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Дорогие читатели!

В нашу жизнь вошли новые словосочетания — самосохранение и устойчивое развитие. Стало ясно, что они определяют успех и эффективность как отдельных индивидуумов, так и бизнес-сообществ и целые отрасли. Устойчивое развитие можно рассматривать в двух плоскостях и сущностях. Одно определение характеризует целенаправленные действия какой-либо системы, которая, развиваясь, движется по целевому вектору, минимально отклоняясь от него под воздействием возникающих внешних сил; другое определение связано с деятельностью человека, общества и природы. Считается, что их совместное развитие будет устойчивым тогда, когда в совокупности становится принятие выгодного решения для всех одновременно.

Последнее десятилетие под эгидой ООН на регулярной основе проходят конференции, призванные сформулировать принципы устойчивого развития предприятий, территорий, регионов страны, охватывающие все виды деятельности (экономические, экологические, политические, социальные, интеллектуальные) через системное представление результативности — экономичности, производительности, деловой активности, инноваций и доходности.

Принципам и механизмам устойчивого развития субъектов хозяйственной деятельности посвящен этот номер журнала.

С уважением, главный редактор, Пётр Грабовый

Dear readers!

New phrases have entered our lives — self-preservation and sustainable development. It has become clear that they determine the success and efficiency of individuals, business communities and entire industries. Sustainable development can be viewed in two dimensions and entities. One definition characterizes the purposeful actions of a system that, while developing, moves along a target vector, deviating minimally from it under the influence of emerging external forces; the other definition is related to the activities of man, society and nature. It is believed that their joint development will be sustainable when in the aggregate becomes the adoption of a favourable decision for all at the same time.

For the last decade, under the auspices of the UN, conferences have been held on a regular basis to formulate the principles of sustainable development of enterprises, territories, regions of the country, covering all types of activities (economic, environmental, political, social, intellectual) through a systemic representation of performance — economic efficiency, productivity, business activity, innovation and profitability.

This issue of the journal is devoted to the principles and mechanisms of sustainable development of economic entities.

Sincerely, Peter Grabovyy, Editor-in-Chief

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АКЦЕНТЫ НОМЕРА

Яськова Н.Ю., Шамшин В.С.

Отметим активно формирующуюся тенденцию использования технологий смешанного финансирования, способных гибко дополнять имеющийся инвестиционный ландшафт городского развития

Овсянникова Т.Ю.

В статье рассматривается проблема пространственной неоднородности развития регионов Российской Федерации и роль градостроительной политики в выравнивании динамики социально-экономического развития регионов страны

Щербаков В.С.

В настоящее время развитие отечественной экономики происходит в постоянно меняющейся внешней среде и неопределенности, связанных как с мировыми тенденциями глобальной экономики, так и с санкционной политикой в отношении России

Хромых В.Д.,
Чубаркина И.Ю.

Одним из примеров реализации проектов экономики замкнутого цикла в России можно назвать экопромпарки

Кузьмич М.О.,
Волгин В.В.

В статье рассмотрены вопросы интеграции информационного моделирования, для улучшения эксплуатационных качеств зданий, базовые понятия жизненного цикла зданий, современные подходы к управлению зданием и повышения эксплуатационных качеств на различных этапах ЖЦ

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В статье рассматривается необходимость сценарирования развития урбанизированных территорий в условиях стремительных изменений социальной, экономической и экологической среды

Волгин В.В.,
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В условиях ограниченности ресурсов и роста требований к качеству ремонта, возникает необходимость в разработке методов, позволяющих объективно оценить надежность ремонтно-восстановительных процессов

Звонов И.А.

В настоящей статье, автор выявил и проанализировал некоторые особенности определения жизненного цикла объектов капитального строительства университетских кампусов и управления их жизненным циклом

Ажимов Т.З.,
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Наиболее существенным фактором, ограничивающим формирование нового строительства, является землепользование

Куракова О.А.,
Минин В.М.

В статье анализируются успешные проекты и инициативы, реализованные в Тыве, с оценкой их воздействия на уровень жизни и развитие жилищного строительства

Гераськин Ю.М.
Городиский К.В.

В настоящее время вопрос импортозамещения для компаний строительного комплекса является очень актуальным

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Development of the Russian economy is currently taking place in an ever-changing external environment and uncertainty related to both global economic trends and the sanctions policy against Russia

Khromykh V.D., Chubarkina I.Y.

One example of the implementation of closed-loop economy projects in Russia can be called eco-industrial parks. Eco-industrial parks are a new approach to the implementation of waste recycling and disposal

Khirevich S.A.

The article discusses the need for scenario planning for the development of urbanized territories in the context of rapid changes in the social, economic and environmental environment

Kuzmich M.O., Volgin V.V.

The article deals with the integration of information modeling to improve the performance of buildings, basic concepts of the life cycle of buildings, modern approaches to building management and performance improvement at various stages of the life cycle

Volgin V.V., Dekhtyar E.V.

In the context of limited resources and increasing demands on the quality of repairs, there is a need to develop methods to objectively assess the reliability of repair processes

Zvonov I.A.

In this article, the author has identified and analyzed some features of defining the life cycle of capital construction objects of university campuses and their life cycle management

Yaskova N.Yu.
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A new investment landscape for urban development

The creation of a network structure of development strategies on a national scale with the corresponding project content will require changes in the investment landscape without any alternative. Its cultural and socio-political interpretation allows us to consider it as a set of investment technologies structured according to the composition of the development project portfolio. The strategic goal of creating a new investment landscape in the context of urban development is to ensure the necessary and sufficient, as well as a balanced amount of financing of the project portfolio, providing accelerated entry into the trajectory of self-sufficient sustainable innovation development in the common space of modern Russia.

The analysis of the current investment landscape of urban development has shown: the dominance of technologies for the development of public capital investments; the consistently expanding participation of development institutions, concerning the creation and use of fund technologies; the return on a new technological basis to the mechanisms of public-private partnership, share technologies, etc.; the emergence of microfinance technologies; the use of information modelling technologies, etc. The analysis of the current investment landscape of urban development has shown the following.

The goals of urban development predetermine the need to form a project portfolio, including both large-scale sectoral/inter-sectoral, regional/interregional, as well as international projects, and local projects of various types. Accordingly, the investment landscape should be able to cover the entire project space with investment resources. The discussion of the prospects for the development of investment technologies revealed a number of advantages of such new for Russian practice technologies as industrial renovation technologies, which allow to free the urban space from emergency industrial facilities, as well as industrial mortgage technologies, which open up the possibility of lending against the collateral of renewable industrial-type real estate. The potential of microfinance technologies that do not require budgetary support and are scalable using the potential of information technologies has also been identified.

Summarizing the results of the investment landscape study, we note that in the context of urban development, such technologies as public-private partnerships, especially for the modernization of housing and communal infrastructure, unit technologies for the creation and modernization of commercial real estate, industrial renovation technologies, as well as microfinance across the entire spectrum of creating a comfortable urban environment, clearly require further development.

Keywords: urban development strategy, investment landscape, project portfolio, investment technologies, information technologies

INTRODUCTION

Actualization of approaches to the formation of the strategic vector of development of modern Russia required the creation of a system of multi-level and multidimensional strategic planning and management. The object of planning and management, whether it is an enterprise, settlement, city, region, industry or country, with its peculiarities and regularities of development is characterized by multidimensional functioning, specificity of resource potential, traditions of business turnover, established institutional structure, psychological type of residents, the nature of expectations of the subjects of urban environment, the level of their business activity, etc. All this determines the choice of methods to influence the development of objects of urban environment. All this predetermines the choice of methods of influence on the development of management objects. They may differ significantly both by regions and by levels of management. What works, for example, in the North turns out to be useless in the South of the country. In the same way, the methods of interregional impact are useless at the local level. In addition, practice has shown that well-developed but isolated strategies have no chance of successful

implementation. According to M.V. Mishustin, Chairman of the Government of the Russian Federation, a network structure of strategies on the scale of the whole country is necessary. Investment and construction projects of various scales, sectoral and territorial affiliation have become the material carrier of the process of implementation of strategic guidelines, substantially covering the solution of infrastructural, environmental and social development tasks. All development projects related to both new construction and modernization or liquidation of real estate funds should cover the entire spatial landscape and fit into the strategic vector of Russia's development.

An analysis of the strategic development context of modern Russia has shown that, despite the explosive growth in the number of import substitution projects, the restoration of critically important industries, the modernization of transport infrastructure, and the creation of a comfortable urban environment, their investment projection reveals the absolute dominance of large-scale, industry-specific projects. Their territorial distribution, with the exception of linear transport infrastructure projects, is mainly concentrated in major cities that have sufficient resource potential or a high probability of expansion

and development. A defining trend of the present time is the implementation of modernization projects for existing enterprises, as well as comprehensive territorial development projects, primarily focused on residential construction.

The transformation of strategic development goals has significantly reshaped the composition of projects in their practical implementation. As a result, the need to change the investment system has become inevitable. The diversity, spatial dispersion, and scale of the projects being implemented have necessitated changes in the investment landscape. In the interpretation of T. Ingold, we adopt the cultural nature of the concept of landscape [1, 2]. Under the investment landscape, we understand a structured system of investment technologies aligned with the composition of the development project portfolio¹. Accordingly, investment technologies initiated by Development Institutions are focused on financing specific types of development projects, depending on their objectives, scale, and characteristics [3]. The strategic goal of creating a new investment landscape in the context of urban development is to ensure a necessary, sufficient, and balanced volume of financing for the project portfolio, facilitating an accelerated transition to a trajectory of self-sufficient, sustainable, and innovative development within the unified space of modern Russia [4, 5].

MATERIALS AND METHODS OF RESEARCH

The investment landscape of modern Russia, as shown by the structural analysis, is characterized by:

- firstly, the large-scale development of technologies for the utilization of public capital investments;
- secondly, intensive participation of development institutions in investment processes, which flexibly change the methods and forms of investment;
- thirdly, the renaissance of a number of technologies of previous periods: public-private partnership, mortgage, share technologies and others;
- fourth, the emergence of microfinance technologies;
- fifth, the widespread use of scoring, information technology and on-line disbursement modes, etc.

Analyzing the current investment landscape, first of all, we should note the single-channel use of household savings, which emerged since 2022 and dominates to this day [6, 7]. They are mostly placed on deposit accounts of commercial banks. According to the Bank of Russia, less than a third of savings are invested in multi-apartment housing projects. The year 2024 was the year when savings in the segment of individual construction became more active. Investments in micro-projects capable of carrying the load of fragmentary adaptation of large-scale projects, improving the ecological balance, ensuring comfortable living, innovative renovation of real estate, resource-saving operational stage of the life cycle of real estate, in the structure of investments are within the statistical error and require not only close attention of the authorities, but also popularization among the population in order to complement and correct large-scale projects, to meet the needs with the participation of the population [8, 9]. In order to identify the demanded structural shifts in the investment

landscape of urban environment development, let us consider the currently formed investment technology package.

1. *Project Financing Technologies*. Their launch took place in 2018. Through the joint efforts of VEB.RF, Sber, VTB, Gazprombank, and Promsvyazbank, a new Development Institution was established in the form of the Project Finance Factory [10]. By refining the investment mechanism, the Factory had launched and supported technological development projects worth 11 trillion rubles by early 2023 and had prepared and financed a pool of projects for 2024. The total volume of financing, including 2024, exceeded 17 trillion rubles.

It is important to emphasize that future financing and the launch of a new portfolio of projects strategically focused on achieving technological sovereignty will be carried out with the support of the Industrial Development Fund (IDF). The selected projects will be funded by the Fund, but the borrowed funds of the IDF will be replaced by VEB's resources. Long-term and large-scale projects approved by the Ministry of Industry and Trade of the Russian Federation will receive financing exceeding 2 trillion rubles from the available funds of the Factory's partner banks². The Ministry of Industry and Trade of the Russian Federation estimates that expanding financial support to cover the deficit in technological development projects will reach 20 % [11].

2. *Bond-Based Borrowing Technologies*. The most successfully applied bond-based investment technology today is the financing mechanism of the Industrial Development Fund, created on the initiative of the Russian Government. The years 2022, 2023, and 2024 have been marked by a steady increase in loan amounts, ranging from 5 million to 5 billion rubles. These loans have been issued at an interest rate of 1–3 % per annum for a period of up to 10 years.

The scale and efficiency of bond-based technologies can be assessed based on the following results: since 2020, more than 500 financed enterprises have launched new production facilities and reached breakeven operations [12]. The expert community highlights the following key features of bond-based technologies:

- full transparency in decision-making regarding loan issuance;
- digital documentation process;
- long-term stability of loan issuance conditions;
- the option to begin principal repayment from the fourth year;
- well-developed consulting and support services;
- strong prospects for signing special investment contracts, among others.

These features predetermine the further accelerated recapitalization of the IDF and the potential inclusion of the Fund in the industrial mortgage program³.

3. *Industrial Renovation Technology*. This technology is being developed at the initiative of the Chamber of Commerce and Industry of the Russian Federation (CCI RF). Its goal is to give a second life to old factories. The pilot project for the renovation of "Brown-field" enterprises was launched in 2020 [13]. As of today, six projects have already been initiated, with 30 more under review.

The industrial renovation technology is based on integrating demolition, recycling, and the sale of secondary resources (such as metal, crushed stone, and brick debris) generated during dismantling, which is carried out by the specialized company "Alexander

1 Technology. Archived April 22, 2016 at the Wayback Machine, Encyclopedia Britannica Online, 2016.
2 Crediting of investment projects within the framework of "Project Finance Factory" will increase up to 6 trillion rubles. URL: https://economy.gov.ru/material/news/kreditovanie_investicionnyh_proektov_v_ramkah_fabriki_proektnogo_finansirovaniya_uvelichitsya_do_6_trln_rublej.html
3 Industrial mortgage. URL: <https://gisp.gov.ru/nmp/measure/12448038>

► GRAD". These processes are combined with site renovation methods. The costs of clearing the area are offset by the sale of high-demand secondary resources. The technology fully complies with environmental standards and does not harm the environment.

4. *Turnkey Construction Tenders*. Initiated by the Ministry of Construction of the Russian Federation. This technology involves combining design, surveys, construction, and equipment supply into a single contract. The investment model for state-funded turnkey projects significantly reduces project implementation timelines and simplifies the creation of a digital twin, which enables the full use of information technology benefits [14].

According to the Ministry of Construction of the Russian Federation, such tenders currently account for 3–5 % of the total number of projects. However, the use of turnkey construction technologies reduces the time required to bring a project to operational status by up to 15 %.

5. *Tax Deduction Technology*. This technology involves exempting part of the profit allocated for upgrading fixed assets from taxation. A final decision, coordinated with the Ministry of Finance of the Russian Federation and the Federal Tax Service, has not yet been made. However, in the fall of 2024, the President of the Russian Federation issued an order to assess the effectiveness of the tax deduction.

