PVC component; *3* — upper PVC component

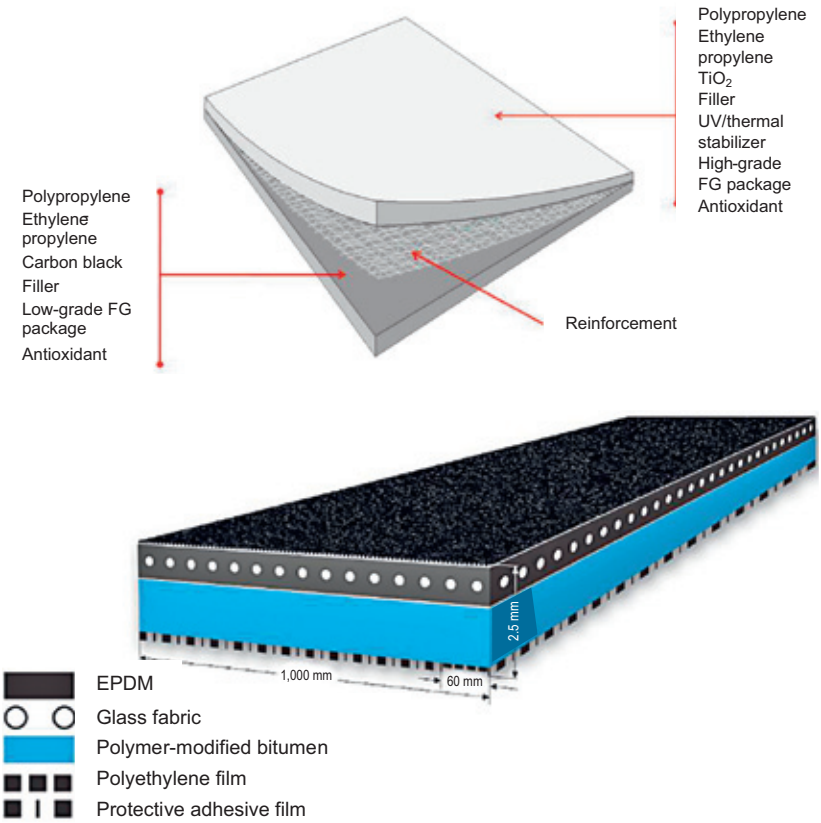


Fig. 1. Compositions of the main types of polymer membranes: PVC, TPO, EPDM [2–6]

is lost, and visual inspection reveals initial signs of microcracking at junction areas. The tests also showed that membranes based on thermoplastic polyolefins exhibit better shape stability at negative temperatures, whereas reinforced PVC membranes retain higher tensile strength (Fig. 1).

Problems arising during the installation and operation of roll and polymer roofing systems reflect systemic deficiencies at all stages, from design to quality control. The study establishes that up to 60 % of roll roofing systems in operation in Russia are in unsatisfactory condition, while more than 40 % of defects are caused by loss of watertightness and leaks [7]. The greatest difficulties occur in regions with negative temperatures: moisture penetrating into the structure freezes, increases in volume, and disrupts the integrity of the roofing system. In winter conditions of the Far North, frozen thermal insulation loses its thermal performance, and the roofing system is subjected to microcracking due to thermal contraction. With the onset of the warm period, a vapor pressure effect develops; it has been recorded that when moist insulation is heated, the partial pressure can reach $0.2 \cdot 10^5$ Pa, which provokes blistering and delamination of roll materials. The key technological violations identified include installation of membranes on a wet substrate, improper detailing of junctions, non-compliance with the required thickness of the roofing assembly, incorrect temperature conditions during mastic application, and the absence of basic quality control measures. An additional risk factor is the low qualification level of contractors: roofing crews often lack the skills to work with modern PVC or TPO membranes, fail to ensure proper seam welding, and perform installation at inadmissible temperatures below –10 °C. A significant issue is also associated with the regulatory framework, as technical regulations have not been updated for decades and do not contain

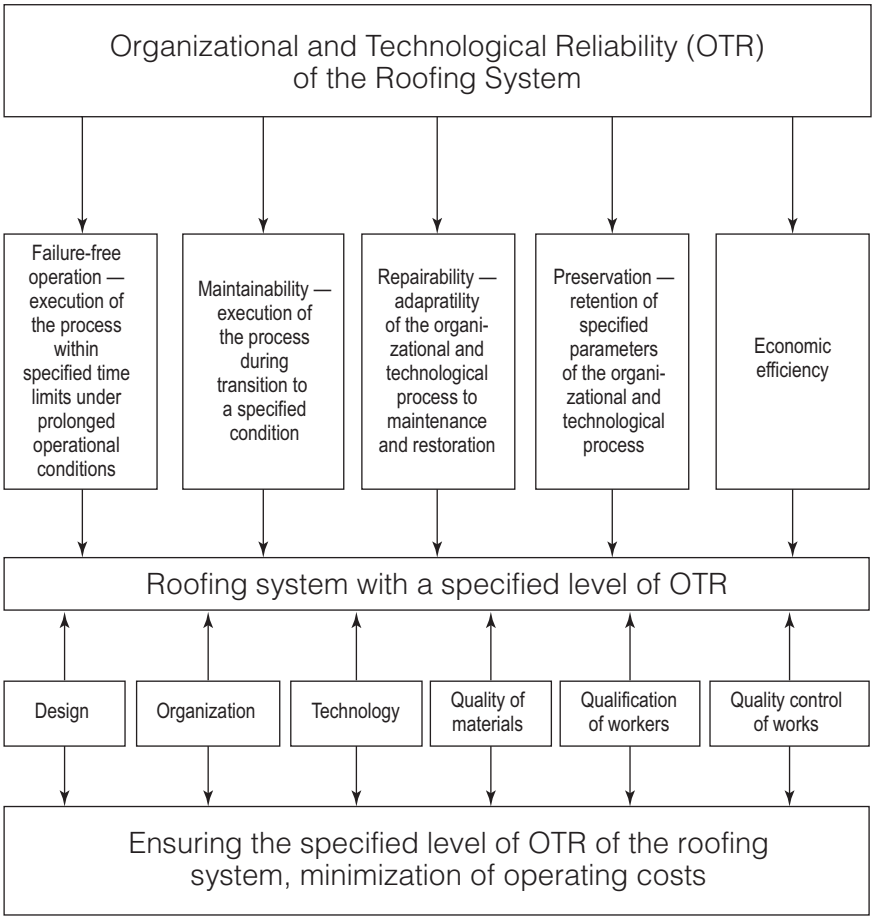


Fig. 2. Organizational and technological reliability of the roofing system [7]

requirements for the use of innovative roofing materials. As a result, contractors rely on internal guidelines provided by suppliers, which do not always account for the actual operating conditions in cold climate regions [8].

Polymer membrane roofing systems are increasingly used in construction due to their high technological efficiency, durability, and resistance to aggressive climatic impacts (Fig. 2). In cold regions, particular value is placed on the ability of PVC membranes to retain their physical and mechanical properties at low temperatures. The material thickness typically ranges from 1.2 to 2 mm, while the mass does not exceed 1.5 kg/m^2, which simplifies transportation and installation [9]. The membranes are reinforced with fiberglass, which increases their tensile strength. When installing roofing systems in northern regions, three main methods of membrane fastening are used: mechanical, adhesive, and ballasted. The mechanical method is considered the most versatile, as it can be applied at subzero temperatures and does not require the use of expensive adhesive compounds, the operation of which is limited to temperatures above +5 °C. In addition, membrane welding performed using automatic and semi-automatic equipment employs hot air at temperatures of up to 600 °C, making it possible to achieve a strong welded joint with a width of at least 35 mm without the risk of loss of watertightness.

Experience in the use of polymer membranes for flat roofs of residential buildings demonstrates high efficiency both in new construction and in reconstruction projects (Table 1). Membrane roofing systems form a continuous waterproof layer with high frost resistance, maintaining elasticity even at temperatures below –30 °C [10]. Depending on the structural characteristics of buildings and operational requirements, an inverted roofing system may be used, in which the waterproofing layer is protected by thermal insulation. This approach is especially important in severe climatic zones, where the membrane is additionally covered by insulation layers and a finishing surface (tiles, gravel), reducing the risk of mechanical damage. At the same time, ensuring the required reliability necessitates compliance with a minimum roof slope of 1 to 3 % to drain atmospheric precipitation, which is particularly critical under conditions of heavy snowfall. Design calculations assume that during intense precipitation up to 5 l of water per minute may fall on 1 m^2 of roof surface, which for an area of 500 m^2 corresponds to a load of 2.5 tons of water requiring efficient drainage through roof drains and stormwater systems. Under these conditions, the membrane must withstand repeated freeze-thaw cycles and exposure to ultraviolet radiation, which is achieved through the use of stabilizers and reinforcing layers.

A comparative analysis of roofing installation options shows that under climatic conditions with sharp temperature fluctuations, the highest efficiency is demonstrated by membrane systems installed using a mechanical fastening scheme with telescopic fasteners and automated welding [11]. Particular attention is paid to quality control of welded joints, including seam width, tightness, and the absence of overheated zones or lack of fusion, which are verified visually and by instrumental methods. Personnel training is also critically important: technological violations such as dragging

Table 1. Characteristics and technological requirements for the installation of polymer membrane roofing systems

Characteristic	Description
Flexibility and elasticity	Membranes exhibit pronounced flexibility, allowing them to compensate for temperature fluctuations and maintain the continuity of the roofing layer under deformation
Resistance to ultraviolet radiation	Special additives in the membrane composition prevent degradation caused by solar radiation, thereby extending the service life of the roofing system
Durability	When all installation requirements are met, the service life of membranes can range from 25 to 30 years; however, violations of installation technology significantly reduce this indicator
Substrate preparation	The base surface must be clean, even, and free from sharp inclusions, as any defects may cause membrane damage and accelerated wear
Mechanical fastening	Installation of membranes using anchors or self-tapping fasteners compensates for thermal movements and is well suited for pitched roofing systems
Adhesive method	The use of adhesive mastics allows sealing of complex areas but requires strict compliance with temperature conditions and thorough preparation of the substrate
Ballasted method	Loose laying of the membrane followed by ballast loading using gravel or paving slabs is suitable for roofs with slopes up to 10°, but it creates additional structural load
Hot-air welding	Membrane sheets are joined using hot air, either manually or automatically. Welding parameters are selected individually depending on membrane type and weather conditions. Quality control includes visual inspection and strength testing
Consideration of climatic conditions	For severe winter conditions, frost-resistant materials are used, with particular attention paid to the strength of welded seams and reliability of fastenings under wind and snow loads
Compliance with safety requirements	When performing work involving hot air or adhesives, proper ventilation, use of personal protective equipment, and strict adherence to recommended temperature regimes are required
Importance of weld seam quality	Deviations in temperature parameters or improper welding speed may lead to incomplete fusion, overheating, or weakening of the joint, making the seam vulnerable to damage
Installation at negative temperatures	Laying membranes without preheating at temperatures ≤ 0 °C leads to loss of elasticity and crack formation. It is recommended to preheat the material to a temperature not lower than –10 °C prior to installation

membrane rolls across the surface, failure to clean edges before welding, or installation of engineering systems without compliance with insulation requirements may lead to leaks and a reduction in the service life of the roofing system. To prevent these issues, the use of regulated quality control procedures is recommended, including seam probes, as well as maintaining a log of acceptance of concealed works. When these requirements are met, the service life of membrane roofs in cold climates can reach 40–50 years without the need for major repairs, provided timely maintenance and proper operation are ensured.

In the conditions of the Far North, the installation of polymer membrane roofing systems requires special organizational and technological solutions that take into account both low temperatures and high wind loads. Within one technical solution, a flat non-accessible roof system using a bitumen-polymer membrane with a thickness of 1.5 mm was analyzed[1]. Thermal insulation consisted of two layers of mineral wool boards with densities of 160 and 80 kg/m^3, respectively, providing a heat transfer coefficient of less than 0.16 W/m^2·°C. A vapor barrier layer based on bitumen-polymer mastic was applied with heating, which allowed adhesion to be maintained at temperatures down to –15 °C. Installation was carried out mechanically using telescopic dowels, while seam welding was performed by automated hot-air equipment at a controlled temperature of 500–600 °C, forming a strong welded seam with a width of 35 mm. Work organization followed the "thermal contour" principle: installation of insulation and membrane was performed in sections not exceeding 100 m^2 per day, with immediate completion of all layers to prevent precipitation ingress and freezing. It was noted that when these technological parameters are observed, the system maintains tightness and thermal performance even under winter operating conditions with temperatures down to –35 °C and wind loads up to 1.2 kPa. Special attention was given to personnel training: welders underwent preliminary certification, and quality control was carried out using vacuum testing devices and visual inspection of welded seams.

In another roofing installation technology based on PVC membranes (Fig. 3) adapted to low-temperature conditions, the process included rolling out the sheets, mechanical fastening along the perimeter and overlap zones, and hot-air welding using automated equipment[2]. The optimal welding temperature was 520–560 °C, with a feed speed of 2.5–3.5 m/min, resulting in a seam width of 35–40 mm. It was noted that to achieve effective seams under subzero temperatures, installation must be performed with preheating of the joint area and preliminary drying of the substrate. In particular, at a temperature of –10 °C, the heating time must be increased, and welding must be accompanied by mandatory seam density control using air pressure testing or manual peel testing. The importance of adapting work schedules to climatic conditions was also emphasized: shift duration is limited to 4–5 hours, with mandatory breaks for technical inspection of equipment and worker warming. To improve organizational and technological reliability, the use of

[1] Technological Map for a Flat Roofing System on a Profiled Base with Mineral Insulation and PVC Membrane. URL: https://nav.tn.ru/cloud/iblock/343/RF_S_PK_TN_TEKHKARTA_Tekhnologicheskaya_karta_na_dvukhsloynuyu_krovlyu_iz_naplavyalemykh_iz_RBM.pdf

[2] Technological Map for the Installation of Roofing Systems with Polymeric Membranes and Mechanical Fastening on a Reinforced Concrete Base. URL: https://isoroc.ru/sites/default/files/2024-02/

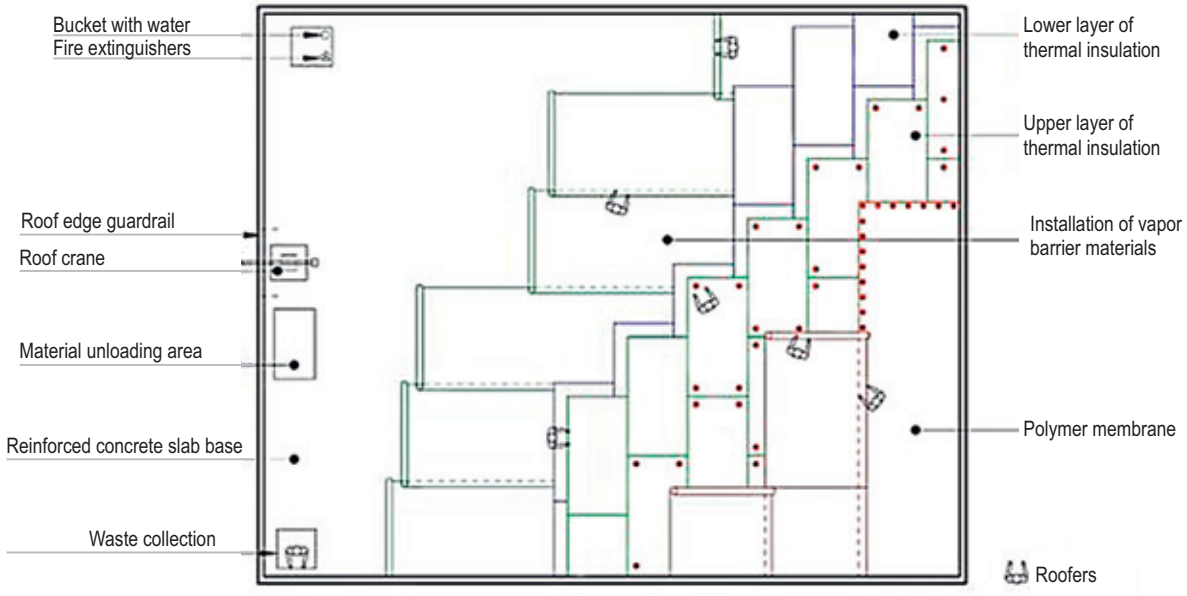


Fig. 3. Layout of workplace organization during the installation of PVC membrane roofing

mobile thermal shelters and temporary heated enclosures at the joints of installation sections was proposed, allowing stable temperature conditions to be maintained and preventing uneven quality of welded joints.

In the considered roofing installation technology using a polymer EPDM membrane, particular attention is paid to ensuring high-quality installation under subzero temperature conditions[3]. In harsh climatic environments, especially at temperatures below –10 °C, one of the key solutions is the use of membranes with internal reinforcement made of a polyester mesh, which provides high resistance to tensile loads up to 850 N/50 mm. Installation is carried out over mineral wool insulation with a low thermal conductivity coefficient ($\lambda \leq 0.038$ W/m·K), which makes it possible to reduce heat losses through the roofing assembly. The membrane is fixed mechanically using telescopic fasteners with a spacing of no more than 200 mm along the perimeter and 300 mm in the field area, which is particularly critical under wind loads typical of northern regions. Seams are welded with hot air at a temperature of 500–600 °C, with mandatory quality control of the welded joint performed visually (uniform dark line) and using a test probe. At the work organization stage, strict temperature regulation is an essential requirement: membrane rolls must be stored in a heated space for at least 12 hours at a temperature not lower than +10 °C before installation, and welding is carried out with adjustments based on a temperature chart that defines welding parameters depending on ambient temperature. In addition, a multi-stage quality control system is implemented, including verification of substrate preparation, weather conditions, welding quality, and compliance with fastening technology. The application of this technology significantly reduces the risk of installation defects and extends the service life of the roofing system to up to 30 years, even under extreme climatic conditions.

Under subzero temperature conditions, reliable installation of roofing systems using polymer membranes requires a special approach to organizational and technological solutions (Table 2). One such solution is the application of mechanically fastened TPO membranes followed by hot-air welding of seams[4]. To ensure coating strength at low temperatures down to –25 °C, the use of equipment with automatic control of temperature, feed speed, and welding pressure becomes a critical requirement, as it prevents the formation of defective seams. The document indicates that the optimal welding temperature range is from +480 to +540 °C at a speed of 2.5–3.5 m/min. Installation is carried out using a sectional laying technique, where membranes are rolled out and temporarily fixed, after which seams with a width of 30–35 mm is welded. To ensure roof tightness under Far North conditions, the mandatory use of a vapor barrier layer (for example, bitumen-impregnated fiberglass mat) and thermal insulation with a thermal conductivity coefficient not exceeding 0.033 W/(m·°C), arranged in two layers, is required. The membrane is fastened to the base through all layers of the roofing assembly using telescopic fasteners installed at a spacing of no more than 300 mm along the perimeter and 500 mm in the central zone of the membrane sheet. Special attention is given to sealing junctions, corners, and roof drains, where an additional reinforced tape is used and welded along the perimeter of the connections. Quality control is performed using peel tests and visual inspection of welded seams. The necessity of strict compliance with temperature requirements for storage and transportation of materials (not lower than +5 °C) is emphasized, as well as mandatory preheating of membrane rolls in an insulated module prior to installation.

The reviewed materials and technologies for installing polymer membrane roofing systems have shown that their performance under subzero temperature conditions is largely determined not only by the properties of the materials themselves, but also by well-structured organizational and technological solutions. Successful application is possible only through an integrated approach that includes adaptation of installation technologies to climatic conditions, strict quality control of works, preliminary preparation of substrates, and compliance with temperature regimes at all stages. The identified problems, including a shortage of qualified personnel and an underdeveloped regulatory framework, limit the possibilities

[3] Installation Manual for EPDM Membrane. URL: https://construction-engineer.ru/wp-content/uploads/2021/07/ Инструкция-по-монтажу-ЭПДМ-EPDM-мембраны.pdf

[4] Installation Instructions for TPO Roll Waterproofing Membranes from Sika. URL: https://construction-engineer.ru/wp-content/uploads/2021/03/Инструкция-по-укладке-рулонной-гидроизоляции-из-ТПО-мембран-от-компании-Sika.pdf

Table 2. Composition of operations and control procedures for polymer membrane roofing systems

Work Stage	Requirements for Parameters	Method and Scope of Inspection	Controlled Indicators
Inspection of welding equipment before work start	Equipment must be technically sound and ensure stable welding temperature and speed	Visual inspection and functional check of the equipment prior to commencement of work	Equipment operability, heating stability
Visual inspection of the welded seam	The seam must be even, without pores, swelling, folds, burn-throughs, or delamination	After completion of welding, a visual inspection of the seam condition is carried out	Integrity and external appearance of the welded joint
Manual non-destructive seam test	After complete cooling, the seam must not delaminate; in case of rupture, the material should tear outside the seam	The seam is manually gripped and sharply stretched to assess adhesion strength	Uniformity of the joint, absence of delamination
Tensile strength test	The rupture location must occur in the base membrane, not along the seam line	The seam is torn manually or using tools, and joint strength is recorded	Strength and reliability of the welded seam
Control of the applied weld bead	The deposited material bead must have uniform thickness without excess or deficiency	During welding, visual inspection of bead shape and uniformity is performed	Uniformity and correct geometry of the deposited layer
Airtightness check of the welded seam	The seam must be completely airtight, preventing air penetration	Pressurized air is supplied into the welding channel using a compressor, followed by pressure testing	Airtightness of the seam
Vacuum leak test	No air leaks should be detected in the seam	A foaming solution is applied, and a vacuum bell is used to detect defects by bubble formation	Presence or absence of leaks in the welded joint

for widespread and reliable use of modern membrane roofing systems in northern regions. At the same time, the potential of such systems remains high, and further research and development should focus on improving installation technologies, quality control tools, and methods for adapting roofing solutions to extreme climatic conditions.

REFERENCES

1. Mishin A.G., Pichugin A.P., Khritankov V.F., Denisov A.S., Kudryashov A.Yu. Features of Construction and Technical Operation of Membrane Roofs in Siberia. Construction materials. 2018; 10:53-58. DOI: 10.31659/0585-430X-2018-764-10-53-58. EDN VLSWIO. (rus.).
2. Mitchell R. Polymer Modified and Cold Process Roofing. IIBEC. 2002; 45-58. URL: https://iibec.org/wp-content/uploads/2002-11-mitchell.pdf
3. Roberts K. Roofing Materials and Systems. CIB World. 2022; 42.
4. Andrej I., Samo L. Durability and Degradation of PVC-P Roofing Membrane — Example of Dynamic Fatigue Testing. Polymers. 2022; 14(7):1312. DOI: 10.3390/polym14071312
5. Jeremey H., Sarah K., Hikaru M., Katerina T. Greener Solutions for TPO Polymer Membrane Roofing. Berkeley Center for Green Chemistry. 2018; 56-70. URL: https://bcgc.berkeley.edu/sites/default/files/ecoblock-final-report_wrefs_final_2018.pdf
6. Thomas D. Economic Impact of Improved Service-Life Prediction for Seams in Low-Slope EPDM Roofing. Conference: Ideas to Impact: How Building Economic Standards Keep You on Track. 2014; 22. DOI: 10.1520/STP158620140035
7. Radkevich A.V., Khudenko V.F., Glushchenko V.M. Existing Problems Analysis of Organizational and Technological Reliability of Roofing Systems. Science and Progress in Transport. 2015; 2(56):222-230. EDN UCMCXP. URL: https://cyberleninka.ru/article/n/analiz-suschestvuyuschih-problem-organizatsionno-tehnologicheskoy-nadezhnosti-krovelnyh-sistem (rus.).
8. Karpov G.N. Membranes demand attention, repairs and care. Vestnik of Orendurg State University. 2006; 2-2(52). EDN JVGPYT. URL: https://cyberleninka.ru/article/n/problemy-pri-ustroystve-rulonnyh-krovel-i-ih-reshenie (rus.).
9. Dzhankulaev A.A., Tukhuzheva L.A. Application of polymer membrane roofing materials. Issues of Science and Education. 2020; 2(85):85-87. EDN ZBCSDE. (rus.).
10. Luzhnov E.A. Method of membrane roof device. Step to Science. 2021; 2:31-34. EDN NKTGNT. (rus.).
11. Latuta V.V., Efimov Yu.M. Flat Roofs of Residential Buildings: Technical Solutions of Roof Structures and Their Installation. Colloquium-journal. 2019; 22-1(46):22-29. DOI: 10.24411/2520-6990-2019-10711. EDN DGDKDR. URL: https://cyberleninka.ru/article/n/ploskaya-krovlya-zhilyh-zdaniy-tehnicheskie-resheniya-konstruktsiy-krovli-i-ih-ustroystvo

Организационно-технологические решения по устройству кровель из полимерных мембран в условиях отрицательных температур

В условиях резкого похолодания, характерного для арктических и приравненных к ним регионов, устройство кровельных покрытий требует применения особых материалов и технологий, способных сохранять эксплуатационные свойства при отрицательных температурах. В статье рассматриваются организационно-технологические решения, связанные с применением полимерных мембранных кровель, включая системы на основе ПВХ (поливинилхлорид), ТПО (термопластичные олефины) и ЭПДМ (этилен-пропилен-диен-мономер). Проведен всесторонний анализ свойств и характеристик этих материалов, с акцентом на их устойчивость к морозам, эластичность, способность сохранять герметичность и стойкость к механическим нагрузкам. Особое внимание уделено практическим аспектам монтажа кровельных систем в зимний период, включая температурные режимы сварки швов, особенности подготовки основания, допустимые условия транспортировки и хранения, а также мероприятия по обеспечению стабильности укладки в условиях сильного ветра, осадков и ограниченной световой активности. Также выделены ключевые проблемы, возникающие при реализации подобных работ: снижение прочности соединений при нарушении температурного режима, рост числа дефектов из-за некачественной подготовки основания, трудности в логистике и нехватка квалифицированных кадров. В статье представлены технологические карты и приемы, позволяющие минимизировать риски в процессе

монтажа, включая использование предварительного прогрева, применение тентов и временных укрытий, контроль над параметрами сварочного оборудования и обучение персонала. Подчеркивается необходимость комплексного подхода к проектированию, логистике и организации производства работ, направленного на обеспечение высокой надежности и долговечности полимерных кровель в условиях отрицательных температур. В результате обоснованы оптимальные решения, сочетающие свойства материалов и требования к технологии монтажа.