6. *Engaging Citizens' Savings in Various Forms of State Project Financing*. This approach is being considered under the condition of increasing the guarantee coverage for citizens' funds from the Deposit Insurance Agency (DIA) up to 2.8 million rubles, providing tax benefits to individuals, and other incentives. The potential models for involving citizens' funds are being developed by the Project Finance Factory in collaboration with the Industrial Development Fund (IDF).

In the segment of *corporate financing* for construction projects, the most in-demand technologies are.

7. *Industrial Mortgage Technologies*, initiated by the Ministry of Construction of the Russian Federation. The application of this technology will enable investments in acquiring industrial assets [15]. In the near future, the industrial mortgage mechanism will be extended to new construction, reconstruction, major repairs, or renovation, with collateral in the form of upgraded industrial real estate [16]. The size, terms, and conditions of loans are expected to be adjusted based on specific needs (currently, discussions are underway to extend loan terms to 10 years, increase loan amounts up to 1.5 billion rubles, and reduce mortgage interest rates from 7 to 3 % per annum).

8. *Infrastructure Mortgage Technologies* are aimed at increasing investment activity, primarily in the modernization, new construction, and reconstruction of transport infrastructure. The Ministry of Economic Development of the Russian Federation, as the initiator of this initiative, has proposed a mechanism for providing capital grants to private partners. The accumulation of funds will be carried out through bond loans secured by state guarantees. To enhance the attractiveness of infrastructure mortgages, tax incentives are expected to be introduced.

This investment technology is intended for construction projects that lack commercial investment appeal, as well as for projects that cannot be implemented using concession-based models. Thus, the scope of its application has been outlined, and detailed development of this technology has begun.

9. *Mixed Financing Technologies* are based on investment mechanisms that align the economic interests of the state and private businesses. The primary type of these technologies is public-private partnership (PPP) technologies [17]. As a form of public-private collaboration, PPP is built on long-term cooperation between the government (the public partner) and businesses [18]. Private companies participate in the creation and operation of capital construction projects at all stages of their lifecycle, fully or partially financing construction processes while assuming risks related to cost increases, quality loss, maintenance, and other factors. Currently, there is an active search for the most effective practices. It is particularly important to highlight the role of PPP in ensuring technological sovereignty [19]. Specifically, *offset contracting technologies* are gaining traction, featuring state-guaranteed procurement of products from newly established manufacturing facilities, the construction of which is financed by private companies [20].

10. *Investment technologies in the housing market* are classified based on the nature of investments and the type of partnership interaction into the following categories:

- technologies of self-financing, referring to the construction of individual housing units using personal funds;
- mortgage and tranche-based lending for both completed and under-construction housing;
- equity financing and shared participation, involving collective investments in housing construction. In the first case, banks participate, transitioning towards project financing, while in the second case, previously discussed bond-based mechanisms are utilized;
- investment-based replacement of housing stock under the renovation program.

11. *Shared investment technologies in construction projects* are based on the accumulation of funds from multiple investors into a specially created fund for the purpose of investing in various types of assets (in this case, real estate). The law⁴ provides for three types of funds: open-end, interval, and closed-end, depending on the nature of share purchase and sale transactions. The closed-end investment fund type is most successfully applied in the creation and subsequent leasing of real estate properties. In practice, shared investment technologies are rarely used and are primarily applied in the construction of income-generating real estate within the small and medium-sized business segments. Their potential for scaling is seen in the use of various share insurance models. The likely initiators of the development of these technologies will be regional authorities.

12. *Crowd technologies* are distributed lending technologies that address the challenges of financing micro-projects by creating a mechanism for accumulating and efficiently investing private funds. Global practice has demonstrated the effectiveness of distributed lending technologies in several forms:

- crowdsourcing, which involves engaging a broad audience to solve a specific problem on a voluntary basis;
- crowdfunding, a form of public financing that pools resources to support the efforts of project initiators;
- crowdfunding, a tool for attracting capital to startups and other ventures.

This type of investment technology is widely used in the United States, the United Kingdom, and other countries. Its potential in Russia has yet to be fully realized.

RESULTS AND DISCUSSION

The challenges of shaping the modern investment landscape are currently being actively discussed across nearly all expert platforms [21]. Among the key technological shortcomings, the following are noted:

- the lack of high-quality project documentation, which prevents an accurate assessment of prospective investment volumes;
- the need to revise the risk assessment model for new projects, shifting towards a portfolio-based risk evaluation approach;
- the absence of digital regulations for new investment technologies;
- an insufficient share of turnkey contracts. It is expected that the share of such contracts should reach 20 % within the next two years;
- a slowdown in the adoption of industrial renovation technologies, among others.

Let us emphasize the most acute discussion problems. For regions with abandoned industrial facilities in emergency condition, the opportunity to prepare sites for further development without additional costs is virtually nonexistent. According to the Chamber of Commerce and Industry of the Russian Federation (CCI RF), there are currently around 20,000 enterprises in Russia that were commissioned 50 to 90 years ago⁵. These have become toxic assets. Even when maintained in operational condition, business entities effectively lose resources for development. The solution to this situation appears to lie in clearing industrial sites and combining industrial renovation with industrial mortgages. The total volume of industrial mortgages is expected to cover up to 10 % of the investment needs for industrial real estate. Moreover, the construction of new production facilities using industrial mortgage technology is projected to reduce the time to reach full operational capacity from two years to just six months. In this scenario, a significant increase in investment activity within the mid-sized business segment can be expected. This is supported by expert evaluations from the CCI RF, which estimate the potential for a fivefold increase in industrial mortgage volumes within the current year.

Regarding the public-private partnership (PPP) technologies in demand for urban development, it should be noted that concession and PPP legislation⁶ has regulated the technologies of concession agreements, as well as agreements on public-private partnerships and municipal-private partnerships. Over six years, amendments to the existing PPP law have been developed. These amendments addressed not only the shortcomings identified in the use of agreements but also regulated the relationships between parties, eliminated excessive requirements (for example, the regulatory timeframe for land allocation was removed), introduced electronic tender procedures, simplified the process of modifying existing concession agreements, allowed for the inclusion of so-called special circumstances in concessions and PPP agreements, adjusted certain essential terms of agreements, and more. Most of these amendments took effect

on October 1, 2023, while some changes have been in force since January 1, 2024.

The development of investment technologies in partnership and concession-based formats, which have a regulated and multi-format structure, is linked to the procedures and capabilities provided by the “ROSINFRA”⁷ information platform. The platform has become a fully functional tool for implementing long-term infrastructure projects, as evidenced by the volume of investments that reached financial closure. Last year, this amounted to 702.7 billion rubles. More than 4,000 projects were implemented, the majority of which were concession-based projects in the municipal and energy infrastructure sectors.

Regarding the improvement of offset contracting technologies, several conditions have been modified:

- first, multiple federal subjects are now allowed to participate in an offset contract;
- second, the minimum transaction amount has been reduced from 1 billion rubles to 100 million rubles;
- third, small and medium-sized enterprises are now permitted to participate.

The optimism of expert expectations will be confirmed in practice. Over the next two years, approximately 20 offset contracts are expected to be concluded.

The relaunch of special investment contract technologies is linked to a change in the authorized organization, which is now the state corporation VEB.RF⁸. Currently, 75 applications are under review for projects with a total value exceeding 1.5 trillion rubles. Essentially, these involve the construction of new factories, such as a methanol production plant in the Volgograd region, valued at 74 billion rubles. Notably, due to the withdrawal of Western investors, provisions have been made for adjusting contract terms as needed.

The Ministry of Construction of the Russian Federation is placing particular emphasis on the implementation of self-financing technologies for individual housing construction. Currently, this sector faces challenges in ensuring adequate quality, safety, and liquidity of properties. Given the growing demand, surveys indicate that one in four households plans to build an individual residential home, and there is an increasing need for long-term systemic solutions leveraging the potential of information technologies.

CONCLUSION

We note an actively emerging trend towards the use of mixed finance technologies that can flexibly complement the existing investment landscape of urban development. Their development will require comprehensive measures to support project initiatives of various types. At the same time, regardless of the scale of projects, they should be included in the priorities of the city's strategic development. The development and implementation of regional investment standards is also becoming obviously necessary. All this creates the basis for the full-scale use of information modelling technologies and the creation of digital twins of projects, allowing not only to streamline and synchronize partnership interaction, accelerate the investment cycle, but also to increase the economic efficiency of the entire set of urban development projects.

5 The mechanism of commercial mortgage for construction and modernization of production will work in the Russian Federation in April. URL: <https://tass.ru/ekonomika/17398999>
6 On Public-Private Partnership, Municipal-Private Partnership in the Russian Federation and Amendments to Certain Legislative Acts of the Russian Federation : Federal Law from 13.07.2015 No. 224-FZ (latest edition). URL: https://www.consultant.ru/document/cons_doc_LAW_182660/
7 Rosinfra. Analytical materials. URL: <https://rosinfra.ru/library>
8 Factory of project financing. URL: <https://xn--90ab5f.xn--p>

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Новый инвестиционный ландшафт городского развития

Создание сетевой структуры стратегий развития в масштабе страны с соответствующим проектным наполнением безальтернативно потребует изменения инвестиционного ландшафта. Его культурологическая и общественно-политическая трактовка позволяет рассматривать его как структурированную сообразно составу проектного портфеля развития совокупность инвестиционных технологий. Стратегическая цель создания нового инвестиционного ландшафта в контексте городского развития заключается в обеспечении необходимого и достаточного, а также сбалансированного объема финансирования проектного портфеля, обеспечивающего ускоренный выход на траекторию самодостаточного устойчивого инновационного городского развития в едином пространстве современной России.

Анализ современного инвестиционного ландшафта городского развития показал: доминирование технологий освоения государственных капитальных вложений; последовательно расширяющееся участие Институтов развития, касающееся создания и использования фондовых технологий; возврат на новой технологической основе к механизмам государственно-частного партнерства, паевым технологиям и др.; возникновение технологий микрофинансирования; использование технологий информационного моделирования всех составляющих инвестиционного ландшафта и др.

Цели городского развития предопределяют необходимость формирования проектного портфеля, включающего как крупномасштабные отраслевые/межотраслевые, региональные/межрегиональные, а также международные проекты, так и локальные проекты различного типа. Соответственно инвестиционный ландшафт должен иметь возможность покрытия инвестиционными ресурсами всего проектного пространства. Обсуждение перспектив развития инвестиционных технологий выявило ряд преимуществ таких новых для российской практики технологий, как технологии промыш-

ленной реновации, позволяющие освободить городское пространство от аварийных промышленных объектов, а также технологии промышленной ипотеки, открывающие возможность кредитования под залог обновляемой недвижимости промышленного типа. Также выявлен потенциал технологий микрофинансирования, не требующих бюджетной поддержки и масштабируемых с использованием потенциала информационных технологий.

Резюмируя результаты исследования инвестиционного ландшафта, отметим, что в контексте городского развития требуют дальнейшего развития такие технологии, как государственно-частное партнерство, в особенности в целях модернизации жилищно-коммунальной инфраструктуры, паевые технологии применительно к созданию и модернизации недвижимости коммерческого назначения, технологии промышленной реновации, а также микрофинансирование по всему спектру создания комфортной городской среды.

Ключевые слова: стратегия городского развития, инвестиционный ландшафт, проектный портфель, инвестиционные технологии, информационные технологии

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Urban planning policy in the context of levelling spatial heterogeneity in the development of Russian regions

The paper deals with the problem of spatial heterogeneity of development of the regions of the Russian Federation and the role of urban planning policy in balancing the dynamics of socio-economic development of the country's territories. It is revealed that main factors contributing to imbalances in socio-economic development of territories are disproportions in distribution of funds and human capital which are the most important economic resources. The author claims that urban planning policy, which provides a high-quality living environment, plays a crucial role in increasing the attractiveness of the territory in terms of attracting investment and human resources. The author analyzes several provisions of the new Spatial Development Strategy of Russia and concludes that these provisions may further increase spatial inequality of the regions' development.

Keywords: *spatial heterogeneity, distribution of investments and human capital, urban planning policy, urban development policy, spatial development strategy*

INTRODUCTION

The issues of spatial development heterogeneity are typical for all macro-territorial states including Russia. Heterogeneity of spatial socio-economic development is primarily caused by imbalances in distribution and consumption of economic resources. In economic theory, studies of the notion "economic area" have been carried out since the beginning of the 20th century. A detailed retrospective analysis of these studies is presented in the works of K.S. Goncharova & G. Shelomentsev (2022) [1], and N.V. Zubarevich & S.G. Safronov (2024) [2]. However, extensive research of spatial economic development heterogeneity began to be carried out only in the second half of the 20th century when the problems of socio-economic inequality started worsening worldwide. The issue of spatial development heterogeneity can be considered in three domains:

1. Global — cross-country distribution of economic resources.
2. National — interregional distribution of economic resources.
3. Regional — territorial distribution of economic resources between settlements.

This article deals with the problem of spatial development heterogeneity of the Russian Federation which manifests itself in heterogeneity of socio-economic development of the country's regions. Analysis of various aspects of this problem is given in the works of many Russian scientists including O.V. Artemova & A.N. Savchenko [3], A.N. Bufetova [4], N.V. Zubarevich [2, 5], E.A. Kolomak [6], V.Yu. Maslikhina [7], P.A. Minakir [8], T.P. Skufina, [9], S.G. Safronov [2] et al.

The author believes that major economic resources that determine the level of development of a particular region are financial capital and human capital. At the same time, distribution of these resources is considerably pre-determined by

the development level of a particular territory. The research conducted by P. Mourao, A. Popescu [10] contains the results of an in-depth bibliographic analysis of various authors' works of theoretical and empirical studies of causal connection between investment, economic growth and competitiveness of a national economy. These studies extend the classic theory of the role of investment as a multiplier-accelerator of economic growth and prove that the relationship between investment, economic growth and national competitiveness is complex and multi-faceted. Apart from that, almost all studies show that there is a reciprocal impact of investment on economic growth, which means that investments act as a multiplier and accelerator of economic growth and an increased national competitiveness, but economic growth generates new investments at the same time.

In our opinion, the theory of economic growth can be supplemented by the inclusion of human capital as an accelerator which is the main economic resource at the present time. Not only is human capital the recipient of funds invested into its formation, but also the attractor of new investments into healthcare, education, culture, housing, and infrastructure which are ultimately the drivers of further economic development.

The higher the level of economic development of a country, region, and municipal education is, the greater the generation of economic resources that are further reinvested in the economy of a territory can be, the higher its investment attractiveness and competitiveness in commodity markets, primarily in the markets of investment and human capital, will become.

DATA AND METHODS

An excellent illustration of the issue of spatial heterogeneity in the development of the Russian Federation is the map of distribution of Russian



Fig. 1. Results of Urban Environment Quality Index calculation (the range index values increase from dark blue to light green)¹

cities by value of Urban Environment Quality Index (Fig. 1). The above-mentioned map clearly depicts intense concentration of cities in the European part of the country in terms of quantity and better quality of urban environment.

Significance of the urban environment as the most important factor in attracting human capital and its spatial distribution is confirmed by widespread development of the following urban planning concepts: “Livable City”, “City for People”, “Smart City”, and numerous city ratings such as: ESG-rating², Rating of Sustainable Development of Russian Cities, Index of Development of Russian Cities’ Public Infrastructure, etc.³

According to surveys (Roscongress, 2024)⁴, not all citizens are satisfied with the level of modern urban development. While 87 % of Moscow and St. Petersburg residents are content with urban environment in their cities, only 60 % are satisfied with this aspect in cities with populations under 100,000.

Meanwhile, the level of urban development of territories which determines the quality of the human environment is one of the most important factors in attraction of human capital into the territory and human capital’s spatial distribution, which, in turn, is the main factor of accumulating investment and economic growth (Fig. 2).

The research carried out by the author using the method of multi-dimensional statistical analysis confirmed serious spatial disparities in distribution of investment and human capital across Russian regions and the role of urban development in this process [11]. For example, analysis of demographic dynamics in Russian regions showed that within the period between 2000–2023 the Volga Federal District lost 9.5 % of its population, the Siberian Federal District — 8.9 %, and the Far Eastern Federal District — 13.2 % (calculated by the author according to Rosstat data⁵). Simultaneously, the analysis of the dynamics and structure of investments showed that in 2023 the volume of investments in the Central Federal District amounted to 33 % of the total amount of investments in the Russian Federation. What is more, the difference between the maximum and the minimum amounts in the regional investments into fixed assets was 537 times — from 7,154 billion rubles in Moscow to 13 billion rubles in the Republic of Kalmykia (calculated by the author according to Rosstat data⁶).

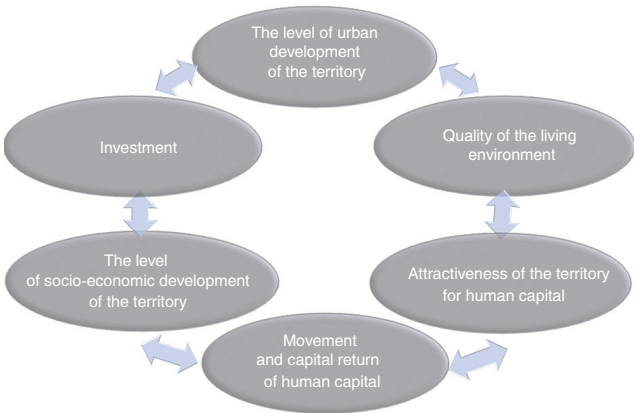


Fig. 2. Reciprocal influence of urban development level on the attractiveness of the territory for human capital and financial capital (Source: compiled by the author)

1 The Urban Environment Quality Index is a tool to assess the quality of a city’s material environment and the conditions in which it is created. URL: <https://xn----dtbcccotsypabxk.xn--p1ai/#/>

2 ESG-assessment of the development of Russian cities: new conditions – new challenges for territories. Expert. Rating Agency. URL: <https://raexpert.ru/docbank/943/216/da5/96383c6a235518f8c09d79c.pdf> (rus.).

3 Brief information about the ratings of sustainable development of cities and regions of the Russian Federation. URL: <https://irsup.hse.ru/ratingsinfo?ysclid=m7uasnk4qi395202471> (rus.).

4 The trajectory of Russia’s economic growth, Roscongress. URL: <https://roscongress.org/en/materials/traektoriya-ekonomicheskogo-razvitiya-rossi> (rus.).

5 The population of the subjects of the Russian Federation as of January 1. Demographic Yearbook of Russia 2023, Rosstat. URL: [torage/mediabank/Prii_Demogr_ejegodnik_2023.xls](https://rosstat.gov.ru/mediabank/Prii_Demogr_ejegodnik_2023.xls) (rus.).

6 Investments in fixed assets by regions of the Russian Federation. Rosstat, 2024. URL: [torage/mediabank/invest_sub.xlsx](https://rosstat.gov.ru/mediabank/invest_sub.xlsx) (rus.).

DISCUSSION

Spatial heterogeneity in distribution of funds and human capital across Russia is not only of socio-economic significance, but also of geopolitical importance: lack of investment and loss of human capital inevitably led to a recession in economy, gradual degradation of territories, social unrest and increased migration of people from underdeveloped territories to developed economic regions of the country.

Formation of a balanced system of spatial development of the country aiming to achieve national goals, improvement of territorial economic conditions as part of the national economy, measured placement of production and population are the most important tasks of the state economic policy at this time.

The report⁴ considers main factors determining the trajectory of Russia's economic development. The authors of this document draw attention to the fact that "there is a need to reconsider traditional approaches to the spatial development of territories. New approaches must be based on polycentric development models, balanced regional growth, and stimulating investment attractiveness not only in major megacities but also in smaller towns and rural areas".

In order to form a new model of regional development, the new Spatial Development Strategy of Russia has been adopted⁷.

The strategy is designed to reconcile the priorities of spatial and industrial development in order to ensure a balanced spatial development of the state economy (Fig. 3). Despite the relevance and significance of the new document, it should be mentioned that it does not say anything about how the new urban planning policy should be put into practice in terms of levelling the spatial development of the country. In addition, Strategy contains provisions that in our opinion will further aggravate the uneven spatial development. In particular, the following aspects of Strategy:

- ensuring infrastructural development based on economic efficiency indicators which means making a decision

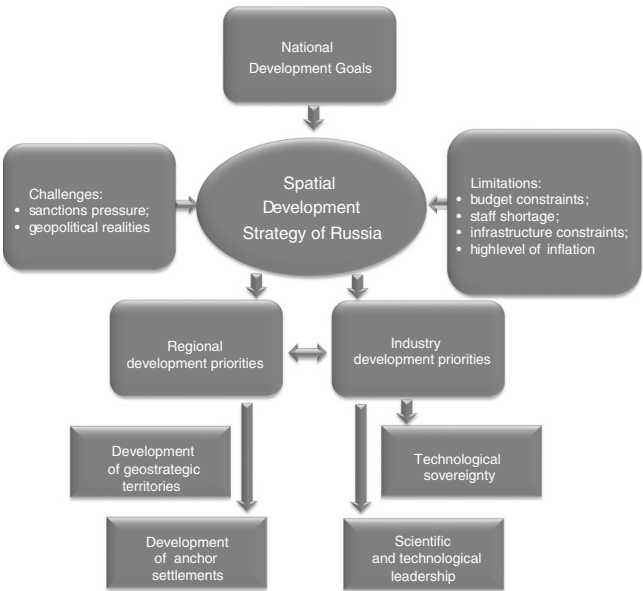


Fig. 3. Challenges, Limitations and Priorities of Russia's Spatial Development Strategy (Source: compiled by the author)

on implementation of a project based on assessment of socio-economic effects of the project and prioritizing projects based on this assessment. It is obvious that any development project will have a greater efficiency when implemented in a large agglomeration with a large population and high incomes. This means that infrastructure projects will continue to be implemented in regions with a high level of socio-economic development;

- increasing the level of independence of territories in solving issues of socio-economic development because of growth of their own incomes and measured policy in the field of inter-budgetary relations. This means that the issues of socio-economic growth in limited-budget territories will not be solved due to budget constraints. It is obvious that this will primarily affect urban planning policy.

Urban planning policy is the prerogative of local authorities. Development of territorial planning documents, as well as development of norms for urban planning regulation require considerable financing. In addition, implementation of investment projects within the framework of government programs and national projects often requires co-financing using local budgets, while participating in such programs presupposes pre-emptive financing from local budgets of pre-investment feasibility studies and project designs. They all require significant financial expenditure on the part of local authorities. Meanwhile, the total amount of local budget revenues in 2023 amounted to 7,136.9 billion rubles which is only 26 % in the budget system of the Russian Federation. At the same time, budget transfers amount to 4,811.0 billion rubles within local budgets⁸. Only 13 % of local budgets is spent on economic development as the major part of budget funds is invested into education and housing and utility services.

CONCLUSION

Levelling spatial development heterogeneity of the Russian territory is crucial for socio-economic and geopolitical situation. Urban planning policy plays a crucial role in formation of a balanced system of spatial development of the country designed to ensure improvement of territorial organization of the national economy, placement of production and infrastructure facilities. Urban planning regulation needs to be the main tool of implementing schemes of production facilities' placement, comprehensive programs of the development of transport, utility, and social infrastructure.

Urban planning regulation needs to ensure achievement of the most important national development goal – creating a comfortable and safe environment for life, and thus contribute to the achievement of other national goals — preserving the population and improving people's well-being, realizing the potential of each person.

The most important area of urban planning regulation is to be spatial levelling in distribution of funds through tools to support urban development activities in low-budget regions, to stimulate transfer of new investment projects to regions with an evident tendency to depopulation, and to support development projects in anchor settlements.

7 The Spatial Development Strategy of the Russian Federation for the period up to 2030 with a forecast up to 2036. Approved by Government Decree No. 4146-r of dated December 28, 2024. URL: <http://government.ru/docs/53917/> (rus.).
8 The results of monitoring the execution of local budgets and inter-budgetary relations in the subjects of the Russian Federation at the regional and municipal levels for 2023. URL: https://minfin.gov.ru/common/upload/library/2024/06/main/Rezultaty_monitoringa_2024.pdf

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Градостроительная политика в контексте выравнивания пространственной неоднородности развития регионов России

В статье рассматривается проблема пространственной неоднородности развития регионов Российской Федерации и роль градостроительной политики в выравнивании динамики социально-экономического развития регионов страны. Показано, что основными факторами неравенства в социально-экономическом развитии территорий являются диспропорции в распределении инвестиционного и человеческого капитала как важнейших экономических ресурсов. Выдвинуто положение о том, что градостроительная политика, обеспечивающая качественную среду жизнедеятельности человека, играет важнейшую роль в повышении привлекательности территории для инвестиционного и человеческого капитала. Анализируются отдельные положения новой Стратегии пространственного развития России и делаются выводы, что эти положения могут усилить пространственное неравенство в развитии регионов.

Ключевые слова: пространственная неоднородность, распределение инвестиций и человеческого капитала, градостроительная политика, стратегия пространственного развития

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Organizational and economic mechanism for the implementation of complex contractual support for industrial construction projects

Development of the Russian economy is currently taking place in an ever-changing external environment and uncertainty related to both global economic trends and the sanctions policy against Russia. The requirement for sustainable economic growth in such conditions is provided, among other things, by industrial construction, which creates fixed assets and carries out their reconstruction, expansion and modernization to create conditions for expanded reproduction and increased competitiveness in industry and infrastructural support for industry, in the energy sector, in the field of information and communications, in the field of engineering infrastructure. Modern forms of implementation of highly efficient and effective industrial construction are based on the practice of construction engineering, which is applied at all stages of the life cycle (LC) of investment and construction projects (ICP). An analysis of the current state of the investment and construction activity (ICA) market in the field of industrial construction reveals the imperfection of existing contract support methods at various stages of LC of ICP for industrial construction and insufficient integration of the required adequate forms of engineering under the guidance of a single integrated contractor, which often leads to a delay in the commissioning of capital construction facilities, additional costs incurred by investors and replacement of contractors during the implementation of ICP, followed by judicial resolution of financial disputes between contractors and customers. In addition, the modern competitive environment requires the commissioning of facilities with innovative and effective characteristics that can be provided by an integrated engineering approach that takes into account the relationship between the technological and organizational and managerial environment at all stages of LC of an industrial construction facility that is developing in time and space. Thus, the current problems of the current state of ICA in the field of industrial construction highlights the need to develop the principles of an integrated engineering approach in relation to industrial construction and to develop on their basis an organizational and economic mechanism for the implementation of integrated contractual support for industrial construction projects that increase the economic efficiency and effectiveness of integrated construction contracts (ICC).

Keywords: *complex construction contracts, industrial construction, construction engineering, principles of the engineering approach, organizational and economic mechanism*

INTRODUCTION

The development of any modern economy is based on material production, energy and engineering infrastructure, ensuring its normal functioning and sustainable growth. Since 2019, there has been an increase in the obsolescence of fixed assets (2019 — 37.8 %, 2020 — 39 %, 2021 and 2022 — 40.5 %, 2023 — 41.2 %)¹, which require reconstruction, while the trend of economic production also shows steady growth², which indicates an increasing burden on aging fixed assets that need to be reconstructed or decommissioned in the coming years, replacing them with new ones. The assessment of the main factors limiting the growth of production reveals the uncertainty of the economic situation as the main one (31–61 % of the total number of factors for the main types of economic activity in industry)³. At the same time, the requirements of economic development determine the need to ensure the growth and expansion of industrial enterprises, their infrastructure, including electricity and heat, information and communications, engineering infrastructure, including residential areas for social and environmental stability. All this is mainly provided by sustainable

industrial construction within the framework of expanded reproduction.

An analysis of implemented ICP in industrial construction shows that the commissioning of industrial construction facilities is associated with high risks of delayed commissioning [1–3], exceeding the cost of construction [4, 5], and changing contractors [6–8] during the implementation of ICP. This problem is associated with long project implementation times and financing intensity [9], high labour intensity and staff qualifications, a high proportion of complex and large-sized technological equipment requiring specialized forms of delivery to the construction site, highly professional installation and commissioning supervision, the need to adapt unified organizational, technological and managerial approaches to the unique characteristics of an industrial construction facility, the need to take into account a large number of regulatory and legislative acts, compliance with requirements in the field of environmental and industrial safety, industrial production technologies and technological processes, sanitary and environmental standards, duration and complexity

1 Fixed assets and other non-financial assets. Data from Rosstat: rosstat.gov.ru/folder/14304. (rus.).

2 Industrial production in Russia. 2023: Stat. sat. Rosstat. Moscow, 2023; 13-29. (rus.).

3 Industrial production in Russia. 2023: Stat. sat. Rosstat. Moscow, 2023; 43. (rus.).

of commissioning, and training requirements for operational personnel.

Since an industrial facility is unique in terms of its combination of technical, technological, layout, structural, organizational, environmental and other characteristics (this conclusion can be drawn from a number of works in the field of industrial construction [10–13]), its construction requires unique competencies and experience, which are provided by integrated construction engineering.