Ключевые слова: *полимерные мембраны, ПВХ, ТПО, ЭПДМ, холодный климат, кровельные технологии, герметизация швов, механическое крепление, сварка горячим воздухом*

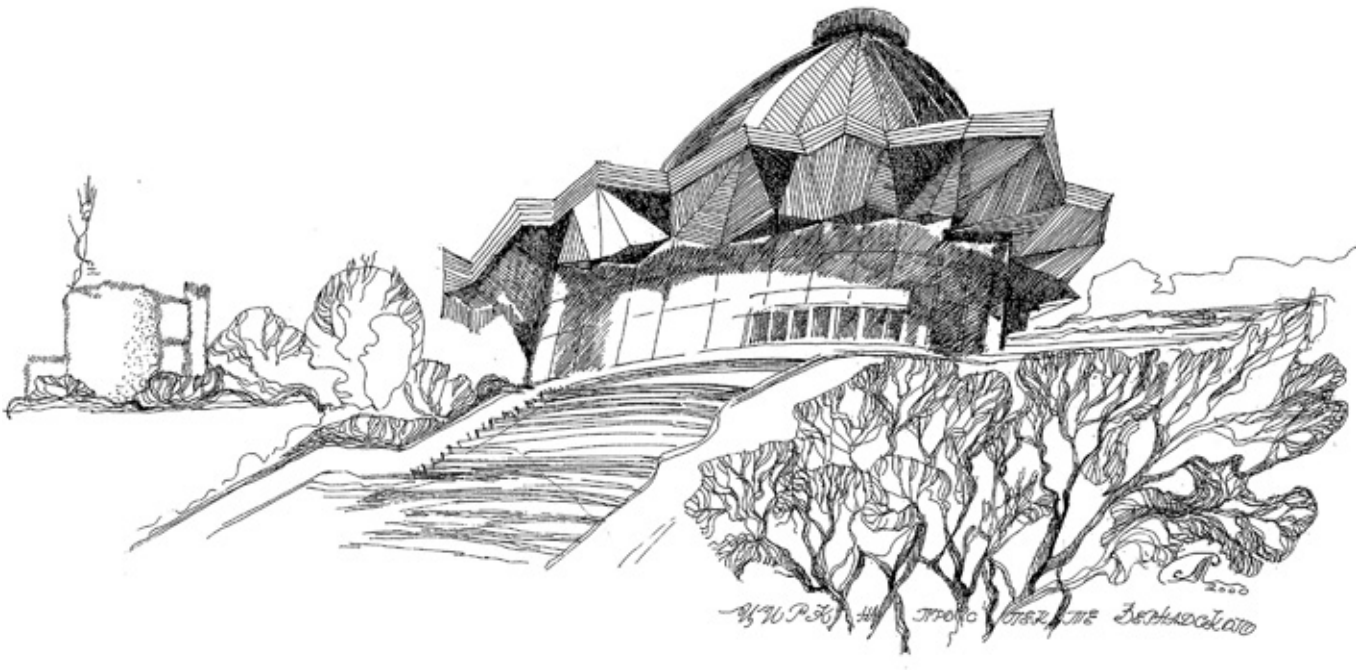
СПИСОК ИСТОЧНИКОВ

1. Мишин А.Г., Пичугин А.П., Хританков В.Ф., Денисов А.С., Кудряшов А.Ю. Особенности устройства и технической эксплуатации мембранных кровель в Сибири // Строительные материалы. 2018. № 10. С. 53–58. DOI: 10.31659/0585-430X-2018-764-10-53-58. EDN VLSWIO.
2. Mitchell R. Polymer Modified and Cold Process Roofing // IIBEC. 2002. Pp. 45–58. URL: https://iibec.org/wp-content/uploads/2002-11-mitchell.pdf
3. Roberts K. Roofing Materials and Systems // CIB World. 2022. 42 p.
4. Andrej I., Samo L. Durability and Degradation of PVC-P Roofing Membrane — Example of Dynamic Fatigue Testing // Polymers. 2022. No. 14 (7). P. 1312. DOI: 10.3390/polym14071312
5. Jeremey H., Sarah K., Hikaru M., Katerina T. Greener Solutions for TPO Polymer Membrane Roofing // Berkeley Center for Green Chemistry. 2018. Pp. 56–70.
6. Thomas D. Economic Impact of Improved Service-Life Prediction for Seams in Low-Slope EPDM Roofing. Conference: Ideas to Impact: How Building Economic Standards keep you on Track. 2014. 23 p. DOI: 10.1520/STP158620140035
7. Радкевич А.В., Худенко В.Ф., Глущенко В.М. Анализ существующих проблем организационно-технологической надежности кровельных систем // Наука и прогресс транспорта. Вестник Днепропетровского национального университета железнодорожного транспорта. 2015. № 2 (56). С. 222–230. EDN UCMCXP. URL: https://cyberleninka.ru/article/n/analiz-suschestvuyuschih-problem-organizatsionno-tehnologicheskoy-nadezhnosti-kro-velnyh-sistem
8. Карпов Г.Н. Проблемы при устройстве рулонных кровель и их решение // Вестник ОГУ. 2006. № 2–2 (52). EDN JVGPYT. URL: https://cyberleninka.ru/article/n/problemy-pri-ustroystve-rulonnyh-krovel-i-ih-reshenie
9. Джанкулаев А.А., Тухужева Л.А. Применение полимерных мембранных кровельных материалов // Вопросы науки и образования. 2020. № 2 (85). С. 85–87. EDN ZBCSDE.
10. Лужнов Е.А. Методы устройства мембранных кровель // Шаг в науку. 2021. № 2. С. 31–34. EDN NKTGNT.
11. Латута В.В., Ефимов Ю.М. Плоская кровля жилых зданий: технические решения конструкций кровли и их устройство // Colloquium-journal. 2019. № 22–1 (46). С. 22–29. DOI: 10.24411/2520-6990-2019-10711. EDN DGDKDR. URL: https://cyberleninka.ru/article/n/ploskaya-krovlya-zhilyh-zdaniy-tehnicheskie-resheniya-konstruktsiy-krovli-i-ih-ustroystvo

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Multi–Criteria Assessment of Organizational Forms for the Production Base for Construction of NPP with VVER–1200

The paper is devoted to solving the scientific-practical problem of multi-criteria assessment of alternative organizational forms for the production base (OFPB) for the construction of nuclear power plants with VVER-1200 reactor units. A classification of Russian regions into four categories is proposed, depending on the availability and degree of development of existing production and transport infrastructure and other criteria influencing the determination of the preferred OFPB. Six alternative organizational forms are formulated, including a comprehensive production base at the NPP construction site, a large inter-district base, a self-sufficient regional base, a mobile on-site base, a minimally necessary base oriented towards external supply, as well as repair and modernization of existing capacities. Each alternative is assessed against a number of criteria: economic, territorial, reliability assurance criteria, temporal and organizational criteria. To solve the multi-criteria problem, the globally proven Analytic Hierarchy Process (AHP) method by T. Saaty is applied, including procedures for pairwise comparisons of criteria and alternatives with verification of the consistency of expert assessments. Full calculations are carried out with the determination of local and global priorities for all alternatives. The results of the study demonstrate that the determination of the preferred organizational form for the production base significantly depends on regional conditions, including the level of infrastructure development, investment strategy, and long-term plans for nuclear energy development in the region. The presented methodology can be applied to justify organizational and technological decisions at the pre-project stage of constructing new power units for NPP with VVER-1200.
Keywords: *organizational form of the production base, VVER-1200, Analytic Hierarchy Process, multi-criteria assessment, Saaty method*



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The construction of nuclear power plants is one of the most complex and resource-intensive types of production activity. The modern energy strategy of Russia envisions the development of nuclear energy as a priority direction to ensure the country's energy security and increase the share of peaceful nuclear power in the nation's generating capacity. In accordance with the General Scheme for the Placement of Electricity Generation Facilities for the Period up to 2042[1], the construction of new nuclear capacities of about 29.3 GW is planned on the territory of the Russian Federation, including replacement power units at existing sites and completely new stations in the territories of Siberia, the Urals, and the Far East.

The core of this development programme consists of power units with Generation III+ VVER-1200 reactor units. This reactor type possesses high safety characteristics, economic efficiency, and has a unified nature, allowing for the application of standard design solutions at various construction sites.

The construction of complex multi-unit facilities, which include nuclear power plants, is based on the organizational and technological principles of flow production. The application of the flow construction method allows for the rationalization of labour resource use, reduction of overall construction timelines for the complex of buildings and structures, and reduction of work costs [1, 2]. However, the implementation of the flow method requires the creation of an adequate production base.

[1] General plan for the placement of power generation facilities on the territory of the Russian Federation for the period up to 2042. Moscow, Ministry of Energy of Russia, 2024. URL: http://government.ru/docs/53923/ (rus.).

The production base for construction represents an integrated complex of stationary and temporary facilities, enterprises, engineering and transport infrastructure, and logistics systems designed to provide construction with material and technical resources: structures, products, semi-finished goods, technological equipment, etc., performing functions of receiving, storing, pre-processing, kitting, and supplying resources to the site of construction and installation works. The purpose of this complex is to create finished construction products, namely fully prepared for operation objects of production and non-production purposes.

The organizational form of the production base significantly influences the technical and economic indicators of the project, and its assessment is a multi-criteria task, the solution of which requires analysis of many parameters, including regional conditions of the construction site, availability of existing production capacities, investment strategy, and the need for a multiplier effect in regional economic development.

The aim of this study is to formulate and solve the task of assessing organizational forms for the production base for construction of NPP with VVER-1200 using the Analytic Hierarchy Process (AHP).

Determination of the preferred organizational form of the production base significantly depends on the regional conditions of construction. Regional conditions in this work are understood as the availability and quality of existing production and transport infrastructure, geographical location relative to centers of raw material and material production, availability of qualified labour resources, and other socio-economic criteria.

The availability of existing production capacities significantly influences the choice of OFPB. Regions with developed industry (Ural Federal District, Krasnoyarsk Krai) possess sufficient potential for localizing production. Remote regions (Far Eastern Federal District) have limited localization potential and often require the development of new production capacities or transportation of material resources over long distances.

Transport accessibility determines the cost of material delivery. Thus, the availability of railway and water transport significantly reduces transportation costs. Territories remote from main transport arteries require the creation of temporary roads and ports, which increases capital costs.

Labour resources and the availability of a qualified workforce with experience in NPP construction influence the choice of construction production technologies. Regions with a shortage of such labour resources require attracting personnel from other regions or training and upskilling existing specialists.

Based on the analysis of regional conditions of the Russian Federation, the following groups of regions can be distinguished. The first group includes industrially saturated regions of the European part of Russia with well-developed industrial and transport infrastructure (Leningrad, Voronezh, Smolensk, Rostov, and Kursk oblasts). The group is characterized by a high concentration of suppliers and a relatively short delivery distance.

The second group is proposed to include resource-self-sufficient regions with a developed industrial cluster (Sverdlovsk, Chelyabinsk oblasts).

The third group includes territories with limited transport accessibility (Murmansk Oblast). There is railway and water communication, but it is overloaded or has a limited navigation period.

The last group includes pioneering development territories (Primorsky Krai, Khabarovsk Krai, Norilsk, Republic of Sakha (Yakutia), Chukotka Autonomous Okrug), characterized by the absence of sufficient infrastructure for constructing high-capacity NPP and significant remoteness from domestic suppliers.

A comparison of groups of regions where NPP power units are being built or planned for construction (according to the General Scheme for the Placement of Electricity Generation Facilities up to 2042)[1] is provided in Table 1.

In accordance with the analysis of regional conditions, the following alternative organizational forms for the production base for construction of NPP with VVER-1200 are proposed for consideration:

1. *Comprehensive production base at the NPP construction site.* A fully deployed construction base, whose production capacities allow for the manufacture of the entire range of reinforced concrete products, the entire quantity of commercial concrete and metal products, and the storage and processing of all material resources necessary for the construction process[2].

2. *Large self-sufficient production base of inter-district, inter-oblast significance*, intended for the construction of a series of power units or several stations in areas with underdeveloped infrastructure and significant remoteness from manufacturers of technological equipment. Such a base covers the construction needs for materials, products, and structures; long-term storage of the entire set of incoming equipment is provided on its territory, along with its inspection, pre-installation preparation, and assembly into larger units. The use of such a base occurs over 10–12 years, and in some cases, it is used as a regional base, meeting the needs of NPP construction at other sites located at a distance from the construction and installation base. For such bases, it is advisable to design buildings and structures in a permanent version [3].

3. *Self-sufficient production base of district, nodal significance.* This alternative is similar to the previous one but is used within the needs of an economic administrative district or a node of concentrated construction — a single NPP project.