The resolution of contradictions between the uniqueness of an industrial construction facility, which must be commissioned within the planned time frame, with the required characteristics and qualifications of performers implementing of ICP at various LC stages should be resolved both at the stage of preparing the selection of a qualified contractor and forms of interaction between project participants, and at the stage of direct implementation of construction contracts through the use of integrated construction engineering based on the principles of developed for industrial construction, This means that contractual support is an important tool for highly efficient and effective ICP implementation. The development of the principles of the engineering approach in relation to industrial construction makes it possible to solve the scientific

problem of modeling the organizational and economic mechanisms of contract support for industrial construction.

SCIENTIFIC AND METHODOLOGICAL PRINCIPLES OF ORGANIZATIONAL AND ECONOMIC MODELING OF CONTRACT PROVISION AND IMPLEMENTATION OF ICC IN THE FIELD OF INDUSTRIAL CONSTRUCTION BASED ON THE ENGINEERING APPROACH

The study revealed the nature [14] and features of contract support for industrial construction, which determine the feasibility of developing and implementing an engineering approach that provides a comprehensive solution to innovative tasks for the construction of industrial and infrastructural facilities unique in their content, energy facilities, information and communication facilities, engineering infrastructure facilities, including residential areas.

The analysis of design-oriented engineering models of industrial construction of technically complex facilities allowed the author to develop and propose the principles of an engineering approach in industrial construction (Table 1), the implementation of which makes it possible to increase the effectiveness of complex construction contracts and ICP in general at all stages of the LC of facility.

Table 1. Principles of the engineering project-oriented approach in the implementation of ICC in industrial construction

Principles	Description	Expression
Integration principle	Combining scientific knowledge and experience to solve engineering, technological, organizational, managerial, supervisory, and production tasks to achieve the goals of ICC, the criterion of effectiveness of which is practical implementation with maximum efficiency	Specific weight of the positive and negative effects of integration. Economic effect of integration. Shorter ICC implementation time. Improvement of the technical characteristics of the facility. Increasing the organizational and technological reliability of ICP implementation. Speed of managerial decision-making
Goal setting principle	The focus of engineering activities is on achieving project objectives, strategic corporate and/or government objectives, and stakeholder satisfaction	Percentage of project goals achieved (general, intermediate). Degree of stakeholder satisfaction
Timeliness principle	Compliance with the current state of scientific and technological progress, project requirements and deadlines for the implementation of ICC	Dynamics of increasing the speed of decisions made
Controllability principle	Ensuring the manageability and interconnection of all ICC implementation processes under the supervision of an engineering consultant (project manager) and a project-oriented office	Degree of controllability (completeness). Proportion of output managed results. Percentage of deviations from the set parameters. Project resilience to external influences
Functionality principle	Compliance of engineering solutions with the specific functions of the facility and the elements of ICC implementation (specialization of personnel, technology, processes)	Compliance of engineering solutions with their functional purpose
Rationality principle	Ensuring a more rational use of project and facility resources, the validity of the application of engineering methods and forms, the use of the best means to achieve goals, maximizing the desired result with limited available resources and funds	Solving optimization problems
Modularity (formalization) principle	Accumulation of standard modules (models, mechanisms, solutions) for scalability, taking into account adaptation	Dynamics of accumulation of standard modules
Efficiency principle	Provability of a positive result at the stage of protection of an engineering solution and its implementation	The ratio of result to cost in terms of time, cost and quality
Measurability principle	Engineering results are measurable	In natural terms. In economic indicators (profitability, marginality, labour savings). Stakeholder satisfaction
Innovation principle	Continuous improvement of products and processes	Risk reduction. Cost reduction. Increased efficiency. Reduction of live labour

End of the Table 1

Principles	Description	Expression
Flexibility principle	Ensuring adaptability to constantly changing external and internal factors of ICP implementation	Average changeover time of a technological system relative to the total time of its effective operation (technological flexibility). Organizational flexibility coefficient. Cost-effectiveness of increasing the flexibility of the production system. Proportion of completed change requests and their effectiveness
Customer orientation principle	Engineering solutions are aimed at satisfying the customer of the facility's products or processes and the ICC stakeholders	Customer satisfaction with the result of engineering solutions adopted for implementation
Specialization principle	Engineering provides the accumulation of competencies and work experience in this sector of industrial construction and related sectors	Increase in the proportion of specialists with the required qualifications. Increase in the share of completed projects in this field, climatic and geographical conditions. Increase in the proportion of facilities completed on time without deviations from the original contract price and with guaranteed technological performance
Development principle	Accounting for the variability of the system, its ability to develop, expand, replace parts, and accumulate information	Reflects the interrelationship of all previous principles

Such principles are inextricably linked to project management and construction engineering, which complement each other. The developed principles closely correlate with state standards in the field of construction engineering and project management, including the developed principles of ICP management in the field of industrial construction [15] using integrated contracts such as EPC (engineering, procurement and construction).

In this regard, the most relevant form of implementation of this approach in the construction of industrial facilities is EPC contracting

within various boundaries, depending on the needs of the customer, the construction site and the financial and investment schemes of the project, which is characterized by an integrated engineering approach and a project-oriented management paradigm.

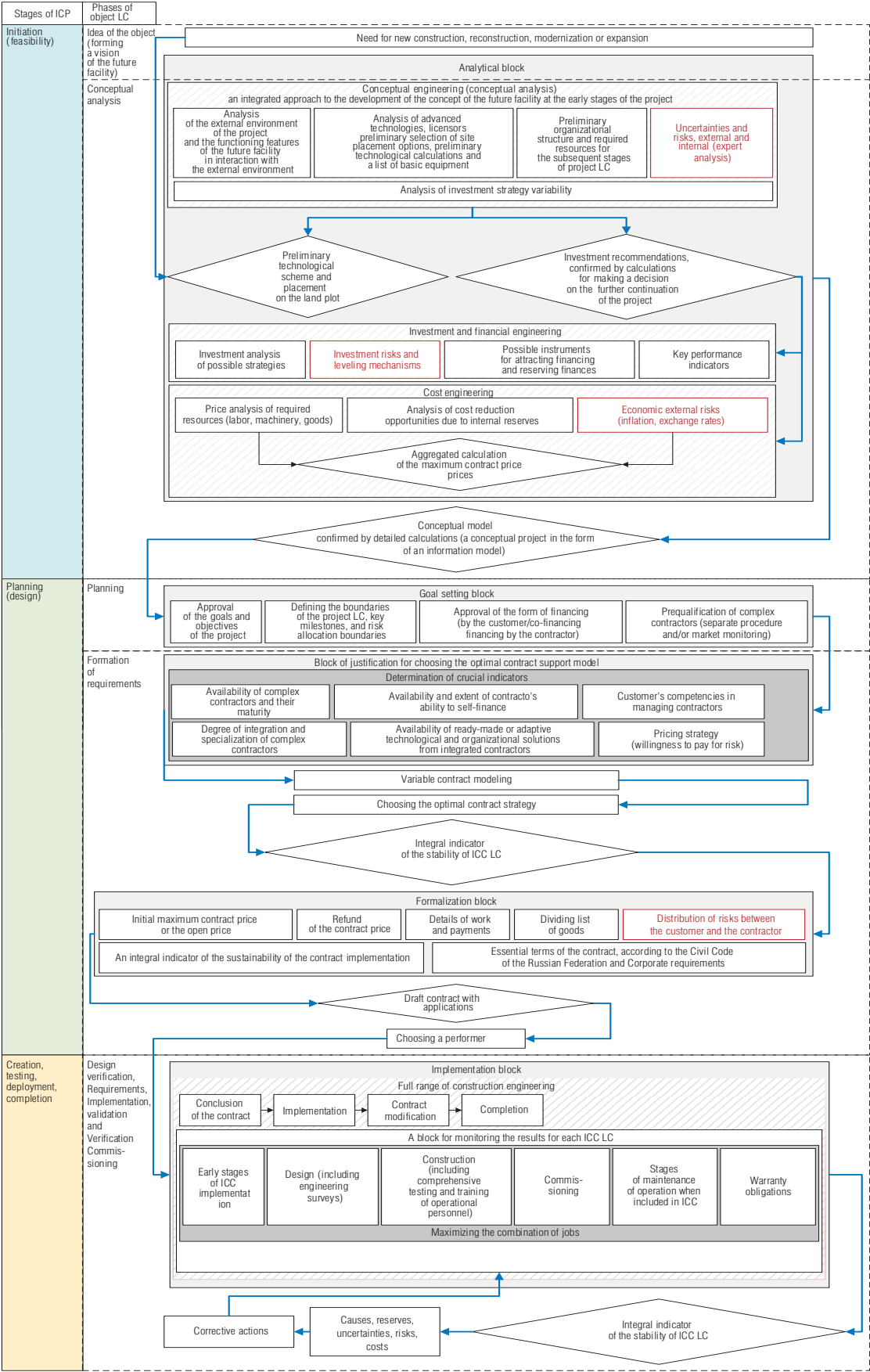
Based on the principles and targets for managing the most significant factors affecting the criteria of efficiency and effectiveness, in order to reduce losses and find reserves to ensure the sustainability of the ICC implementation, the author proposed the following indicators of ICC LC sustainability (Table 2).

Table 2. ICC LC sustainability indicators

Number	ICC LC sustainability indicator	Calculation methods
St ₁	Degree of deviations from the planned targets for the completion of the stages	1. According to the mastered volume. 2. By deviation from the planned deadlines. 3. On labour productivity. 4. By generation
St ₂	Degree of deviations in quality indicators at the stages of engineering surveys, design, construction, comprehensive testing, personnel training and commissioning	1. Proportion of rejected works or returned for revision. 2. Percentage of changes in the project documentation due to errors or insufficient research at the survey stage. 3. Percentage of deviations from the contract price due to unaccounted expenses
St ₃	Degree of utilization of the production system	1. Level of proportionality of staff workload depending on the type and complex of work. 2. Proportion of machines and mechanisms that are idle
St ₄	Dynamics of decisions made by the customer when requests for changes are received (speed of response to changes)	1. Percentage of decisions taken by the customer on change requests with deviations from the contractual deadlines for responding to change requests. 2. Percentage of change requests returned to the contractor for revision. 3. Percentage of decisions made by the customer without any requests for changes from the contractor
St ₅	Dynamics of changes in the cost of stages	1. Share of changes in the cost of the stages specified in the supplementary agreements in the contract price. 2. Share of the contract price change. 3. Proportion of incomplete development stages during the transition to the next stage
St ₆	Customer satisfaction level	1. CSAT by polling. 2. Proportion of complaints from the customer. 3. Proportion of escalated issues at a higher level of the hierarchy in the organization. 4. Stakeholders' satisfaction after achieving the project objectives (intermediate and final)
St ₇	Investment intensification	1. Percentage of deviations from the investment schedule. 2. Proportion of overdue payments to executors and sub-executors. 3. Share of reserves used for the investment of the project

End of the Table 2

Number	ICC LC sustainability indicator	Calculation methods
St ₈	Dynamics of labour shortage	1. Proportion of staff performing related duties on the project. 2. Percentage of work not completed on time due to lack of staff. 3. Deviation of the number of personnel from the planned targets
St ₉	Proportion of changes in technical solutions agreed by the customer affecting the timing and cost	1. Proportion of critical path changes in the calendar and network schedule. 2. Proportion of reserve reductions in non-critical work
St ₁₀	Proportion of work suspensions affecting the timing and cost	1. Proportion of work suspensions due to technical reasons. 2. Proportion of work suspensions due to violations of occupational safety and industrial safety. 3. Proportion of work suspensions due to weather conditions. 4. Proportion of work suspensions due to non-delivery of inventory. 5. Proportion of work suspensions due to non-payment. 6. Proportion of work stoppages due to inconsistent flows. 7. Proportion of work suspensions due to social reasons (strike, non-payment of wages, deterioration of working conditions, etc.)
St ₁₁	Degree of compliance with government programs	1. Percentage of unfulfilled tasks related to the implementation of government concepts, programs, plans, orders, and investment programs. 2. Percentage of deviations from the planned program indicators
St ₁₂	Share of technical supervision and executive authorities' complaints	1. Critical weight of the regulations allowing the suspension of work or activity of the enterprise. 2. Degree of satisfaction of the inspecting and supervisory executive authorities
St ₁₃	Percentage of deviations from the terms of the contract	1. Percentage of deviations from the terms of the contract allowing the termination of the contract. 2. Percentage of deviations from the terms of the contract allowing the suspension of financing
St ₁₄	Share of replaced sub-executors in the process of ICC implementation	1. Share of replaced sub-executors in the total amount of the contract. 2. Proportion of sub-executors who received a ban on continuing work. 3. Proportion of uncoordinated sub-executors by the customer
St ₁₅	Share of implemented innovations that reduce the time, cost or improve the quality of work and the facility itself	1. Share of innovations that shorten construction time. 2. Share of innovations that reduce the cost of ownership of an object. 3. Share of innovations that increase labour productivity. 4. Share of innovations that increase efficiency. 5. Share of innovations that reduce harmful emissions
St ₁₆	Proportion of violations of safety, labour protection and industrial safety that led to the suspension of work or fines	1. Proportion of delays in the critical path of the calendar and network schedule due to violations of occupational health and safety, industrial safety. 2. Proportion of fines and penalties due to violations of occupational health and safety, industrial safety
St ₁₇	Share of applied penalties in the cost of ICC	1. Critical level of fines and penalties preventing the financing of the project by the contractor. 2. Proportion of claims against the contractor
St ₁₈	Proportion of claims and complaints received by the general contractor and subcontractors affecting cost, timing and quality	1. Critical level of claims and complaints that do not allow continued financing of the contractor or sub-executors. 2. Critical level of claims and complaints, which does not allow the use of the results of the work. 3. Critical level of claims and complaints, due to the critical failure of deadlines
St ₁₉	Proportion of risks that have resulted in negative changes in the cost, duration, or quality of the project	1. Proportion of documented risks that resulted in an increase in value. 2. Proportion of documented risks that resulted in increased deadlines. 3. Proportion of documented risks that have led to a deterioration in the quality of the facility or work
St ₂₀	Percentage of decisions made by the customer for the contractor as part of the fulfillment of the contractor's obligations	1. Percentage of the contractor's obligations fulfilled by the customer. 2. Critical level of decisions (technological, organizational, financial) made by the customer on issues in the contractor's area of responsibility
St ₂₁	Percentage of deviations in the delivery time of equipment and materials to the construction site	1. Proportion of delivery time deviations that affected the timing of the critical path. 2. Proportion of delivery time deviations that affected the intensification of flows
St ₂₂	Proportion of project goals not achieved (intermediate and final)	1. Percentage of project goals achieved within the planned time frame. 2. Proportion of intermediate goals achieved that affect the achievement of the final goals of the project
St ₂₃	Degree of controllability (completeness)	1. Number of calendar and network schedule changes agreed upon by the customer. 2. Number of management decisions made that deviate from the documented deadlines in the project of-fice protocol. 3. Proportion of unforeseen risks that have occurred. 4. Proportion of risks documented by the customer in the contractor's documentation area of responsibility



The mechanism of ICC implementation in industrial construction

The methodological approach to the formation of the ICC implementation mechanism in industrial construction involves further formalization of ICC LC sustainability objective function.