4. *Small on-site base in a mobile version.* Designed for the construction of one or two NPP power units in an industrially developed area. Performs limited functions and, as a rule, serves as a complement to the main method of supplying material resources from large nodal enterprises capable of meeting most of the construction needs. An on-site base from a previously built industrial object or a construction plant intended to meet the needs of mass construction can be used. The base is equipped with temporary buildings

[2] OTPS, VOLUME 10 SECTION 1. Organizational and technological rules for the construction of nuclear power plants with WWER 1200 reactors : Order of the State Corporation Rosatom dated December 28, 2022 No. 1/1807-P (rus.).

Table 1. Comparison of regional groups

Regional group	Group characteristics	Regions in the group where NPP power units are being built or planned for construction	NPP Unit Types
1. Industrially-saturated regions	High supplier concentration (average delivery distance <300 km). Developed transport network. Presence of an operating NPP and a satellite city with qualified labour resources	Leningrad Oblast (LAES-2) Voronezh Oblast (NAES-2) Smolensk Oblast (Smolensk NPP-2) Rostov Oblast (Southern NPP) Kursk Oblast (Kursk NPP-2)	VVER-1200 VVER-1200, VVER-optim VVER-optim VVER-optim VVER-TOI
2. Resource-self-sufficient regions with a developed industrial cluster	Regions with powerful metallurgical, cement, and other industries	Sverdlovsk Oblast (Reftinskaya NPP) Chelyabinsk Oblast (South Ural NPP)	RBN RBN
3. Territories with limited transport accessibility	Regions with limited logistics, predominantly by sea or overloaded railway routes	Murmansk Oblast (Kola NPP-2)	VVER-S/600
4. Pioneering development territories	Absence of infrastructure sufficient for constructing high-capacity NPP. Significant remoteness from suppliers (delivery distance reaches > 5,000 km). Presence of seismic activity and harsh climate. Shortage of specialized personnel and material resources	Primorsky Krai (Primorskaya NPP) Khabarovsk Krai (Khabarovskaya NPP) Krasnoyarsk Krai (Norilsk ASMM) Republic of Sakha (Yakutsk ASMM) Chukotka Autonomous Okrug (Chukotka ASMM)	VVER-1000 VVER-S/600 RITM-400 RITM-200N Shelf-M

with mobile equipment, designed for multiple uses and rapid relocation. During NPP construction using such a production base, the organization of material, component, and technological equipment supplies must strictly follow the schedule to avoid construction delays [3].

5. *Minimally necessary on-site base with an orientation towards external supply* of the maximum possible quantity of products. The mandatory facilities of such a base must include: a concrete plant for constructing critical structures with a capacity, reinforcement and formwork shop for manufacturing small piece metal products and sites for their assembly into installation fragments, storage and pre-installation preparation sites for main equipment, sections for ventilation, anti-corrosion, painting, and insulation works, as well as a canteen and an administrative and amenity building (AAB)[2].

6. *Repair and modernization of existing production capacities.* This organizational form, unlike the previous considered alternatives, does not involve investing capital expenditures in the erection of new production capacities. All funds are directed towards the repair and modernization of existing production facilities of inter-district, inter-oblast, and district, nodal significance located in the construction region, with subsequent contractual reservation of all or part of the capacities for the construction of the NPP.

The task of assessing organizational forms of production bases is multi-criteria, as all alternatives possess advantages and disadvantages relative to each other. Solving such a task requires the application of mathematical methods that allow synthesizing multiple criteria into a single assessment of the preference of each alternative.

The Analytic Hierarchy Process (AHP), developed by Thomas Saaty [4], is one of the most effective approaches to solving multicriteria choice problems. AHP is based on pairwise comparisons of criteria by importance and alternatives for each criterion, which allows considering subjective expert assessments and overcoming the problem of incommensurability of different criteria.

Based on the conducted analysis of design-estimate and working documentation for various NPP projects with VVER-1200, as well as regulatory and technical documentation, scientific, educational, and methodological literature[3, 4] [5–11], the following assessment criteria are proposed for use:

1. Economic:

- *capital costs for creation, repair, or modernization of production capacities* — one of the key indicators of the economic feasibility of the assessed OFPB. Minimizing capital costs allows reducing the project's investment requirements;
- *logistics costs for the supply of material and technical resources*: structures, products, semi-finished goods, technological equipment, etc. Determined by logistics supply schemes, transportation distance, cost of transport services, and capital investments in creating transport infrastructure and transshipment points. High logistics costs significantly affect the final cost of materials;
- *risk of cost increase for produced products* — the criterion is associated with inflationary costs, currency fluctuations, changes in the regulatory framework, and other factors influencing the cost of material and technical resources.

2. Territorial:

- *proximity of the production base to the construction site* — influences both logistics costs and the possibility of real quality control and storage conditions;
- *area of alienated territories* — the total area of land plots required for locating the NPP construction production base.

3. Reliability Assurance Criteria:

- *supply reliability* — characterized by the fault-free normal functioning of the supply chain (under given operating conditions) considering the influence of the external environment [12];
- *quality control of incoming products* — determines the possibility of ensuring that material and technical resources comply with the requirements of design and working documentation and regulatory documents. A high level of quality control is critically important for nuclear energy facilities.

4. Temporary:

- *timeframes for production capacities to reach the required productivity level* — influence the duration of the preparatory period and represent the time interval from the decision to erect, repair, or modernize production capacities until reaching a productivity level capable of covering the NPP's needs at the construction stage corresponding to the commissioning of said capacities;
- *risk of schedule disruption (of the Work Production Schedule — WPS)* — characterizes the probability of disruption to the Work Production Schedule (WPS) timeline in case of problems with the main supply channel for material and technical resources.

5. Organizational:

- *manageability* — characterizes the degree of complexity in managing and coordinating various elements of the production base and the necessary costs for managerial personnel and control systems.

Based on the results of forming various alternative OFPB for NPP construction with VVER-1200 and selecting assessment criteria, a hierarchical representation of the task was built (Fig. 1).

The further algorithm for solving the task includes the following steps [15]:

- formation of a table of characteristics for economic, territorial, reliability, temporal, and organizational criteria K_i of alternatives A_i for the OFPB for NPP construction with VVER-1200;
- selection of a set N of non-dominated alternatives (Pareto set) from the general set of alternatives n. All alternatives are pairwise compared with each other according to all criteria. If during the comparison of any alternatives it turns out that one is not better than the other in any criterion, then it can be excluded from consideration. The excluded alternative does not need to be compared with other alternatives, as it is clearly unpromising;
- expert assessment of the criteria for choosing a rational OFPB by degree of importance is performed. The expert fills out a pairwise comparison matrix of size $K \times K$, where K is the number of criteria. The rules for filling the matrix are indicated in Table 2.

Intermediate values (2, 4, 6, 8, 1/2, 1/4, 1/6, 1/8) can be used for assessment;

- processing of assessments using methods of expert analysis is performed. There are a number of algorithms implementing the pairwise comparison method: they differ in the number of expert assessments used (individual and collective

[3] Morozenko A.A., Subbotin A.S., Kolchin V.N., Shashkov A.A. *Organizational and technological solutions for the main buildings of thermal power plants and nuclear power plants : a teaching aid (educational electronic publication)*. Moscow, Publishing house of MISI – MGSU, 2019. URL: https://rusneb.ru/catalog/000199_000009_010358433/ (rus).

[4] Subbotin A.S., Shashkov A.A., Kuzmin N.Yu., Voronkov I.E. *Technology and organization of construction of buildings and structures of thermal and nuclear power engineering : a teaching aid (educational electronic publication)*. Moscow, MISI – MGSU, 2020. URL: https://rusneb.ru/catalog/000199_000009_010669863/ (rus).

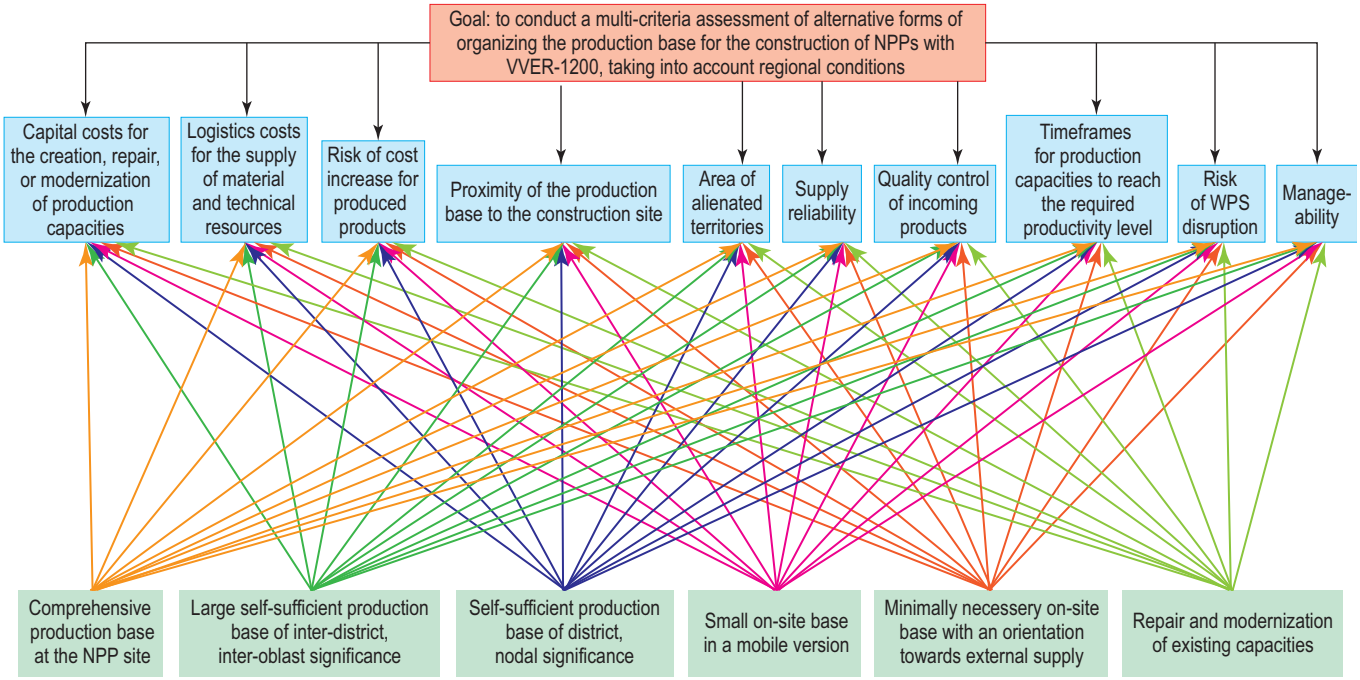


Fig. 1. Hierarchical representation of the multi-criteria task for assessing organizational forms of the production base for NPP construction with VVER-1200 for solution by the Analytic Hierarchy Process method

Table 2. Rules for filling the pairwise comparison matrix according to the Saaty method

X_{ij}	Value
1	The *i*-th и *j*-th criteria are approximately equal in value
3	*i*-th criterion is slightly more important than the *j*-th
5	*i*-th criterion is more important than the *j*-th
7	*i*-th criterion is significantly more important than the *j*-th
9	*i*-th criterion is clearly more important than the *j*-th

assessments), in scales for comparing alternatives, etc. This work uses the most widely applied pairwise comparison method (Saaty method). However, since the Saaty method is based on comparing alternatives performed by one expert, the agreed assessment of the author's team will be adopted as the criterion importance assessments in the further calculation.

The PRICE of each criterion is determined by formula (1) — geometric means of the matrix rows:

$$C_i = \sqrt[K]{\prod_{j=1}^{K} X_{ij}}, \quad (1)$$

where X_{ij} is the importance assessment of criterion K_i relative to K_j; $i = 1, \ldots, K$.

The sum of the prices of all criteria is found (2):

$$C = \sum_{i=1}^{K} C_i. \quad (2)$$

Local priorities (criterion weights) are calculated, formula (3):

$$L_{K_i} = V_i = C_i / C; \quad (3)$$

- verification of expert assessments for consistency is performed.

The sums of the columns of the pairwise comparison matrix is determined (4):

$$R_j = \sum_{i=1}^{K} X_{ij}, \quad (4)$$

where $j = 1, \ldots, K$.