ORGANIZATIONAL AND ECONOMIC MECHANISM FOR THE IMPLEMENTATION OF COMPLEX CONTRACTUAL SUPPORT FOR INDUSTRIAL CONSTRUCTION PROJECTS

To implement the developed approaches within the framework of contract provision and implementation of ICC in industrial construction, a model for choosing optimal contract forms and a mechanism for the formation and implementation of ICC has been formalized (Fig.).

At the stage of project initiation using construction engineering in the early stages of the project (conceptual engineering, investment and financial engineering and cost engineering), the mechanism includes blocks for collecting information about the planned

construction site, analysis and evaluation to make a decision on the continuation of the project and the creation of an information and conceptual framework for contract modeling, the preliminary location of the facility and the flow chart, collectively representing the information model of the object. At the stage of requirements development, an integral ICC LC sustainability indicator is formed, which is formalized as an appendix to the contract with the evaluation methodology, for controlling during the implementation and at the end of the project.

In case of deviations from the planned sustainability indicators during the implementation of the ICC at each of the LC stages, a search is carried out for causes, reserves, risks, and an assessment of the costs of corrective actions (Table 3).

As part of the study, it is necessary to carry out a calculated approbation of the developed scientific and methodological provisions for the implementation of the mechanism of integrated contract support and the implementation of projects in the field of industrial

Table 3. Controlling the indicators of organizational and economic efficiency of ICC in industrial construction

Number	ICC LC sustainability indicator	Corrective actions	Pre-project stage	Design/engineering surveys	Procurement/delivery	Construction/commissioning
St ₁	Degree of deviations from the planned targets for the completion of the stages	Variability depending on the identified causes: managerial, economic, organizational, psychological response	•	•	•	•
St ₂	Degree of deviations in quality indicators at the stages of engineering surveys, design, construction, comprehensive testing, personnel training and commissioning	1. Intermediate verification of the results within the framework of the information model of the facility. 2. Conclusion of an agreement with an independent expert organization responsible for regulatory control of documentation and construction control	–	•	•	•
St ₃	Degree of utilization of the production system	1. Hiring additional staff. 2. Rational allocation of labour resources. 3. Provision of additional machines and mechanisms. 4. Additional unscheduled financing	–	•	•	•
St ₄	Dynamics of decisions made by the customer when requests for changes are received (speed of response to changes)	1. Attracting additional resources to analyze change requests. 2. Staff professional development	•	•	•	•
St ₅	Dynamics of changes in the cost of stages	1. Employing additional personnel for cost analysis. 2. Analysis of the causes of under-development and management decision-making	–	•	•	•
St ₆	Customer satisfaction level	1. Analysis of the causes of dissatisfaction and ranking according to the degree of impact on the project. 2. Adjusting project objectives and informing stakeholders	•	•	•	•
St ₇	Investment intensification	1. Opening of an additional credit line. 2. Financing of sub-executors at the expense of the customer. 3. Analysis of reserves for continued financing. 4. Co-financing	–	•	•	•



Continue of the Table 3

Number	ICC LC sustainability indicator	Corrective actions	Pre-project stage	Design/engineering surveys	Procurement/delivery	Construction/commissioning
St ₈	Dynamics of labour shortage	1. Creation of an additional structural unit for the search and recruitment of personnel. 2. Retraining and advanced training. 3. Hiring additional sub-executors	—	•	•	•
St ₉	Proportion of changes in technical solutions agreed by the customer affecting the timing and cost	1. Analysis of the causes of changes. 2. Ranking of new requirements and rejecting minor ones that do not affect the project objectives	—	•	•	•
St ₁₀	Proportion of work suspensions affecting the timing and cost	1. Analysis of the reasons for the suspension of work. 2. Variability depending on the identified causes: managerial, economic, organizational, psychological response	—	•	•	•
St ₁₁	Degree of compliance with government programs	1. Analysis of the compliance of the project objectives with government programs. 2. Analysis of the appropriateness of additional costs for the implementation of government programs. 3. Analysis of the possibility of implementing government programs	•	•	•	•
St ₁₂	Share of technical supervision and executive authorities' complaints	1. Strengthening internal oversight. 2. Use of reserves for correcting comments and prescriptions	—	—	—	•
St ₁₃	Percentage of deviations from the terms of the contract	1. Analysis of the reasons for the suspension of work. 2. Variability depending on the identified causes: managerial, economic, organizational, psychological response	—	—	—	—
St ₁₄	Share of replaced sub-executors in the process of ICC implementation	1. Strengthening control over the coordination of sub-executors. 2. Strengthening the customer's control over the fulfillment of sub-executors' obligations. 3. Strengthening the customer's control over the fulfillment of the general contractor's obligations to sub-contractors	—	•	•	•
St ₁₅	Proportion of violations of safety, labour protection and industrial safety that led to the suspension of work or fines	1. Strengthening internal oversight. 2. Conclusion of an agreement with an independent expert organization responsible for regulatory control of documentation and construction control	—	—	—	•
St ₁₆	Share of applied penalties in the cost of ICC	1. Analysis of the reasons for the suspension of work. 2. Variability depending on the identified causes: managerial, economic, organizational, psychological response	—	•	•	•
St ₁₇	Proportion of claims and complaints received by the general contractor and subcontractors affecting cost, timing and quality	1. Analysis of the reasons for the suspension of work. 2. Variability depending on the identified causes: managerial, economic, organizational, psychological response	—	•	•	•

End of the Table 3

Number	ICC LC sustainability indicator	Corrective actions	Pre-project stage	Design/engineering surveys	Procurement/delivery	Construction/commissioning
St ₁₈	Proportion of risks that have resulted in negative changes in the cost, duration, or quality of the project	1. Analysis of the reasons for the suspension of work. 2. Variability depending on the identified causes: managerial, economic, organizational, psychological reaction	–	•	•	•
St ₂₉	Percentage of decisions made by the customer for the contractor as part of the fulfillment of the contractor's obligations	1. Change of performers. 2. Hiring an engineering consulting organization from the field of industrial construction	•	•	•	•
St ₂₀	Percentage of deviations in the delivery time of equipment and materials to the construction site	1. Analysis of the reasons for the suspension of work. 2. Variability depending on the identified causes: managerial, economic, organizational, psychological response	–	–	•	
St ₂₁	Proportion of project goals not achieved (intermediate and final)	1. Analysis of the reasons for the suspension of work. 2. Variability depending on the identified causes: managerial, economic, organizational, psychological response	•	•	•	•
St ₂₂	Degree of controllability (completeness)	1. Analysis of the reasons for the suspension of work. 2. Variability depending on the identified causes: managerial, economic, organizational, psychological response	–	•	•	•

construction. As part of the testing, it is necessary to form an integral indicator based on an analysis of the specifics of the implementation of a specific ICP in the chosen field of industrial construction, to predict the resulting economic effects achieved by minimizing negative effects at all stages of ICC LC. The calculated effects of the implementation of the developed methodological provisions and practical recommendations will serve as the basis for further improvement of ICP implementation mechanisms in industrial construction.

CONCLUSIONS

1. Development and improvement of the sustainability of ICP in industrial construction under the influence of negative factors should be based on the application of integrated design-oriented engineering approaches to the development and implementation of ICC, including mechanisms for integrating engineering activities and harmonizing the interaction of stakeholders at various stages of the project life cycle, taking into account the introduction of innovations.
2. The most adequate models of construction contracts for the implementation of integrated project-oriented engineering are EPC contracts, which provide advantages over other types of contracts.
3. Developed principles of contract support in the field of industrial construction within the framework of expanded reproduction make it possible to form a target mathematical and economic function of the integral ICC LC sustainability indicator in relation to industrial construction.
4. Developed principles and mechanism aimed at improving the effectiveness of ICP implemented by ICC, taking into account the principles of engineering activities in the field of industrial construction and, in particular, design-oriented management systems,

- as well as industry-specific features of the construction sector, can ensure the sustainability and development of industrial construction in general.
5. Scientific and practical research results and recommendations can ensure the sustainable growth of domestic engineering in the field of industrial construction and improve competencies in the field of design-oriented systems, harmonizing the interests and goals of ICA participants. The results obtained can be used in the activities of customer enterprises in the field of industrial construction, corporate associations in the field of industry, taking into account their territorial and industry specifics. A promising area of further research is the development of scientific and methodological approaches to assessing the sustainability of ICP in a turbulent economy and the requirements of accelerated industrialization.
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Организационно-экономический механизм реализации комплексного контрактного обеспечения проектов промышленного строительства

В настоящее время развитие отечественной экономики происходит в постоянно меняющейся внешней среде и неопределенности, связанных как с мировыми тенденциями глобальной экономики, так и с санкционной политикой в отношении России. Требование устойчивого экономического роста в таких условиях обеспечивается, в том числе, промышленным строительством, которое создает основные фонды и проводит их реконструкцию, расширение и модернизацию для создания условий расширенного воспроизводства и повышения конкурентоспособности в промышленности и инфраструктурном обеспечении промышленности, в энергетике, в области информации и связи, в сфере создания инженерной инфраструктуры. Современные формы реализации высокоэффективного и результативного промышленного строительства основаны на практике строительного инжиниринга, который применяется на всех этапах жизненного цикла (ЖЦ) инвестиционно-строительных проектов (ИСП). Анализ текущего состояния рынка инвестиционно-строительной деятельности (ИСД) в сфере промышленного строительства вскрывает несовершенство существующих методов контрактного обеспечения на различных этапах ЖЦ ИСП промышленного строительства и недостаточную интеграцию требуемых адекватных форм инжиниринга под руководством единого комплексного подрядчика, что часто приводит к срыву сроков ввода в эксплуатацию объектов капитального строительства, дополнительным затратам инвесторов и замене подрядчиков в процессе реализации ИСП с последующим судебным разрешением финансовых споров между подрядчиками и заказчиками. Кроме того, современная конкурентная среда требует ввода в эксплуатацию объектов с инновационными и эффективными характеристиками, которые могут быть обеспечены комплексным инжиниринговым подходом, учитывающим взаимосвязь технологической и организационно-управленческой среды на всех этапах ЖЦ развивающегося во времени и пространстве объекта промышленного строительства. Таким образом, актуальная проблематика современного состояния ИСД в сфере промышленного строительства выводит на первый план необходимость выработки принципов комплексного инжинирингового подхода применительно к промышленному строительству и разработки на их основе организационно-экономического механизма реализации комплексного контрактного обеспечения проектов промышленного строительства, повышающих экономическую эффективность и результативность комплексных строительных контрактов (КСК).

Ключевые слова: комплексные строительные контракты, промышленное строительство, строительный инжиниринг, принципы инжинирингового подхода, организационно-экономический механизм

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Иерусалим. Святой колодец. Л.И. Павлова. Рисунок, тушь, перо.

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Basics of scenario development of urbanized territories

The need for scenario planning for the development of urbanized territories in the context of rapid changes in the social, economic and environmental environment is discussed. Modern cities and urbanized territories face many challenges, including climate change, population growth, economic instability and social conflicts. Despite the existence of various methods and approaches to the development of urban spaces, many of them do not take into account the dynamic nature of the processes, which leads to insufficient flexibility and management efficiency. Statically defined options for territorial development actually negate their flexibility and, as a rule, are not implemented properly. The author proposes to introduce a comprehensive level-sectoral approach to scenario development of territories, which will adapt to changes in real time, that is, have a dynamic nature. This approach includes the integration of various aspects of planning and management, both within various sectors of the economy and taking into account different levels of territorial development. It emphasizes the importance of interaction between different sectors and levels of governance, which contributes to more effective adaptation of cities to new challenges and requirements. As a result of applying this approach, it is possible to improve the quality of life of city residents, improve the environmental situation and create a more sustainable infrastructure. The paper also emphasizes that scenario planning is a key tool for achieving effective management of urbanized areas in conditions of uncertainty and rapid change in the external environment, ensuring sustainable and harmonious development of cities and their suburbs in the long term.

Keywords: territorial development, strategy, quality of living environment, scenario approach, dynamically balanced development

Russia needs a long-term development strategy focused on improving the quality and standard of living of people, modernizing and increasing the competitiveness of the national economy, and reducing environmental and climate risks. Therefore, in modern socio-economic conditions characterized by the instability of the situation on global markets and the aggravation of financial security problems at all levels of government in the Russian Federation, the task of increasing the efficiency of using the internal resources of territorial systems is becoming increasingly urgent. Its solution is based on qualitative forecasting and planning [1].

However, the task of forecasting the development of territories is extremely difficult in itself due to both objective and subjective reasons, among which it should be noted the imperfection of statistical accounting, the significant influence of the external environment, the severe limitation of internal resources, etc. The use of expert methods in this case often does not allow us to fully take into account the totality of influencing factors [2, 3].

There are various classifications of approaches in the field of territorial system modelling in Russian and foreign literature. In particular, four aggregated classes can be distinguished, differing in the logic of system construction, the methods of formalization and modelling used [4, 5]:

- models of general economic equilibrium;
- models based on the use of probabilistic and statistical methods;
- models of system dynamics and other simulation-type models;
- models based on the use of various intelligent information technologies.

One of the widely used methods in forecasting socio-economic processes is the scenario approach. The scenario approach is one of the widely used methods in forecasting socio-economic processes. The classical method of scenario planning consists in identifying basic quantitative and qualitative development trends and tracking changes in society under their influence. General principles and methods of scenario development for long-term forecasts of socio-economic development are presented in a number of works, however, in each specific case, the scheme for constructing forecast scenarios is determined by the tasks facing the developers and the specifics of the forecasting object [6, 7].

The scenarios of the long-term development of the Russian economy presented in the forecast developments of various organizations can be roughly divided into two groups: "thematic" and "complex" scenarios. The "thematic" scenarios are based on some motivated ideas about the preferences of various groups of the population in the future socio-economic development of the country (for example, government, scientific, cultural, and other elites). The experience of developing such scenarios is reflected in the work of the Centre of Macroeconomic Analysis and Short-term Forecasting for Russia: scenarios of "super-industrial modernization", "leap into globalization", "economic isolationism", "energy autism" [8]. In "complex" scenarios, various combinations of external and internal factors are grouped depending on the assessment of the "degree of favorability" of development conditions (low, medium, high; pessimistic, realistic and optimistic; etc.). According to this principle, the scenarios of medium-term forecasts and the long-term forecast of the Institute of National Economic Forecasting of the Russian

Academy of Sciences (inertial and internally oriented, investment) are formed [9]. In fact, the “pessimistic, realistic and optimistic” scenarios are conservative, innovative and targeted (accelerated) scenarios of the “Long-term forecast of socio-economic development of the Russian Federation for the period up to 2030”¹. In different versions of the long-term forecast, other names of scenarios were used: conservative, energy-based and innovative, but the substantive prerequisites of the three scenarios are approximately the same.