An auxiliary quantity λ is calculated by summing the products of the column sums of the matrix by the criterion weights, formula (5):

$$\lambda = \sum_{j=1}^{K} R_j \cdot V_j; \quad (5)$$

- using formula (6), a quantity called the Consistency Index (*CI*) is found:

$$CI = (\lambda - N)/(N - 1). \quad (6)$$

- depending on the dimension of the pairwise comparison matrix, the Random Consistency Index (*RCI*) is found. The *RCI* values are given in Table 1.6 [15]. For the previously selected ten criteria ($K = 10$), $RCI = 1.49$.
- the Consistency Ratio (*CR*) is found (7):

$$CR = CI/RCI. \quad (7)$$

If the consistency ratio exceeds 0.2, then refinement of the pairwise comparison matrix is required:

- formation of $N \times N$ matrices of pairwise comparisons of alternatives A_i for each criterion K_j;
- determination of local priorities of alternatives A_i relative to criterion K_j ($L_{A_i}^{K_j}$) similarly using formulas (1)–(3);
- calculation of global priorities of alternatives using formula (8):

$$G_{A_i} = \sum_{j=1}^{K} L_{A_i}^{K_j} \cdot L_{K_j}, \quad (8)$$

where $i = 1, \ldots, N$;

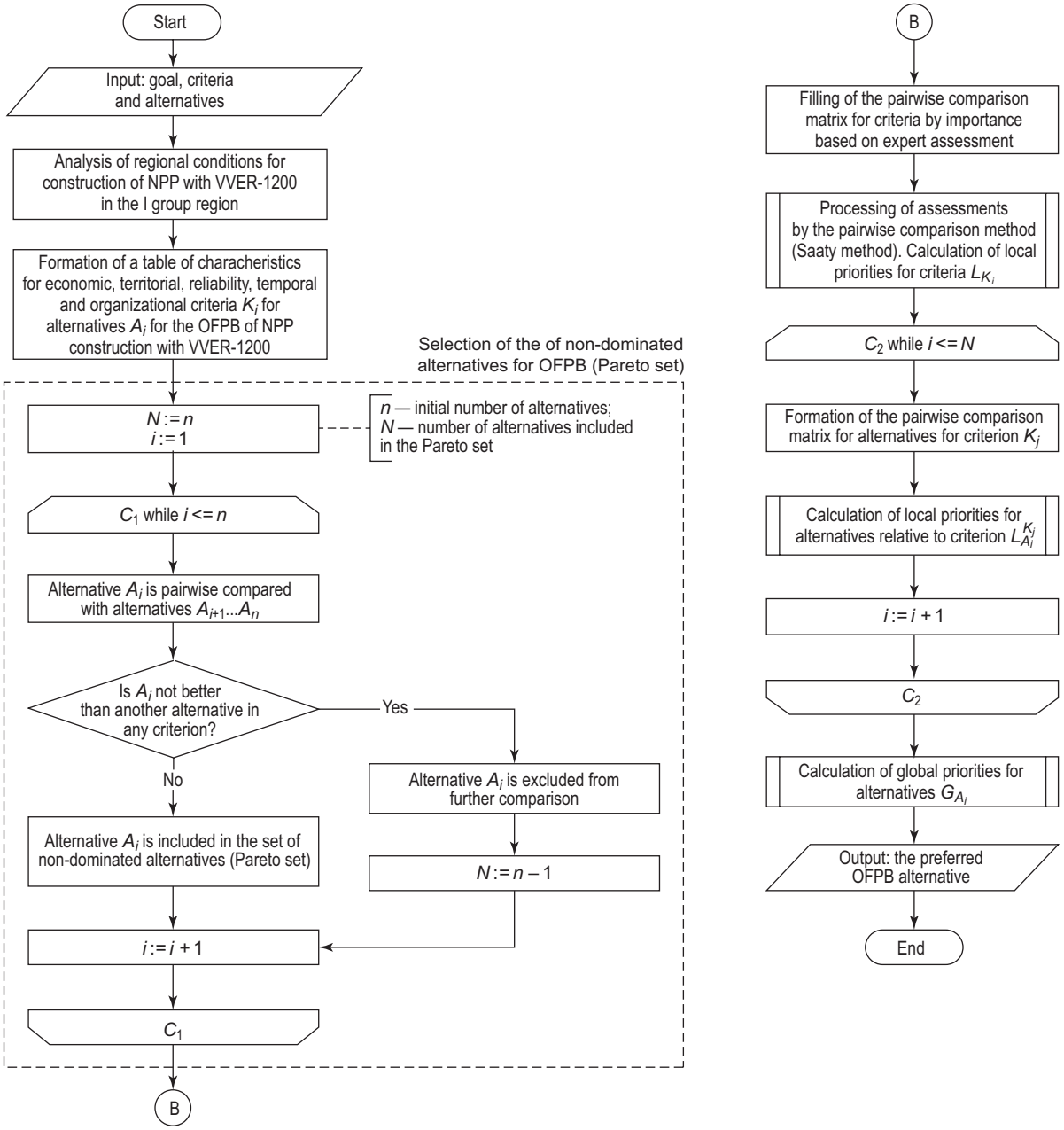


Fig. 2. Flowchart of the algorithm for assessing the OFPB for NPP construction with VVER-1200

- the highest global priority corresponds to the preferred alternative for the organizational form of the production base for NPP construction with VVER-1200 (considering all criteria and their degree of importance) in the selected regional conditions.

Let's consider a calculation example for an NPP project with VVER-1200 in a Category I region, as the most realistic within construction in the Russian Federation.

Goal: to perform a multi-criteria assessment of alternative organizational forms for the production base for NPP construction with VVER-1200 considering regional conditions.

The algorithm flowchart is presented in Fig. 2.

Let's form a table of characteristics for criteria K_i of alternatives A_i (Table 3).

None of the alternatives is worse than another in all criteria; the Pareto set includes all 6 presented alternatives.

The expert assessment of criteria for choosing a rational OFPB by degree of importance is presented in Table 4.

Table 5 summarizes the values of local priorities for all criteria.

The Consistency Ratio CR = 0.046 < 0.2, therefore, matrix refinement is not required.

Similarly, the local priorities of alternatives A_i relative to criterion K_j are determined (values are presented in Fig. 3).

The final values of global priorities for alternatives are indicated in Table 6.

Based on the obtained results, it can be concluded that the preferred organizational form for the production base for NPP construction with VVER-1200 for conditions in the European part of Russia is the erection of a comprehensive production base at

Table 3. Characteristics of alternatives

Criteria \ Alternatives	A_1. Comprehensive production base at construction site	A_2. Large self-sufficient inter-district base	A_3. Self-sufficient district base	A_4. Small mobile on-site base	A_5. Minimally necessary base with external supply orientation	A_6. Repair and modernization of existing capacities
K_1. Capital costs for creation, repair, or modernization of production capacities	High	Very high	High (slightly higher than A_1)	Medium-low	Low	Medium
K_2. Logistics costs for supply of material and technical resources	Low	High	Medium	High	Very high	Medium
K_3. Risk of cost increase for produced products	Low	Medium	Medium-high	High	Very high	Medium
K_4. Proximity of production base to construction site	Very close	Far	Medium distance	Close	Medium distance	Medium distance
K_5. Area of alienated territories, Ha	40–80+	70–100+	45–85+	20–30	10–20	< 5
K_6. Supply reliability	Very high	High	High	Medium	Low-medium	Medium-high
K_7. Quality control of incoming products	Very high	High	High	Medium	Low-medium	Medium-high
K_8. Timeframes for production capacities to reach required productivity level, months	15–27+	24–36	18–30	< 2–5	3–9	6–18
K_9. Risk of WPS schedule disruption	Low	Low-medium	Low-medium	Medium-high	High	Medium
K_{10}. Manageability	Medium complexity	High complexity	Medium-high complexity	Low-medium complexity	Very complex	Medium complexity

Table 4. Pairwise comparison matrix of criteria by importance

K_i \ K_j	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9	K_{10}
K_1	1	1	5	3	7	1/5	2	1/2	1/4	6
K_2	1	1	5	2	7	1/5	2	1/3	1/4	5
K_3	1/5	1/5	1	1/2	3	1/7	1/2	1/5	1/7	2
K_4	1/3	1/2	2	1	5	1/6	1/2	1/5	1/6	3
K_5	1/7	1/7	1/3	1/5	1	1/9	1/5	1/7	1/8	1/2
K_6	5	5	7	6	9	1	6	3	2	9
K_7	1/2	1/2	2	2	5	1/6	1	1/3	1/5	3
K_8	2	3	5	5	7	1/3	3	1	1/2	7
K_9	4	4	7	6	8	1/2	5	2	1	7
K_{10}	1/6	1/5	1/2	1/3	2	1/9	1/3	1/7	7	1

Table 5. Values of Local Priorities for Criteria

L_{K1}	0.093
L_{K2}	0.084
L_{K3}	0.029
L_{K4}	0.043
L_{K5}	0.014
L_{K6}	0.292
L_{K7}	0.055
L_{K8}	0.149
L_{K9}	0.221
L_{K10}	0.020

Table 6. Values of Global Priorities for Alternatives

G_{A1}	0.3094
G_{A2}	0.1321
G_{A3}	0.1484
G_{A4}	0.1601
G_{A5}	0.1112
G_{A6}	0.1388

the NPP construction site. This alternative provides the most favorable balance between supply reliability, capital and logistics costs, quality control, and other criteria, which is critically important for nuclear energy projects.

The assessment of organizational forms for the production base for NPP construction with VVER-1200 is a complex task requiring analysis of many interrelated criteria of a technical, economic, and organizational nature. The application of the Analytic Hierarchy Process allows systematizing the process, considering criteria in their mutual hierarchy of priorities, and obtaining a justified solution corresponding to the specific conditions of each project.

The results of the conducted study show that for most construction sites in Russia in Category I regions, the preferred OFPB is the creation of a comprehensive production base at the NPP construction site. Despite the developed production and transport infrastructure of the considered region, organizational forms oriented towards supplies turn out to be significantly less preferable. This can be explained by the relatively low reliability of supplies, high risk of WPS schedule disruption, and significant logistics costs, which is generally characteristic of the Russian Federation due to highly extended transportation schemes and a high risk of untimely deliveries[2].

At the same time, the determination of the preferred OFPB should be carried out considering specific regional conditions, the availability of existing production infrastructure, the long-term development programme of the site, and the strategy for investing

$L^{K_1}_{A_1}$	0.081
$L^{K_1}_{A_2}$	0.036
$L^{K_1}_{A_3}$	0.054
$L^{K_1}_{A_4}$	0.264
$L^{K_1}_{A_5}$	0.391
$L^{K_1}_{A_6}$	0.175

$L^{K_2}_{A_1}$	0.420
$L^{K_2}_{A_2}$	0.078
$L^{K_2}_{A_3}$	0.193
$L^{K_2}_{A_4}$	0.078
$L^{K_2}_{A_5}$	0.036
$L^{K_2}_{A_6}$	0.193

$L^{K_3}_{A_1}$	0.413
$L^{K_3}_{A_2}$	0.184
$L^{K_3}_{A_3}$	0.112
$L^{K_3}_{A_4}$	0.071
$L^{K_3}_{A_5}$	0.035
$L^{K_3}_{A_6}$	0.184

$L^{K_4}_{A_1}$	0.452
$L^{K_4}_{A_2}$	0.039
$L^{K_4}_{A_3}$	0.093
$L^{K_4}_{A_4}$	0.230
$L^{K_4}_{A_5}$	0.093
$L^{K_4}_{A_6}$	0.093

$L^{K_5}_{A_1}$	0.059
$L^{K_5}_{A_2}$	0.028
$L^{K_5}_{A_3}$	0.040
$L^{K_5}_{A_4}$	0.192
$L^{K_5}_{A_5}$	0.279
$L^{K_5}_{A_6}$	0.403

$L^{K_6}_{A_1}$	0.413
$L^{K_6}_{A_2}$	0.182
$L^{K_6}_{A_3}$	0.182
$L^{K_6}_{A_4}$	0.068
$L^{K_6}_{A_5}$	0.045
$L^{K_6}_{A_6}$	0.109

$L^{K_7}_{A_1}$	0.413
$L^{K_7}_{A_2}$	0.182
$L^{K_7}_{A_3}$	0.182
$L^{K_7}_{A_4}$	0.068
$L^{K_7}_{A_5}$	0.045
$L^{K_7}_{A_6}$	0.109

$L^{K_8}_{A_1}$	0.077
$L^{K_8}_{A_2}$	0.027
$L^{K_8}_{A_3}$	0.052
$L^{K_8}_{A_4}$	0.450
$L^{K_8}_{A_5}$	0.235
$L^{K_8}_{A_6}$	0.159

$L^{K_9}_{A_1}$	0.342
$L^{K_9}_{A_2}$	0.208
$L^{K_9}_{A_3}$	0.208
$L^{K_9}_{A_4}$	0.076
$L^{K_9}_{A_5}$	0.052
$L^{K_9}_{A_6}$	0.114

$L^{K_{10}}_{A_1}$	0.209
$L^{K_{10}}_{A_2}$	0.078
$L^{K_{10}}_{A_3}$	0.124
$L^{K_{10}}_{A_4}$	0.342
$L^{K_{10}}_{A_5}$	0.038
$L^{K_{10}}_{A_6}$	0.209

Fig. 3. Local priorities of alternatives relative to criteria

capital funds. The application of the presented methodology for assessing organizational forms of the production base using AHP allows making justified decisions that ensure the optimization of technical and economic indicators for NPP construction projects with VVER-1200.