The purpose of this study is to analyze the methodological aspects of the existing scenario approach and to form the theoretical foundations of the scenario development of urbanized territories, taking into account the basic directions of the theory of dynamic equilibrium.

Forecast scenarios involving spatial aspects of development are being developed for regions of one country or group of countries, and they can also be roughly divided into “meaningful” and “complex” ones. A “meaningful” approach to constructing spatial development scenarios is more common in the study of spatial interactions for groups of countries within the framework of integration associations² [10]. The advantage of a “meaningful” approach is the detailed elaboration of alternative strategies for the spatial distribution of the population and economic activity. The scenarios of the territorial development of the EU countries in the long term until 2030 and 2050 are built in accordance with possible strategies for the development of the European area³. An integrated approach to the development of spatial development scenarios includes a systematic analysis of the current situation, the involvement of stakeholders and the application of a systematic approach that considers the territory as a complex interconnected system [11]. An important aspect is the creation of alternative scenarios, taking into account uncertainty factors and assessing their impact on the social, economic and environmental spheres.

There are also works that consider scenarios for the development of residential and commercial real estate within certain territorial systems under conditions of uncertainty [12, 13].

The peculiarity of the approach proposed by the author in urbanized areas, when quantifying forecast scenarios, is as follows. Depending on the hypotheses embedded in the spatial scenario, priorities for the spatial distribution of resources and economic activity are formed, which, in turn, determine the dynamics of the development of each territory and the trajectory of the economy as a whole as a summary indicator of the dynamics of individual territories. It is recommended to use the spatial distribution of investments in the territorial context as a control parameter in the calculations. Differences in investment dynamics are proposed to be considered across 8 industry complexes: agriculture, mining, processing, energy, trade, transport and communications, commercial services and social services. Thus, it is possible to form a spatial structure of investments in the final form, relative to the spatial distribution of investments across various industry complexes.

Thus, the principle described above will make it possible to use an integrated level-sectoral approach when developing scenarios for the development of territories. The essence of the proposed approach is to take into account not only various management levels within a territorial feature (quarter, microregion, urban area, city, urban district, municipality, municipal district, agglomeration, subject

of the federation — territory, region, federal district, country, international association), but also the existing state and forecast prospects for the development of industries within the boundaries of the territories under consideration (industry, agriculture, forestry, construction, other types of activities in the field of material production, agricultural services, transport, communications, trade and catering, logistics-technical supply and sales, procurement, information and computing services, real estate operations, general commercial activities to ensure the functioning of the market, geology and exploration of the subsoil, geodetic and hydrometeorological services, housing, utilities, non-industrial types of consumer services, health care, physical education and social security, public education, culture and art, science and scientific services, finance, credit, insurance, pension provision, management, public associations).

The sum of the sectoral and regional components is important for scenario calculations for spatial development options. It characterizes the differentiation of investment distribution in the regional context. The implemented indicator thus acts as a differentiated supplement to the national component. This methodological technique represents the value of projected economic growth in the region as the sum of nationwide and geographically differentiated components.

As a result, the volume of investments in fixed assets in the forecast period within the boundaries of the territory (ln^i) is proposed to be calculated as follows:

$$ln^i = ln^S + ln^{lok}; \quad (1)$$

$$ln^S = ln_{ret}^S \cdot T_r^{ln}; \quad (2)$$

$$ln^{lok} = ln_{ret}^{lok} \cdot T_r^{ln} + \left(\frac{\sum_{i=1}^n Ind_{ter}}{n} - 1 \right), \quad (3)$$

where ln^S — volume of investments in fixed assets in the forecast period within the boundaries of the territory under consideration, due to the country-wide economic dynamics;

ln^{lok} — volume of investments in fixed assets in the forecast period within the boundaries of the territory under consideration, due to the specifics of territorial development conditions;

ln_{ret}^S — volume of investments in fixed assets, due to the country-wide economic dynamics, in the retrospective period for the territory under consideration;

T_r^{ln} — growth rate of investments in fixed assets in the retrospective period in the territory under consideration;

ln_{ret}^{lok} — volume of investments in fixed assets determined by regional development conditions in the retrospective period for the territory under consideration;

Ind_{ter} — territorial indicators of sustainable socio-economic development.

During the study of several dozen indicators, the following model was prepared:

$$ln_{ret}^{lok} = f(Ind_{ter}). \quad (4)$$

1 Forecast of the long-term socio-economic development of the Russian Federation for the period up to 2030. The Ministry of Economic Development of Russia. 2013. URL: www.consultant.ru/document/cons_doc_LAW_144190 (Accessed: 09.03.2025). (rus.).

2 European Territorial Scenarios 2050. ESPON 2050. URL: <http://www.et2050.eu> (Accessed: 09.03.2025).

3 Long-term forecast of the economic development of the Eurasian Economic Union until 2030. Moscow, June 2015. URL: <http://eurasianstudies.org/wp-content/uploads/2017> (Accessed: 09.03.2025).

Here, the following indicators are used as territorial indicators of sustainable socio-economic development, normalized to the average Russian level: enterprises' own funds; investments in fixed assets from the federal budget; multiplier of investments in fixed assets from the federal budget; input of fixed assets; share of total investments in fixed assets aimed at modernizing production; volume of housing construction and so on.

The value of the above value determines the increased investment activity in the region and, as a result, more intensive inter-regional economic cooperation along the established production chains.

A dynamically balanced approach to the development of urbanized territories should be based on the principles of sustainable development and systemic thinking, which allows for flexible response to changes, integration of economic, social and environmental aspects, as well as involvement of various stakeholder groups in the planning process. It should facilitate risk forecasting and management, take into account the long-term consequences of decisions and actively use modern technologies for data analysis, considering the city as a complex interconnected system. This will ensure an integrated and sustainable approach to development, contributing to the harmonious coexistence of different interests and improving the quality of life for future generations.

As the main indicator characterizing the balance of a particular scenario of development of an urbanized territory, the author proposes to introduce the index of sustainable development (sustainability) (I_{sd}). Which acts as the following function:

$$I_{sd} = f(GP, IN, B, NWF, Inf, ER, QLE, LP, UR, KR, PH, Ot), \quad (5)$$

where GP is the gross product of the territory;

IN is the volume of investments;

B is the budget balance;

NWF is the national wealth fund;

Inf is the inflation rate;

ER is the exchange rate of the national currency;

QLE is the quality of the living environment;

LP is the labour productivity;

UR is the unemployment rate;

KR is the key rate;

PH is the price of hydrocarbons;

Ot is other factors.

At the same time, I_{sd} at different stages of cyclical development can take different values: ≥ 1.0 — growing; $\leq 1.0-0.5$ — average falling; $\leq 0.5-1.0$ — average growing; $\leq 0.5-0.1$ — crisis.

The influence of this or that factor on the sustainability index is presented in Table.

Thus, it can be noted that the historical experience of Russia and the experience of other countries shows that sustainable development is impossible without full-fledged strategic planning adapted to the realities of the modern socio-economic system of Russia.

Strategic programmes and projects of the state at the federal and regional levels should be aligned with the strategies and programmes of state corporations, as well as take into account the plans of private business.

Using a scenario approach to develop spatial development forecasts allows us to assess the long-term consequences of implementing alternative strategies for territorial development, link the macroeconomic forecast with real socio-economic processes taking place in the regions, identify sources of growth, the nature of which is related to space, and identify the most acute problems in the development of regions.

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Основы сценарирования развития урбанизированных территорий

В статье рассматривается необходимость сценарирования развития урбанизированных территорий в условиях стремительных изменений социальной, экономической и экологической среды. Современные города и урбанизированные территории сталкиваются с множеством вызовов, включая изменение климата, рост населения, экономическую нестабиль-

ность и социальные конфликты. Несмотря на наличие различных методов и подходов к развитию городских пространств, многие из них не учитывают динамическую природу процессов, что приводит к недостаточной гибкости и эффективности управления. Статически определенные варианты территориального развития фактически нивелируют их гибкость и, как правило, не исполняются должным образом. Автор предлагает внедрить комплексный уровень-отраслевой подход к сценарному развитию территорий, который будет адаптироваться к изменениям в реальном времени, т.е. иметь дина-

мический характер. Этот подход включает в себя интеграцию различных аспектов планирования и управления как в рамках различных отраслей экономики, так и с учетом разных уровней территориального развития. Он акцентирует внимание на важности взаимодействия между различными секторами и уровнями управления, что способствует более эффективной адаптации городов к новым вызовам и требованиям. В результате применения данного подхода возможно повысить качество жизни горожан, улучшить экологическую ситуацию и создать более устойчивую инфраструктуру. В статье также подчеркивается, что сценарное планирование является ключевым инструментом для достижения эффективного управления урбанизированными территориями в условиях неопределенности и быстрого изменения внешней среды, обеспечивая устойчивое и гармоничное развитие городов и их пригородов на долгосрочную перспективу.

Ключевые слова: территориальное развитие, стратегия, качество среды жизнедеятельности, сценарный подход, динамически сбалансированное развитие

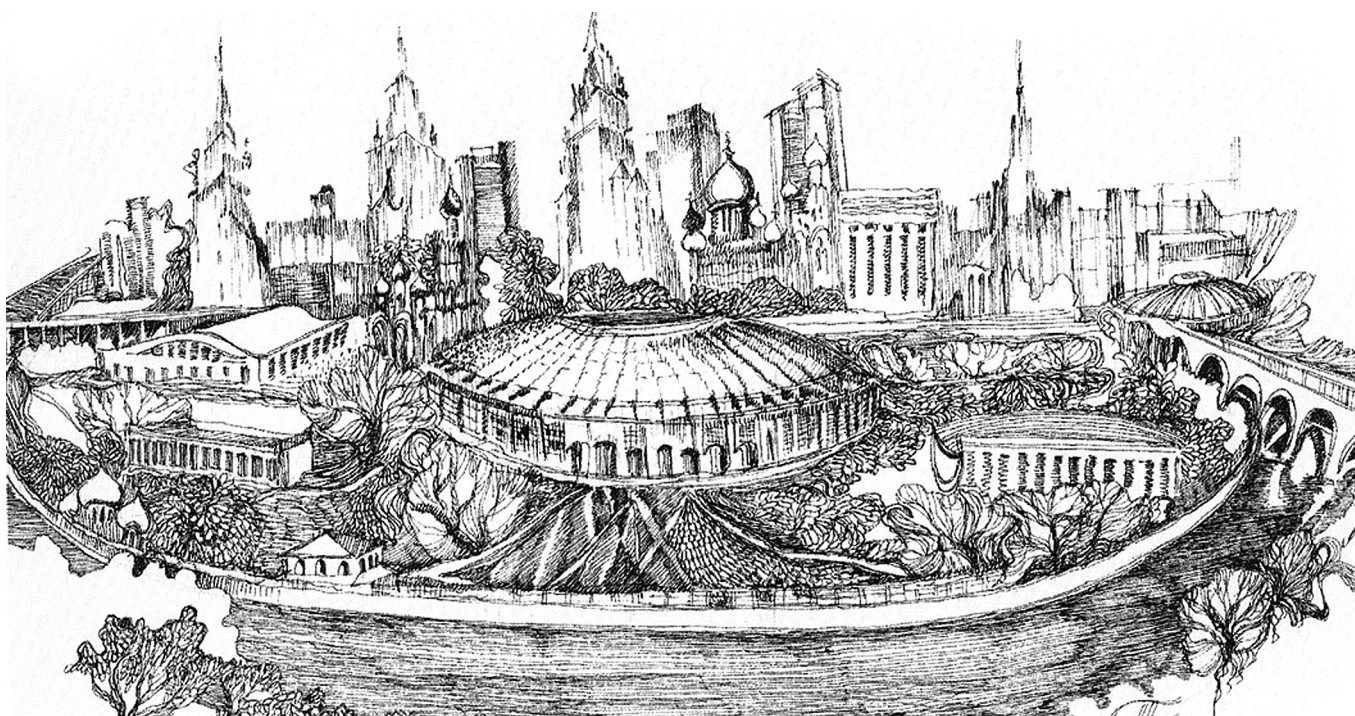
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Integration of information modelling to improve the performance of capital construction objects: modern approach and perspectives

The paper deals with the integration of information modelling to improve the performance of buildings, basic concepts of the life cycle of buildings, modern approaches to building management and performance improvement at various stages of the life cycle. In modern conditions, information modelling technology (IMT) becomes the main tool to improve the performance of objects. Building performance parameters (BPP) — characteristics of the building, showing the evaluation of the object functioning in accordance with the established/set criteria. Modern approaches to the introduction of information modelling in operational processes are considered, such as: the use of digital twins, digital passportization, implementation of software solutions. The prospects of applying IMT for more accurate planning of preventive works, operative detection and elimination of faults, which leads to significant cost reduction at the operation stage, are also discussed in detail. It is important to specify that construction is improving and becoming fast every year, this leads to an increase in the number of commissioned real estate objects. The main reason for this rapid rate of growth is due to the integration of IMT into the life cycle stages of construction projects. The other side, which is negative and needs significant and deep elaboration and fresh ideas, is the enormously high costs during the operational phase, which is problematic to predict in most cases. Deficiencies in previous phases are activated and become more pronounced in the operational phase. IMT is an important process in all phases of the life cycle, in the operational phase the value of this technology lies in the data that carries up-to-date information about the project and in the increased level of integration of work with it.

Keywords: information modelling technology, digital twin, building performance, life cycle of construction object, real estate management

INTRODUCTION

Modern construction is a complex process requiring thorough consideration of all construction elements. Therefore, integrating various technologies to ensure efficient building operation is a particularly important component. Building Information Modelling (BIM) is a modern method used for construction, equipping, and managing the life cycle of buildings. This approach considers the construction project as an integrated complex that includes infrastructure elements, technological systems, and the construction object itself [1].

Information models provide opportunities for managing construction schedules, risks, and cost estimates. BIM technology enables visualization of any building system and element in a three-dimensional format, planning and calculating their arrangement, and analyzing the operational characteristics of designed structures to help select the most rational solution. These methods allow for minimizing corrections and remarks, reducing work execution time, and significantly cutting costs at both the construction stage and during the building's subsequent operation. The integration of BIM technology helps lower the total cost estimate of designed buildings and structures, substantially reducing operating expenses and optimizing utility costs for property owners.

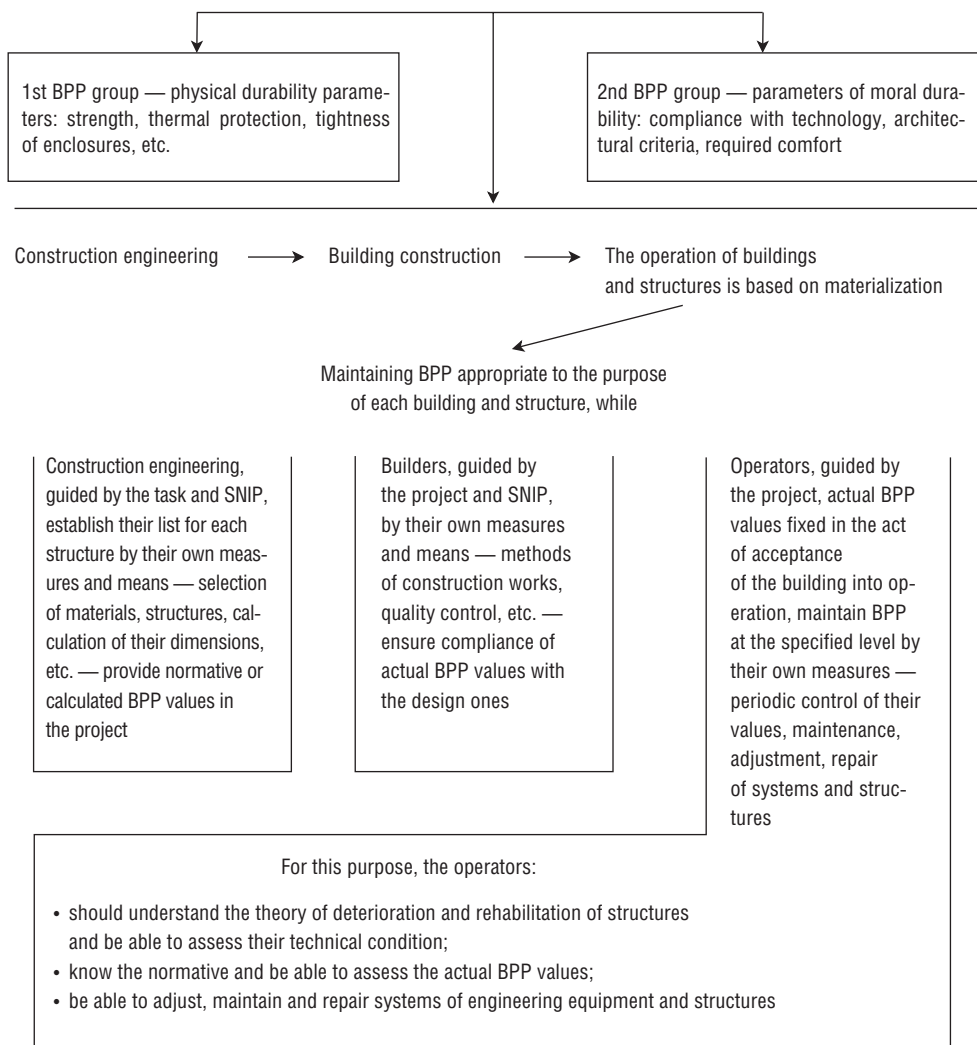
According to statistics from experts within the Expert Council and the Working Group under the Ministry of Construction of the Russian Federation regarding BIM integration in industrial and civil construction, construction companies primarily use BIM at the design stage (up to 80 % of total BIM

adoption), approximately five times less at the construction stage (around 15 %), and the lowest utilization occurs at the operation stage (about 5 %) [2].

Financial expenditures of up to 80 % of the total estimated cost are associated with management and the operational stage of the building's life cycle. Given this data, limiting the integration and use of BIM at various stages of the building's life cycle is unwise. By designing and implementing a digital model — a "digital twin" of the building [3] — object management and operation become more efficient. Additionally, there is a significant increase in the service life of engineering systems, communications, and the building as a whole, leading to reduced expenses and an improved quality of life for the property owner(s) [4].

The experience of using BIM abroad [5, 6] clearly demonstrates and recommends the development and updating of reconstruction, renovation, and maintenance processes for buildings and structures. However, in Russia, the application of BIM in this area has received little attention, even though it is crucial for building operation practices.

The operation and repair phase of buildings is a costly and critical stage in the entire building life cycle. As previously mentioned, this accounts for up to 80 % of the total life cycle cost. Therefore, during the operation stage, BIM offers significant opportunities for integration and application. The building information model can always provide up-to-date information on the condition of structural elements, engineering systems, etc. This enables the development of a precise schedule and plan for maintenance work, cost estimates, identification



Performance parameters of buildings and structures

of necessary contractors, and oversight of completed work. These parameters can be useful for both management companies and property owners engaged in rental business.

The relevance of this topic lies in the fact that Russia currently has a vast housing stock [7, 8], and large-scale projects for comprehensive territorial development are actively being implemented in place of industrial zones. The already developed housing stock, which is owned by both the state and private individuals, requires constant maintenance and capital repairs. New construction also demands electronic passporing to ensure precise control, execution of repair works, and elimination of defects that arise during the building's construction phase. This method will enhance efficiency and reduce building operation costs.

Let us consider the groups of operational qualities of buildings. There is a set of indicators that must be considered during the design and construction of a building. These criteria are divided into two groups [9]:

Group 1: Parameters related to the physical durability of the building, such as moisture resistance, thermal insulation, structural strength, and wear resistance.

Group 2: Parameters related to the moral longevity of the building, such as compliance with modern trends in design, planning,

and architectural solutions, as well as the use of new engineering equipment and methods.

All quantitatively measurable qualities are represented in numerical form, while the rest are evaluated subjectively. These operational quality parameters (OQP) are taken into account at various stages of construction, starting from building design (fig.).

A significant problem is that some buildings do not meet the original project specifications once construction is complete. The discrepancy between planned and actual indicators can be substantial, resulting in significant financial costs to the owner. This phenomenon can be referred to as a "gap"; if the gap is large, adjustments to certain construction elements may be required, changes may have to be made or, in extreme cases, the building may not be allowed to operate. In addition, the transition from traditional methods to new technologies is often challenging. For example, the integration of BIM may be resisted by property managers or owners due to insufficient knowledge of the technology. It is therefore crucial to promote the widespread adoption of BIM at various stages of the lifecycle, possibly through Russian government regulations. To date, Government Decree No. 2357, which comes into force on 1 July 2024, already mandates the implementation of BIM in the construction sector [10].

► The prospects for integrating information modelling to improve the performance of civil buildings lie in several aspects:

- Digital Twins. The widespread use of digital twins will enhance both analytical and economic capabilities of BIM in different life cycle stages. With digital twins, property owners and managers can reconstruct every parameter and element from the real environment into the digital model. Designers can conduct digital simulations and analyze expected results before making adjustments to project documentation that could impact the physical and actual building in the future [11, 12];
- Electronic Passporting. The electronic passport of real estate objects is an automated platform for storing and processing technical documentation data. This system organizes technical information and provides tools for working with parametric data. It includes an interactive building model that allows for more accurate and comprehensive visualization of object characteristics. The software suite contains functions for generating reports on the current technical condition of the building and assessing risks of emergency situations. The electronic passport system also stores catalogs of project, operational, and technical documentation and ensures compliance with maintenance recommendations through various monitoring methods aimed at addressing deficiencies [13, 14];
- Virtual Reality. Today, BIM is considered one of the foundations of digital transformation in the construction industry. The combination of BIM and VR presents tremendous opportunities at the design, construction, and operational stages.

A key advantage of this integration is improved interaction with property owners or management companies. Owners can immerse themselves in a virtual environment and actively participate in the design and subsequent operation process. Builders can easily oversee work processes and identify critical issues requiring special attention. This practical involvement provides more informed feedback and adjustments that reflect owners' preferences, construction oversight, and more. Moreover, this technological fusion increases project efficiency by enabling the creation of virtual models that help detect potential problems before construction begins, preventing costly mistakes [15].

CONCLUSION

The rapid growth of new construction, territorial development programs, and the renewal of existing urban fabric are highly relevant and promising topics that require detailed elaboration and the implementation of various technologies and methods to address current challenges. The integration of BIM for improving building operational qualities is a crucial segment that will resolve a wide range of problems at different stages of the building life cycle.

Интеграция информационного моделирования для улучшения эксплуатационных качеств объектов капитального строительства: современный подход и перспективы

В статье рассмотрены вопросы интеграции информационного моделирования для улучшения эксплуатационных качеств зданий, базовые понятия жизненного цикла зданий, современные подходы к управлению зданием и повышению эксплуатационных качеств на различных этапах ЖЦ. В сов-

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ременных условиях технология информационного моделирования (ТИМ) становится главным инструментом, который позволяет улучшить эксплуатационные характеристики объектов. Параметры эксплуатационных качеств здания (ПЭК) — характеристики здания, показывавшие оценку функционирования объекта в соответствии с установленными/заданными критериями. Рассмотрены современные подходы к внедрению информационного моделирования в эксплуатационные процессы, такие как: использование цифровых двойников, электронная паспортизация, внедрение программных решений. Также подробно обсуждаются перспективы применения ТИМ для более точного планирования профилактических работ, оперативного выявления и устранения неисправностей,

что приводит к значительному снижению затрат на этапе эксплуатации. Важно уточнить, что строительство с каждым годом совершенствуется и становится быстрым, это приводит к увеличению числа вводимых в эксплуатацию объектов недвижимости. Главной причиной такого быстрого темпа роста обусловлена интеграция ТИМ в этапы жизненного цикла объектов строительства. Другая сторона, которая является негативной и нуждается в значительной и глубокой проработке, а также в свежих идеях — это колоссально высокие затраты на этапе эксплуатации, которые проблематично предсказать в большинстве случаев. Недоработки на предыдущих этапах активизируются и проявляются более ярко на этапе эксплуатации. ТИМ является важным процессом на всех этапах ЖЦ, на этапе эксплуатации ценность данной технологии заключается в данных, которые несут в себе актуальную информацию о проекте, и в повышенном уровне интеграции работы с ними.

Ключевые слова: технология информационного моделирования, цифровой двойник, эксплуатационные качества здания, жизненный цикл объекта строительства, управление недвижимостью

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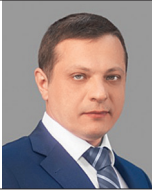
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Methodological approach to calculating the integral indicator of organizational and technological reliability of repair and restoration processes of apartment buildings

The housing stock is subject to moral and physical deterioration, which requires timely repair and restoration work. The efficiency of such work directly affects the durability of structural elements, the performance characteristics of buildings and the cost of their maintenance. In the context of limited resources and increasing demands on the quality of repairs, there is a need to develop methods to objectively assess the reliability of repair processes. One of the key approaches to such an assessment is the use of an integral organizational and technological indicator of reliability, which takes into account a set of factors affecting the efficiency of the repair work performed. This indicator allows you to quantitatively assess the impact of organizational, technological and economic factors on the reliability of the process, identify problem areas in the repair management system and predict the time between repairs. This article presents a methodology for calculating the integral indicator of the organizational and technological indicator of the reliability of repair processes, based on a comprehensive consideration of many factors and their significance. The development of this methodology will improve the objectivity of assessing the reliability of repair processes, optimize the distribution of resources, and increase the service life of buildings through rational planning of repair activities. The proposed approach can be used both in the design of repair work and in their analysis and improvement during the operation of buildings.

The developed neural network model uses a multi-layer approach with an activation function in hidden layers and a sigmoid in the output layer. Input data are normalized and processed using the backpropagation method, which allows for more accurate forecasting of inter-repair periods and assessment of the operational reliability of a building.

Keywords: *reliability of buildings, inter-repair period, indicator of organizational and technological reliability, neural network model, repair and restoration process*

The reliability of repair and restoration processes is determined by their ability to ensure the required level of operational characteristics of the building during the period between repairs [1]. Reliability is influenced by organizational, technological and economic factors that determine the quality of work, the durability of structural elements and the efficiency of repair management [2].

For a comprehensive assessment of reliability, an integral indicator is introduced that combines various aspects of repair work [3, 4] and allows taking into account their significance. Such an indicator is formed on the basis of standardized values of factors reflecting the key characteristics of the repair and restoration process.

Traditional methods of calculating reliability are based on statistical data, expert assessments and standard indicators [5]. However, these methods often do not take into account complex nonlinear dependencies between parameters, which complicates accurate forecasting between repairs [6]. In this regard, a promising direction is the use of artificial neural networks, which allow analyzing multidimensional dependencies and identifying hidden patterns [7].

To build a neural network model for calculating the integral organizational and technological indicator of the reliability of repair and restoration processes, a multi-layer neural network (MLP — Multi-Layer Perceptron) is used [8]. Such a network allows analyzing the relationships between factors, taking into

account their significance and predicting the overall reliability indicator (Fig. 1) [9].

1. Input factors (input layer neurons).
 - 1.1. Organizational and technological factors (Q_i).
 - 1.1.1. Q_1 — Quality of repair and construction works.
 - 1.1.2. Q_2 — Equal strength of materials of structural elements and engineering systems.
 - 1.1.3. Q_3 — Level of improvement and landscaping.
 - 1.1.4. Q_4 — Energy efficiency of the building.
 - 1.1.5. Q_5 — Repairability of building elements and systems.
 - 1.1.6. Q_6 — Adaptability to modern design and technological solutions.
 - 1.1.7. Q_7 — Possibility of organizing a flow method for performing repair works.
 - 1.1.8. Q_8 — Selection of rational organizational forms of project management of restoration works.
 - 1.1.9. Q_9 — Level of qualification of workers and engineering and technical personnel.
 - 1.2. Technical factors (T_j).
 - 1.2.1. T_1 — Level of technical equipment of contracting organizations.
 - 1.2.2. T_2 — Durability of structural elements.
 - 1.2.3. T_3 — Reliability of suppliers of materials and equipment.
 - 1.2.4. T_4 — Technical control of the life cycle of repair and restoration works.
 - 1.2.5. T_5 — Level of complexity of repair works.
 - 1.2.6. T_6 — Complexity of repair and restoration works.