REFERENCES

1. Dikman L.G. Organization of Construction Production : textbook for Construction Universities. Moscow, Publishing House of the Association of Construction Universities, 2006; 603. EDN QNMKTJ. (rus.).
2. Grabovyy P.G., Belyakov S.I., Bizhanov A.Kh., Volgin V.V., Galishnikova V.V., Grabovoi K.P. et al. Organization of construction and real estate development. Vol. 1. Organization of construction : textbook in 3 volumes, 5th revised and enlarged ed. Under the general scientific editorship of prof. P.G. Grabovyy. Moscow, ASV, 2024; 690. EDN ZZZBMQ. (rus.).
3. Morozenko A.A., Belov V.V., Kabanov A.S. Organizational, technological and layout solutions for the construction and installation base of NPPs : a tutorial. Moscow, Publishing House MISI – MGSU, 2019; 136. EDN IFASBL. (rus.).
4. Saaty T.L. Decision making with the analytic hierarchy process. International Journal of Services Sciences. 2008; 1:83-98. URL: https://www.academia.edu/9110698/Decision_making_with_the_analytic_hierarchy_process
5. Grabovyy P.G., Lapidus A.A. Construction Management. Part One. Organizational Management Models and Contractual Structures of a Capital Construction Project : textbook in 2 Parts. Moscow, ASV, 2022; 484. EDN AVCVGP. (rus.).
6. Mozhilov Yu.N., Kokosadze E.L., Koltun O.V., Kryzhanovsky A.L., Morozenko A.A., Pavlov A.S. Organization and technology of construction of nuclear power plants : textbook edited by V.I. Telichenko. Moscow, MGSU, 2012; 400. EDN QNQFPJ. (rus.).
7. Dubrovsky V.B., Lavdansky P.A., Engovatov I.A. Construction of Nuclear Power Plants : textbook for Universities. Moscow, Publishing House of the Association of Construction Universities, 2010; 368. EDN QMLEPB. (rus.).
8. Voronkov I.E., Usmanov T.A. Logistics Technologies Used in the Contruction of Nuclear Power Plants. Industrial and Civil Engineering. 2021; 2:49-56. DOI: 10.33622/0869-7019.2021.02.49-56. EDN MZNUUO. (rus.).
9. Sborshchikov S.B., Bakhuss E.E., Markova I.M. Organizational Solutions to Ensure the Quality of Construction of Nuclear Power Facilities. New Technologies in Construction. 2023; 9(4-42):202-207. DOI: 10.24412/2409-4358-2023-4-202-207. EDN DAGGTR. (rus.).
10. Sborshchikov S.B. Intensification of Construction of Facilities of Nuclear Power. Organizational and Technological Solutions. Scientific and Technical Bulletin of the Volga Region. 2014; 6:321-323. EDN THHMHH. (rus.).
11. Pergamenshchik B.K., Telichenko V.I., Temishev R.R. Construction of special protective structures of nuclear power plants. Under the general editorship of Doctor of Technical Sciences, Professor V.I. Telichenko. Moscow, MPEI Publishing House, 2011; 240. (rus.).
12. Puzyanova I.A., Anikin B.A. Integrated supply chain planning : textbook. Moscow, Yurait Publishing House, 2014; 320. EDN VTUGIP. (rus.).

Многокритериальная оценка форм организации производственной базы строительства АЭС с ВВЭР-1200

Статья посвящена решению научно-практической задачи многокритериальной оценки альтернативных форм организации производственной базы (ФОПБ) строительства атомных электростанций с реакторными установками ВВЭР-1200. Предложена классификация российских регионов на четыре категории в зависимости от наличия и степени развития существующей производственной и транспортной инфраструктуры и других критериев, оказывающих влияние на определение предпочтительной ФОПБ. Сформулированы шесть альтернативных форм организации, включая комплексную производственную базу на площадке строительства АЭС, крупную межрайонную базу, самодостаточную районную базу, мобильную приобъектную базу, минимально необходимую базу с ориентацией на внешнюю поставку, а также ремонт и модернизацию существующих мощностей. Каждая альтернатива оценена по ряду критериев: экономическим, территориальным, критериям обеспечения надежности, временным и организационным критериям. Для решения многокритериальной задачи применен апробированный в мировой практике метод анализа иерархий Т. Саати, включающий процедуры парных сравнений критериев и альтернатив с проверкой согласованности экспертных оценок. Проведены полные расчеты с определением локальных и глобальных приоритетов всех альтернатив. Результаты исследования демонстрируют, что определение предпочтительной формы организации производственной базы в значительной степени зависит от региональных условий, включая уровень развития инфраструктуры, страте-

гию инвестирования и долгосрочные планы развития атомной энергетики в регионе. Изложенная методика может быть применена при обосновании организационно-технологических решений на предпроектной стадии строительства новых энергоблоков АЭС с ВВЭР-1200.

Ключевые слова: *форма организации производственной базы, ВВЭР-1200, метод анализа иерархий, многокритериальная оценка, метод Саати*

СПИСОК ИСТОЧНИКОВ

1. Дикман Л.Г. Организация строительного производства : уч. для строительных вузов. М. : Издательство Ассоциации строительных вузов, 2006. 603 с. EDN QNMKTJ.
2. Грабовой П.Г., Беляков С.И., Бижанов А.Х. Волгин В.В., Галишникова В.В., Грабовой К.П. и др. Организация строительства и девелопмент недвижимости. Том 1. Организация строительства : уч. в 3-х т., 5-е изд., перераб. и доп. / под ред. П.Г. Грабового. М. : АСВ, 2024. 690 с. EDN ZZZBMQ.
3. Морозенко А.А., Белов В.В., Кабанов А.С. Организационно-технологические и компоновочные решения строительно-монтажной базы АЭС : уч. пос. М. : Изд-во МИСИ – МГСУ, 2019. 136 с. EDN IFASBL.
4. Saaty T.L. Decision making with the analytic hierarchy process // Int. J. Services Sciences. 2008. No. 1. Pp. 83–98. URL: https://www.academia.edu/9110698/Decision_making_with_the_analytic_hierarchy_process
5. Грабовый П.Г., Лапидус А.А. Управление строительством. Ч. 1. Организационные модели управления и контрактные конструкции объекта капитального строительства : уч. в 2 ч. М. : АСВ, 2022. 484 с. EDN AVCVGP.
6. Доможилов Ю.Н., Кокосадзе Э.Л., Колтун О.В., Крыжановский А.Л., Морозенко А.А., Павлов А.С. Организация и технология строительства атомных станций : уч. / под ред. В.И. Теличенко. М. : МГСУ, 2012. 400 с. EDN QNQFPJ.
7. Дубровский В.Б., Лавданский П.А., Енговатов И.А. Строительство атомных электростанций : уч. для вузов. М. : Издательство Ассоциации строительных вузов, 2010. 368 с. EDN QMLEPB.
8. Воронков И.Е., Усманов Т.А. Логистические технологии, используемые при возведении атомных электростанций // Промышленное и гражданское строительство. 2021. № 2. С. 49–56. DOI: 10.33622/0869-7019.2021.02.49-56. EDN MZNUUO.
9. Сборщиков С.Б., Бахус Е.Е., Маркова И.М. Организационные решения обеспечения качества строительства объектов ядерной энергетики // Новые технологии в строительстве. 2023. № 9 (4–42). С. 202–207. DOI: 10.24412/2409-4358-2023-4-202-207. EDN DAGGTR.
10. Сборщиков С.Б. Интенсификация строительства объектов атомной энергетики. Организационно-технологические решения // Научно-технический вестник Поволжья. 2014. № 6. С. 321–323. EDN THHMHH.
11. Пергаменщик Б.К., Теличенко В.И., Темишев Р.Р. Возведение специальных защитных конструкций АЭС / под ред. В.И. Теличенко. М. : Издательский дом МЭИ, 2011. 240 с. EDN SUOOOJ.
12. Пузанова И.А., Аникин Б.А. Интегрированное планирование цепей поставок : уч. М. : Издательство Юрайт, 2014. 320 с. EDN VTUGIP.

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Social Franchising: Domestic and Foreign Experience in Construction

The objective of this study is to conduct a comparative analysis of models, tools, and empirical effects of implementing the social franchise mechanism in the Russian Federation and international markets, with a view to identifying best practices and critical drivers of success. The research methodology includes systematic analysis, comparative analysis, case study analysis, and a review of academic literature, industry reports and regulatory documents. The analysis revealed fundamental differences between social franchise models: in Russia, it is based on a donor-project paradigm with intensive methodological support and symbolic royalties, while in global practice, an entrepreneurial-sustainable model prevails, focused on partial or complete economic self-sufficiency of franchisees. A comprehensive review of existing literature reveals several key factors that contribute to the success of a social franchise. These factors include service standardization and the measurement of social impact achieved, the comprehensive development of franchisee potential, the implementation of a system for monitoring key performance indicators (KPI) and social return on investment (SROI), and the use of digital platforms and CRM systems. The findings confirm the effectiveness of social franchising as a tool for scaling socially significant initiatives. In order to develop the mechanism in Russia, several measures are proposed, including the introduction of hybrid financial models, the establishment of consulting centres, the strengthening of influence based on assessment data, and the adaptation of the regulatory environment.

Keywords: *social franchise, franchising model, scaling, social impact, comparative analysis, sustainable development*



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INTRODUCTION

Current global challenges, including economic instability, growing social inequality and resource shortages, encourage the development of new mechanisms for scaling social services. In this context, social franchising is becoming an increasingly important tool for the replication of proven social entrepreneurship solutions. The International Franchise Association asserts that the implementation of this system is achieved through the establishment of long-term partnerships. In this context, the franchisor grants the franchisee a license to utilize its proprietary model. This arrangement facilitates the transfer of the franchisor's brand identity, the implementation of its business processes, and the provision of methodological and monitoring support. The primary objective of this support is the resolution of local social issues.

The key feature of social franchising is its marked deviation from the conventional commercial franchising paradigm. While the latter is predominantly concerned with the generation of profit, the former is oriented towards the optimization and scaling of social impact. This difference is reflected in financial models, pricing methodologies, and revenue distribution algorithms. Research has demonstrated that social franchises exhibit a streamlined entry threshold for prospective franchisees, the provision of grant subsidies, and an enhanced system of social impact and sustainability metrics [1].

An analysis of international practices reveals the high effectiveness of social franchises as a tool for solving socially significant problems in various sectors. In the field of healthcare, the VisionSpring and Aravind Eye Care System models have been shown to facilitate access to ophthalmic services for individuals of low income (Smith, 2022). In the field of education, the Bridge International Academies franchise has been instrumental in the standardization of school education across African countries. Grameen Bank (Bangladesh) is a leader in the field of financial inclusion, implementing projects that encourage labour integration. The construction sector is of particular importance to this study. Successful examples include Habitat for Humanity, with its global affordable housing programs, and the Indian network Casa Fбcil, which demonstrates the potential of social franchising in the development of housing infrastructure.

In the Russian Federation, the social entrepreneurship segment and related business scaling tools are undergoing intensive institutionalization. According to the monitoring conducted by the Our Future Foundation, there has been steady growth in the number of impact organizations over the past five years; however, their replication rate remains low. Despite the existence of a number of successful cases, including “House by the Sea” and Big Change, in addition to the fund's pilot initiatives, there remains a paucity of comprehensive verification and benchmarking of domestic and foreign experience in the domain of social franchising within the construction industry. This deficiency hinders the formulation of effective roadmaps for development, incorporating mechanisms for public-private partnerships and ESG-oriented financing [2].

METHODS

The integrated approach uses: systems analysis to interpret social franchising as an ecosystem; a comparative method to identify universal and contextual features of the experience of the Russian

Federation and foreign countries; case studies of representative examples of successful franchises; content analysis of scientific and regulatory sources [3].

The empirical basis of the work was an array of data collected from the following resources: international bibliometric scientific citation platforms Scopus, Web of Science, and RSCI; reporting materials and registers of specialized institutions — Our Future Foundation, Agency for Social Investments (RF); International Franchise Association (IFA), The Global Social Franchising Initiative, European Franchise Federation (EU); open data arrays and case documentation; regulatory documents, defining legal relations in the field of franchising and social entrepreneurship. To assess the construction complex, studies of foreign practices for regulating investment and construction processes (USA, Great Britain, Germany, UAE, China) were additionally used [4–6].

RESULTS AND DISCUSSION

The study revealed significant differences in institutional approaches to the development of social franchising in Russia and abroad. A comparative analysis of the key models is presented in Table 1 [7].

Table 1. Comparative analysis of social franchising concepts

Characteristic	International experience	Russian practice
Financial model	Focus on self-sufficiency, royalties 3–7 % for scaling a network franchise	Non-repayable financing, grant dependence on government subsidies
Entry conditions	Minimal or averaged lump-sum payment	Often free or nominal payment
Legal framework	Special legal regulation of social entrepreneurship	Legal regulation of Chapter 54 of the Civil Code of the Russian Federation “Commercial Concession”
Performance measurement	SROI system, impact-metrics	Predominantly qualitative metrics
Scaling	Dozens of branches, thousands of recipients	Few points, local coverage

As illustrated in Fig. 1, there is a clear discrepancy between global expertise and the domestic social franchising model.

As illustrated in Table 2, a more detailed analysis of typical social franchising cases is provided, demonstrating the variety of models found in different countries and economic sectors.

An analysis of foreign franchising models reveals a focus on the establishment of social enterprises. The VisionSpring case in India, for instance, demonstrates the effectiveness of the “social franchise” model, evidenced by its capacity to generate revenue through a nominal lump-sum fee ranging from $500 to $1,000, complemented by royalties amounting to 5–7 % of revenue. The platform offers a multifaceted support system, encompassing training, wholesale logistics, marketing assistance, and rigorous quality auditing. In the USA, Habitat for Humanity employs a construction scheme that utilizes grant subsidies amounting to 80 % of costs, with no requirement for royalty payments. The emphasis is placed on methodology, volunteer resources, and fundraising. The German brand Massiv – Holz – Haus offers a direct franchise model with a substantial initial payment of €150–300 thousand, complemented by moderate royalty fees of 3–5 %, providing comprehensive support encompassing technologies, IT infrastructure, and engineering [8].

In contrast to the international models, Russian initiatives demonstrate an alternative development trajectory. The social franchise “House by the Sea” functions as a methodological platform, offering free or symbolic license fees and no regular royalties. The primary emphasis is on the transfer of work technologies, training content, and expert consulting support. Concurrently, in associated domains such as education, full-format commercial impact franchises are employed. The “Baby Club” network of children's centres, for example, has an average lump-sum fee of 0.5–1.5 million rubles and royalties of 5–10 % of turnover (BMC, 2019). This encompasses branding, methodological package, software, marketing, training, financial planning, operational regulations, legal support, CRM system, and audit.

It is imperative to allocate particular attention to the analysis of the final social impact (see Table 3). It is evident that global initiatives have the capacity to effect a substantial and enduring impact. For instance, the Aravind Eye Care network in India comprises over 70 branches, providing services to more than 5 million patients and performing over 500,000 operations annually, with reduced tariffs of up to 80 %. The Akiba Mashinani Trust programme encompassed 12 districts in Kenya, playing a pivotal role in the construction of 1,200 residential units and the generation of 800 employment opportunities [9].

The analysis of achieved results and the cumulative social effect requires special attention. As demonstrated in Fig. 2, international projects exhibit several orders of magnitude greater beneficiary coverage in comparison to their Russian counterparts, respectively. This phenomenon is especially evident in the construction sector, where initiatives such as Habitat for Humanity and Casa Fácil have been instrumental in facilitating widespread access to affordable housing for the population [10].

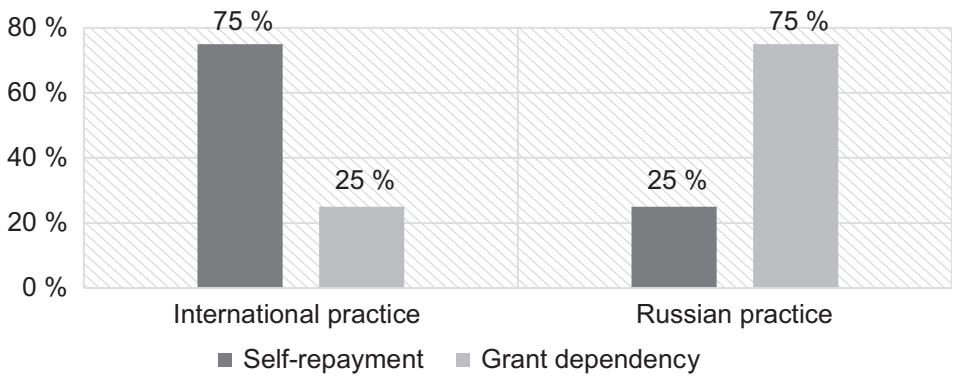


Fig. 1. Comparative analysis of financial and economic mechanisms of social franchising

Table 2. A comprehensive study of social franchise formats by region and initiative

Project	Franchise Model	Franchising Conditions (Lump-sum fee)	Regular Payments (Royalties)	Scope of Support from Franchisor
Vision Spring (India)	Business Format	Symbolic ($500–$1,000)	5–7 % of turnover	Professional training, wholesale supplies, strategic marketing, quality management
Habitat for Humanity (USA)	Construction Model	Grant coverage up to 80 %	None	Methodology, social volunteers, crowd-fundraising
Massiv-Holz-Haus (Germany)	Direct Franchise	High (€150–300 thousand)	3–5 % of turnover	Comprehensive offering: ICT, innovations, engineering
“House by the Sea” (Russia)	Methodological	Gratuitous or nominal	None	Activity methodologies, training, consulting
Franchise preschool educational networks, “Baby Club” (Russia)	Business Format	Medium (0.5–1.5 million rubles)	5–10 % of turnover	Branding, methodologies, software, marketing, training

Table 3. Extended evaluation of social franchise results

Country/Project	Number of replications	Beneficiary coverage	Measurable social outcome
Aravind Eye Care (India)	>70 centers	>5 million patients/year	Over 500 thousand operations annually, costs reduced by 80 %
Akiba Mashinani Trust (Kenya)	12 regions	>5 thousand families	1,200 residential units built, 800 vacancies created
Casa Fácil	85 cities	>15 thousand people	3,000 affordable housing projects
“Dom u Morya” (House by the Sea) (Russia)	5 regions	>200 orphanage graduates	Employment of graduates > 70 %, postgraduate professional adaptation
Social projects of the “Our Future” Foundation (Russia)	>30 projects	>50 thousand people	Organization of over 2,000 inclusive vacancies for socially vulnerable

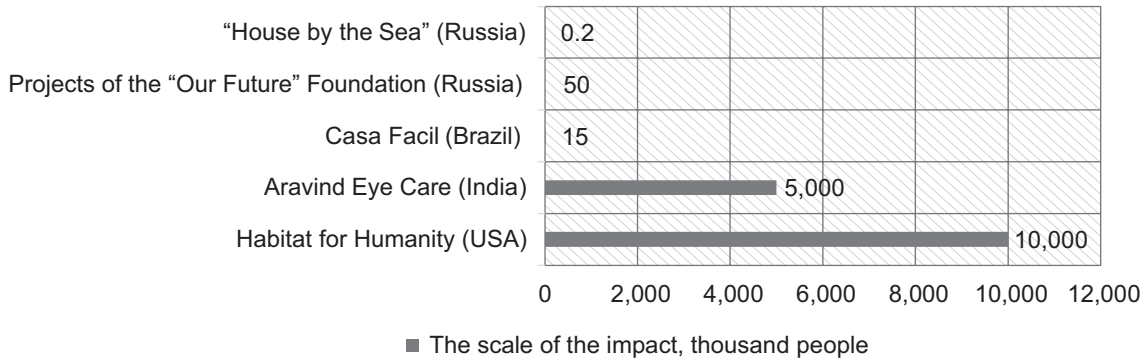


Fig. 2. A comparative analysis of the impact scale of social franchises

It is evident that Russian initiatives have a considerable social impact at the municipal level. However, the scaling of these initiatives is constrained by two primary factors: firstly, a shortage of financial and human resources, and secondly, an overregulated institutional environment. The most significant barrier to progress in this field is the verification of results. While foreign franchises actively utilize SROI, Theory of Change, and impact metrics, domestic teams are at times constrained to formal, fragmented reporting without stakeholder participation and long-term competent benchmarking validation [11].

A review of the literature on the subject of social franchising in Russia reveals several challenges of particular concern. Firstly, there is a paucity of regulation of the legal framework for the format's operation. Secondly, there is a constant shortage of investment resources in the replication phase of proven cases. Thirdly, there is insufficient standardization of services and a lack of expertise in the formation of franchise packages, methodological materials, and training programs. Finally, there is limited awareness among potential partners about the tools and indicators of the model's social impact [12, 13].

International experience demonstrates that social franchising can serve as an effective mechanism in the construction sector to address shortages of social housing, promote green, energy-efficient construction, and introduce universal design principles into urban development. According to industry research, in 2024, applications for construction and renovation franchises in Russia accounted for 11.5 % of the market, reflecting significant entrepreneurial interest that has not yet been converted into socially oriented business models [14–16].

The practices of the United Arab Emirates (UAE) and China clearly confirm that the comprehensive digital transformation of the construction sector — involving Building Information Modelling (BIM), the Internet of Things (IoT), artificial intelligence (AI), digital twins and big data — is a key driver for scaling any business concept, including social franchising. Unified platform solutions have been demonstrated to minimize both Capital Expenditure (CAPEX) and Operating Expenditure (OPEX), whilst concomitantly increasing Total Quality Management (TQM) of social franchises. This has been evidenced by European-Asian pilot cases in various climatic zones and regulatory environments, as illustrated in Fig. 3 [17].

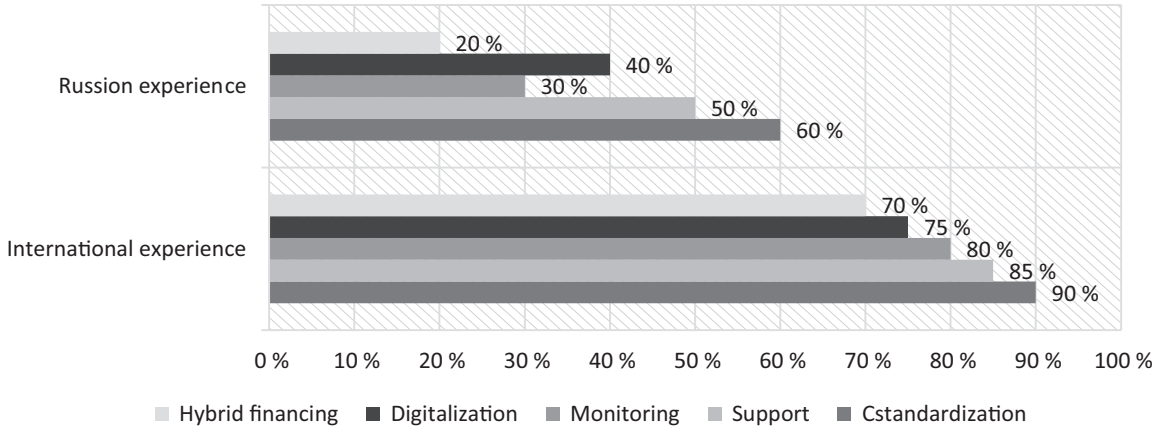


Fig. 3. Comparative analysis of the presence of critical success factors

CONCLUSION

A detailed analysis confirmed the considerable effectiveness of social franchising as a means of expanding socially significant initiatives and replicating sustainable development and ESG standards, including in the areas of infrastructure, inclusive construction, and barrier-free environments. A number of structural differences were identified. Firstly, the foreign format is focused on entrepreneurial sustainability, while the Russian format is focused on a donor-project model.

Drawing upon a range of international case studies and a thorough analysis of deficiencies within the Russian Federation, a series of proposals have been formulated with the aim of enhancing the effectiveness of social franchising mechanisms within the construction sector.

At the federal level, the following three factors must be given due consideration if the evolution of social franchising is to be strategically managed: the development of a roadmap outlining the desired future direction of social franchising; the establishment of a guarantee fund for social franchise projects; the provision of targeted tax preferences to network participants. The integration of social franchises into programmes for the provision of affordable housing and the comprehensive development of community areas is of particular importance.

Secondly, it is imperative for infrastructure operators to establish multidisciplinary consulting centres for the commercialization of social initiatives. Such commercialization may be achieved through franchising, scaling educational tracks, and replicating proven management practices. The primary focus remains oriented towards the development and implementation of industry-specific requirements for social franchising in the construction sector, encompassing digital BIM models and eco-standards.

Thirdly, it is recommended that social entrepreneurs should ensure that social impact assessment metrics are embedded at the deepest level, that integrated hybrid financial mechanisms are improved, and that the use of end-to-end digital solutions is expanded. In the field of construction, this phenomenon is exemplified by the extensive utilization of Building Information Modelling (BIM) technologies. These technologies facilitate the augmentation of conventional projects with a predictable quality, adhering to stipulated deadlines and estimates.

The primary research agenda is focused on the establishment of standardized legal constructs for social franchising, which are to be aligned with various industry regulations. This is primarily relevant for the engineering and construction sector. Additionally, there is a need to develop an integrated multifactorial methodology for measuring the economic and social performance of social franchising platforms.

REFERENCES

1. Mukhacheva A.V. National projects in the social sphere: implementation efficiency, regional risks, digital technologies application. Municipality: economy and management. 2025; 1(50):49-66. EDN NPDJQB. (rus.).
2. Kulkova V.Yu., Yuzhakova I.Yu. Methodological approach to assessing the activities of socially oriented non-profit organizations: adaptation of foreign experience to Russian practices. Economic. Law. Innovation. 2023; 4:25-33. DOI: 10.17586/2713-1874-2023-4-25-33. EDN REDPEZ. (rus.).
3. Yuvitsa N.V. Modernization of social enterprises taking into account foreign and domestic experience. Russia: development trends and prospects : Proceedings of the XIII International Scientific and Practical Conf. Moscow, Institute of Scientific Information on Social Sciences of the Russian Academy of Sciences, 2022; 17(2):362-366. EDN SZIFMW. (rus.).
4. Aleksandrova L.Yu. Potential and Current Problems of Franchising Development as a Form of Small and Large Businesses. Cooperation. Journal of Economics, Entrepreneurship and Law. 2021; 11(1):179-192. DOI: 10.18334/epp.11.1.111528. EDN TDILYX. (rus.).
5. Zinatullina A.R., Rakhmatullin Yu.Ya. Social Enterprise Franchising. International Journal of Humanities and Natural Sciences. 2021; 12-1(63):188-191. DOI: 10.24412/2500-1000-2021-12-1-188-191. EDN RXWPVN. (rus.).
6. Mazepov P.E. The Problems of regulating social franchising in Russian legislation. Legal studies. 2021; 5:16-23. DOI: 10.25136/2409-7136.2021.5.35742. EDN GSWWYC. (rus.).
7. Plyukhina A.A. Social enterprises and social entrepreneurship. National and foreign experience. Science and art of management. Bulletin of the institute of economics management and law of the Russian State University for the Humanities. 2024; (4):32-45. DOI: 10.28995/2782-2222-2024-4-32-45. EDN VRNHKE. (rus.).
8. Zimenkov R.I. American Corporations: Franchising Practices. Russian Foreign Economic Journal. 2022; 8:70-82. DOI: 10.24412/2072-8042-2022-8-70-82. EDN ORZSYM. (rus.).
9. Karavaev I.A. The Role of Franchising (Commercial Concession) in Ensuring the Technological Sovereignty of the Russian Federation. Evolution of Russian Law : Proceedings of the XXII International Scientific Conf. of Young Scientists and Students. Ekaterinburg, Ural State Law University named after V.F. Yakovlev, 2024; 673-680. EDN UBLTAE. (rus.).
10. Musina A.F. The Role of Franchising in the Development of Small Business in Russia. Science, Society, Innovation: Current issues in contemporary research : Collection of articles from the International

Scientific and Practical Conference. Penza, Science and Education, 2023; 157-159. EDN NCZZZY. (rus.).
11. Malkova I.V. Franchising business model: essence, development trends, problems and prospects in the Russian economy. Moscow University Bulletin. Series 21. Public Administration. 2022; 3:21-44. EDN DWGZRC. (rus.).
12. Soboleva P.M. Franchising in Russia. Current Issues of Economics and Management in the 21st Century : Collection of Scientific Articles from the XI International Scientific and Practical Conference. In 2 Parts. Novokuznetsk, Siberian State Industrial University, 2025; 134-139. EDN NPAXCF. (rus.).
13. Lamichhane B.D., Bahadur Lama P., Subedi R., Prasad Timilsina S. Factors Determining the Performance of Construction Enterprises: Evidence from Nepal. Qubahan Academic Journal. 2025; 5(4):409-420. DOI: 10.48161/qaj.v5n4a1624. EDN RAIFOY.
14. Lazanyuk I.V., Yakovleva T.V. Foreign experience in the implementation of PPP projects for the improvement of the Russian model. RUDN Journal of Economics. 2020; 28(3):608-619. DOI: 10.22363/2313-2329-2020-28-3-608-619. EDN HKXZVJ.
15. Iddy J.J. Knowledge transfer mechanisms in franchise network. Journal of Knowledge Management. 2021; 25(5):1006-1026. DOI: 10.1108/JKM-03-2020-0195. EDN NNTGGN.
16. Lanfranchi A., Melo P.L. de R., Norini F.M., Telles R. Institutional environment and internationalization of franchise chains: a regional and global analysis. International Journal of Emerging Markets. 2021; 16(4):726-744. DOI: 10.1108/ijoem-03-2019-0188. EDN HKQNIE.
17. E3S Web of Conferences : International Scientific Siberian Transport Forum — TransSiberia 2023, EDP Sciences – Web of Conferences (Les Ulis). 2023; 402. EDN LYZTHS.

Социальная франшиза: отечественный и зарубежный опыт в строительстве

Целью исследования является проведении всестороннего сравнительного анализа моделей, инструментов и эмпирических эффектов применения механизма социальной франшизы в Российской Федерации и на международных рынках для идентификации лучших практик и критических драйверов успеха. Методология включает системный анализ, сравнительно-сопоставительный подход, разбор конкретных кейсов, а также контент-анализ академических статей, отчетов отраслевых институтов и нормативно-правовой базы. Анализ выявил принципиальные различия моделей социальной франшизы: в России она строится на донорско-проектной парадигме с интенсивной методологической поддержкой и символическими роялти, тогда как в мировой практике преобладает предпринимательско-устойчивая модель, ориентированная на частичную или полную экономическую самодостаточность франчайзи. На основе анализа кейсов выявлены ключевые факторы успеха социальной франшизы: стандартизация предоставляемых сервисов и достигаемого социального эффекта, комплексное развитие потенциала франчайзи, внедрение системы мониторинга ключевых показателей эффективности (KPI) и социальной рентабельности инвестиций (SROI), а также использование цифровых платформ и CRM-систем. Выводы подтверждают высокую результативность социальной франшизы как инструмента масштабирования социально значимых инициатив. Для развития механизма в России предложены меры: внедрение гибридных финансовых моделей, формирование консалтинговых центров, усиление влияние, основанное на данных оценки, и адаптация регуляторной среды.

Ключевые слова: *социальная франшиза, франчайзинг-модель, масштабирование, социальный импакт, сравнительный анализ, устойчивое развитие*

СПИСОК ИСТОЧНИКОВ

1. Мухачёва А.В. Национальные проекты в социальной сфере: эффективность реализации, региональные риски, применение цифровых технологий // Муниципалитет: экономика и управление. 2025. № 1 (50). С. 49–66. EDN NPDJQB.
2. Кулькова В.Ю., Южакова И.Ю. Методический подход к оценке деятельности социально ориентированных некоммерческих организаций: адаптация зарубежного опыта в российские практики // Экономика. Право. Инновации. 2023. № 4. С. 25–33. DOI: 10.17586/2713-1874-2023-4-25-33. EDN REDPEZ.
3. Ювица Н.В. Модернизация социальных предприятий с учетом зарубежного и отечественного опыта // Россия: тенденции и перспективы развития : мат. XIII Междунар. науч.-практ. конф. М. : Институт научной информации по общественным наукам РАН, 2022. № 17 (2). С. 362–366. EDN SZIFMW.
4. Александрова Л.Ю. Потенциал и современные проблемы развития франчайзинга как формы сотрудничества малого и крупного бизнеса // Экономика, предпринимательство и право. 2021. № 11 (1). С. 179–192. DOI: 10.18334/epp.11.1.111528. EDN TDILYX.
5. Зинатуллина А.Р., Рахматуллин Ю.Я. Особенности франчайзинга в социальной сфере // Международный журнал гуманитарных и естественных наук. 2021. № 12–1 (63). С. 188–191. DOI: 10.24412/2500-1000-2021-12-1-188-191. EDN RXWPVN.
6. Мазепов П.Е. Проблемы регламентации социального франчайзинга в российском законодательстве // Юридические исследования. 2021. № 5. С. 16–23. DOI: 10.25136/2409-7136.2021.5.35742. EDN GSWWYC.
7. Плюхина А.А. Социальные предприятия и социальное предпринимательство: отечественный и зарубежный опыт // Наука и искусство управления. Вестник Института экономики, управления и права РГГУ. 2024. № (4). С. 32–45. DOI: 10.28995/2782-2222-2024-4-32-45. EDN VRNHKE.
8. Зименков Р.И. Франчайзинг в практике американских корпораций // Российский внешнеэкономический вестник. 2022. № 8. С. 70–82. DOI: 0.24412/2072-8042-2022-8-70-82. EDN ORZSYM.
9. Караваев И.А. Роль франчайзинга (коммерческой концессии) в обеспечении технологического суверенитета Российской Федерации // Эволюция российского права : мат. XXII Междунар. науч. конф. молодых ученых и студентов. Екатеринбург : Уральский государственный юридический университет им. В.Ф. Яковлева, 2024. С. 673–680. EDN UBLTAE.
10. Мусина А.Ф. Роль франчайзинга в развитии малого бизнеса в России // Наука, общество, инновации: актуальные вопросы современных исследований : сб. ст. Междунар. науч.-практ. конф. Пенза : Наука и Просвещение, 2023. С. 157–159. EDN NCZZZY.
11. Малькова И.В. Франчайзинговая модель бизнеса: сущность, тенденции развития, проблемы и перспективы в российской экономике // Вестник Московского университета. Сер. 21. Управление (государство и общество). 2022. № 3. С. 21–44. EDN DWGZRC.
12. Соболева П.М. Франчайзинг в России // Актуальные проблемы экономики и управления в XXI веке : сб. науч. ст. XI Междунар. науч.-практ. конф. в 2-х ч. Новокузнецк : Сибирский государственный индустриальный университет, 2025. С. 134–139. EDN NPAXCF.
13. Lamichhane B.D., Bahadur Lama P., Subedi R., Prasad Timilsina S. Factors Determining the Performance of Construction Enterprises: Evidence from Nepal // Qubahan Academic Journal. 2025. No. 5 (4). Pp. 409–420. DOI: 10.48161/qaj.v5n4a1624. EDN RAIFOY.
14. Lazanyuk I.V., Yakovleva T.V. Foreign experience in the implementation of PPP projects for the improvement of the Russian model //

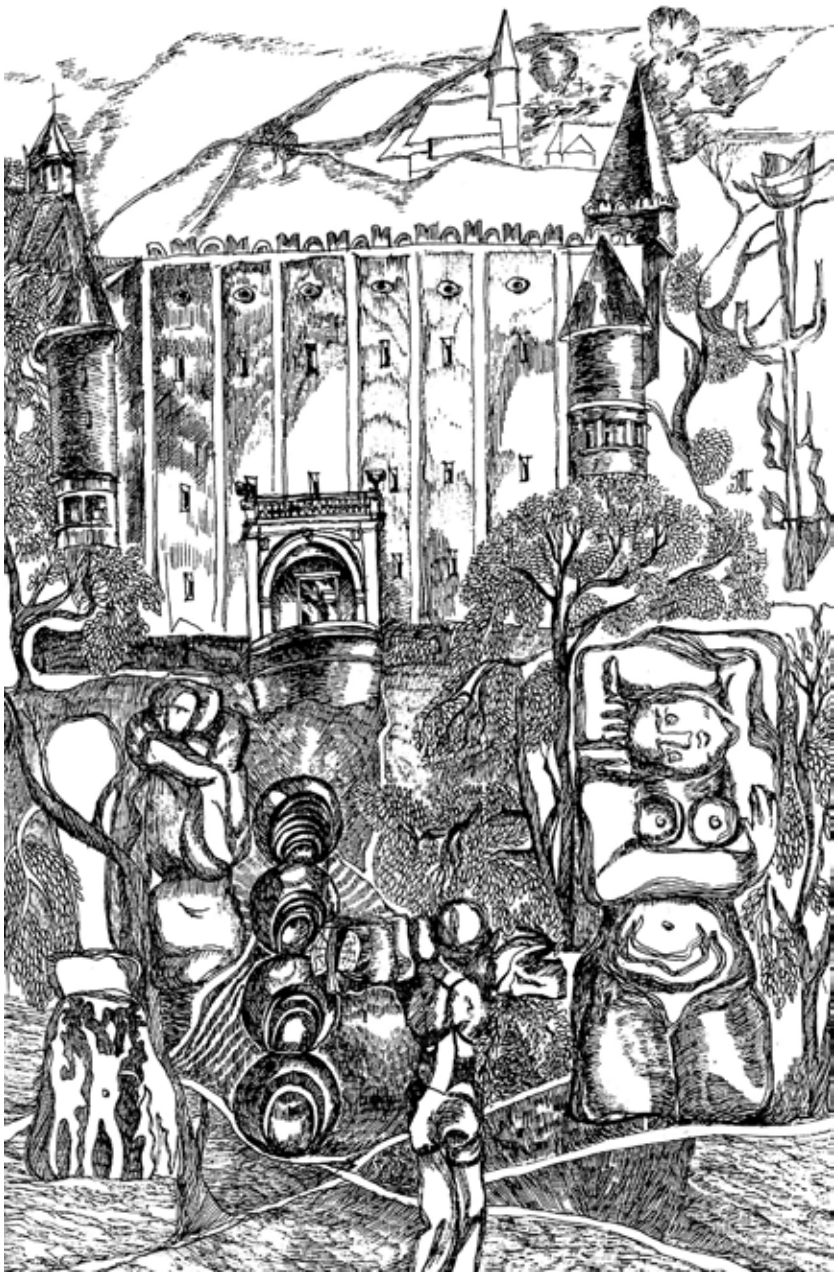
RUDN Journal of Economics. 2020. No. 28 (3). Pp. 608–619. DOI: 10.22363/2313-2329-2020-28-3-608-619. EDN HKXZVJ.
15. Iddy J.J. Knowledge transfer mechanisms in franchise network // Journal of Knowledge Management. 2021. No. 25 (5). Pp. 1006–1026. DOI: 10.1108/JKM-03-2020-0195. EDN NNTGGN.
16. Lanfranchi A., Melo P.L. de R., Norini F.M., Telles R. Institutional environment and internationalization of franchise chains: a regional and global analysis // International Journal of Emerging Markets. 2021. No. 16 (4). Pp. 726–744. DOI: 10.1108/ijoem-03-2019-0188. EDN HKQNIE.
17. E3S Web of Conferences : International Scientific Siberian Transport Forum — TransSiberia 2023, EDP Sciences – Web of Conferences (Les Ulis). 2023. No. 402. EDN LYZTHS.

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