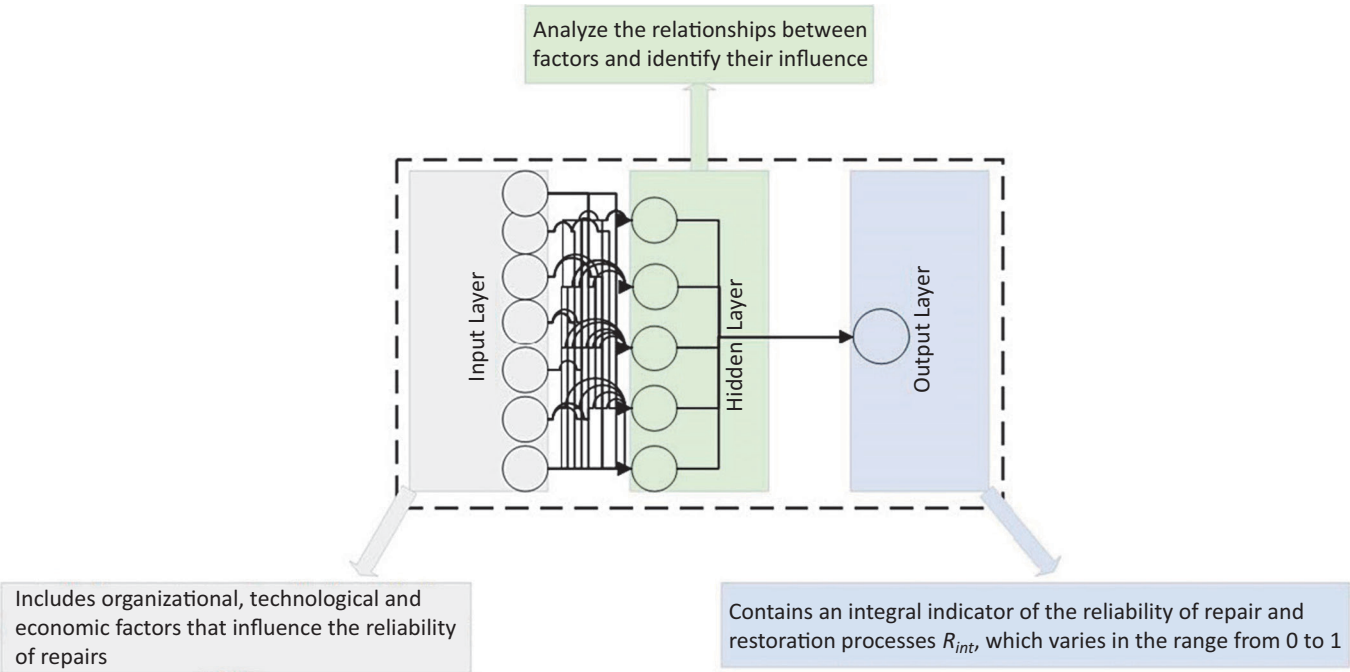


Fig. 1. Neural network model for calculating the integral organizational and technological indicator of reliability

- 1.2.7. T_7 — Coordination of actions by volume, place and time between successively performed works.
- 1.2.8. T_8 — Service life of the building and the number of years since the last major repairs.
- 1.2.9. T_9 — Level of mechanization and robotization of works.
- 1.2.10. T_{10} — Level of influence of physical wear of elements on the building as a whole.
- 1.3. Socio-economic factors (E_i).
- 1.3.1. E_1 — Planned cost of repair and restoration work.
- 1.3.2. E_2 — Share of physical depreciation in the total replacement cost of the building.
- 1.3.2. E_3 — Inflation index I_t .
- 1.3.3. E_4 — Capital-labor ratio.

The input layer consists of 23 neurons (according to the number of factors considered), the first hidden layer includes 10–14 neurons (identification of local dependencies), the second hidden layer of 5–8 neurons (analysis of interactions) and the output final layer consists of 1 neuron (final reliability indicator R_{int}).

The activation function for hidden layers is calculated using formula 1 and allows for nonlinear dependencies to be taken into account:

$$ReLU f(x) = \max(0, x). \tag{1}$$

The activation function for the output layer is calculated using the sigmoid function according to formula 2 (R_{int} must be in the range [0.1]):

$$f(x) = \frac{1}{1 + e^{-x}}. \tag{2}$$

Each neuron in the hidden layers calculates an output value using formula 3:

$$H_i = f\left(\sum_{j=1}^n W_{ij} \cdot X_j + b_i\right), \tag{3}$$

where $f(x)$ — activation function;

- W_{ij} — weight coefficient of connection;
- X_j — input values of factors;
- b_i — bias.

The final formula for calculating the integral indicator of the organizational and technological indicator within the framework of the analysis under consideration is calculated using formula 4:

$$R_{int} = f\left(\sum_{i=1}^n W_i \cdot R_i + b\right), \tag{4}$$

- where W_i — weight coefficients of factors;
- R_i — normalized input values of factors;
- b — bias.

Fig. 2 shows a graphical model of a neural network for calculating the reliability of repair processes.

The developed neural network model for calculating the integral organizational and technological indicator of the reliability of repair and restoration processes allows for the effective analysis of complex relationships between organizational, technical and economic factors affecting the durability and efficiency of building operation [10, 11].

The use of a multilayer neural network (MLP) makes it possible to take into account various parameters, including the quality of construction work, the technical condition of structural elements, economic costs and the predicted reliability of repair processes. The inclusion of hidden layers in the network architecture made it possible to identify nonlinear dependencies that are difficult to use traditional analysis methods [12].

The advantages of using this calculation method include increased accuracy of forecasting the time between repairs, optimization of repair and maintenance costs by identifying critical factors, and the flexibility of the model allows for adapting various situations to specific operating conditions and changing parameters [13, 14].

The developed approach can be used to make informed decisions on planning and implementing repair activities [15]. Further

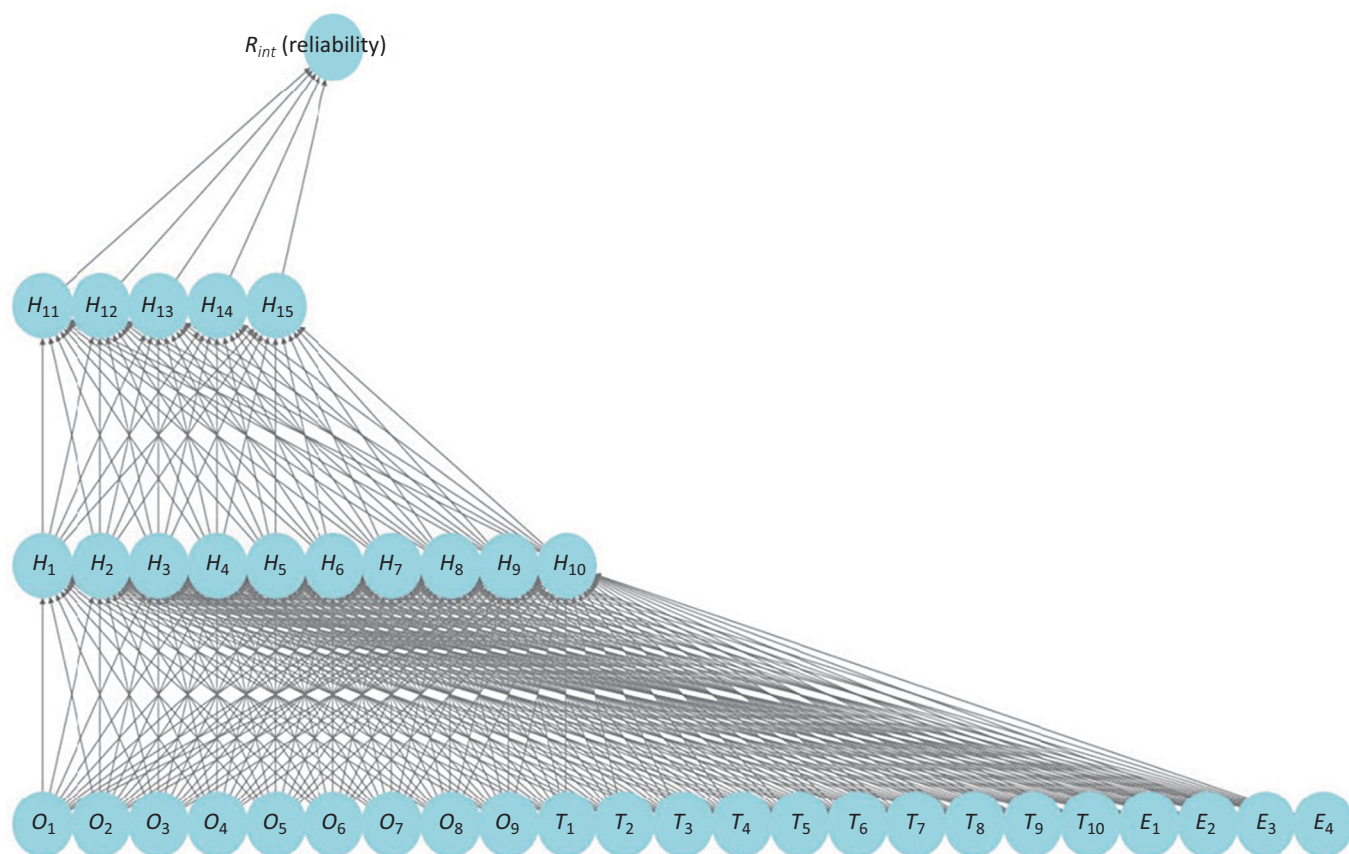


Fig. 2. Graphic model of a neural network for calculating the reliability of repair processes

development of the model is possible by including additional factors, expanding the data set, and using deep learning to more accurately forecast the reliability of buildings [16, 17].

Thus, the neural network method for calculating the integral reliability indicator is an effective tool for analysis and decision-making, contributing to an increase in the service life of buildings, a reduction in operating costs and an increase in functional reliability.

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Методический подход к расчету интегрального показателя организационно-технологической надежности ремонтно-восстановительных процессов многоквартирных домов

Жилой фонд подвержен моральному и физическому износу, что требует проведения своевременных ремонтно-восстановительных работ. Эффективность проведения таких работ напрямую влияет на долговечность конструктивных элементов, эксплуатационные характеристики зданий и затраты на их содержание. В условиях ограниченности ресурсов и роста требований к качеству ремонта возникает необходимость в разработке методов, позволяющих объективно оценить надежность ремонтно-восстановительных процессов.

Одним из ключевых подходов к такой оценке является использование интегрального организационно-технологического показателя надежности, который учитывает совокупность факторов, влияющих на эффективность проведенных ремонтных работ. Данный показатель позволяет количественно оценить влияние организационных, технологических и экономических факторов на надежность процесса, выявить проблемные места в системе управления ремонтом и прогнозировать межремонтные сроки.

В данной статье представлена методика расчета интегрального показателя организационно-технологического показателя надежности ремонтно-восстановительных процессов, основанная на комплексном учете множества факторов и их весомости. Разработка данной методики позволит повысить объективность оценки надежности ремонтных процессов, оптимизировать распределение ресурсов, увеличить срок службы зданий за счет рационального планирования ремонтных мероприятий. Предложенный подход может быть использован как при проектировании ремонтных работ, так и при их анализе и совершенствовании в ходе эксплуатации зданий.

Разработанная нейросетевая модель использует многослойный подход с функцией активации в скрытых слоях и сигмоиду в выходном слое. Входные данные нормализуются и обрабатываются с помощью метода обратного распространения ошибки, что позволяет повысить точность прогнозирования межремонтных сроков и оценки эксплуатационной надежности здания.

Ключевые слова: надежность зданий, межремонтный срок, показатель организационно-технологической надежности, нейросетевая модель, ремонтно-восстановительный процесс

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An interdisciplinary approach to lifecycle management of university campus facilities

This article is a continuation of the series of publications devoted to the program creation of university campuses, which are one of the main drivers of scientific and technological development and training of highly qualified personnel today.

In the previous publications in this area, the author investigated the possibilities of using “Educational and technological conditions” as a new type of engineering parameters-measurers of the material and spatial environment, “Educational and technological task” as a new type of document that is part of the design task or part of the contract for the provision of services for the management or technical operation of capital construction of campuses, “Combinatorial matrix” as an institute for the development of university campuses within the framework of the program for the development of university campuses.

In this article, the author has identified and analyzed some features of defining the life cycle of capital construction objects of university campuses and their life cycle management. The author assessed the degree of influence of these features on different stages of the life cycle, depending simultaneously on the goals of national projects in the field of personnel training, and simultaneously on the material and technical base of educational organizations of higher education. The increasing emphasis of this direction is determined by the great challenges facing the Russian economy at the moment in the field of technological development. Science and technology get a new role as fundamental elements in solving many national and global problems. The article also reveals some approaches to the organization of educational environment, changing in the conditions of transition from post-industrial to information economy.

Keywords: Life cycle, life cycle management, university campuses, material-spatial environment, socio-economic effects, analytical indicators, interdisciplinary approach

INTRODUCTION

In recent years, the world is actively developing the activity on life cycle management of capital construction objects of various functional purposes. Its basis is formed by the goals of the owner of objects, and these goals are not constant, but on the contrary, can change dramatically during the existence of the object. The goals may have different orientations, ways of achievement, required costs and degrees of influence of the object, its characteristics and properties. Managing the life cycle of real estate objects is an important and urgent task, because real estate plays a key role in the economy and society [1]. Buildings, structures, infrastructure with different parameters and characteristics, exist for a long time and go through different stages of the life cycle also differently. It is obvious that each stage of the life cycle of the object, especially if it is a multi or even multifunctional object, will correspond to characteristic goals and objectives. In general, all stages can be considered as a process of object development aimed at improving its efficiency and consumer appeal within the framework of change management.

FEATURES OF THE LIFE CYCLE OF UNIVERSITY CAMPUS FACILITIES

A specialized, safe, efficient, and comfortable physical and spatial environment plays a major role in the life of university campuses. All these features aim to maximize the outcome of owning

and managing campus facilities throughout their life cycle. For example, according to¹, the life cycle of a capital construction object is the period of the object's existence, during which engineering surveys, design, construction, technical re-equipment, reconstruction of linear objects, reconstruction of capital construction objects, major repairs of capital construction objects, major repairs of linear objects, and liquidation of the object are carried out. But this definition does not allow to reveal the variety of goals, objectives, development prospects facing the university at the pre-project stage, at the stage of preparation of design solutions, during construction and especially during the period of functioning. After all, here will necessarily be present the formation of plans for the development of the territory, ideas on the gradual increase in the number of graduates, vision of the development of research tasks to be solved, options for ways to manage the real estate complex and much more.

In systems engineering (GOST R 57193–2016²) there is a more precise definition of the life cycle as the development of an object system from the origin of an idea to its realization². And within the framework of the system approach to technology, we can emphasize the principles that form the basis of the life cycle:

1. Within the life of the object, its development, change, including the change of investment priority is carried out.
2. At each stage of the life cycle of the construction object the corresponding engineering life support

1 GOST R 58179–2018. Engineering in construction. Terms and definitions. dated 16.07.2018.
2 GOST R 57193–2016. Systems and software engineering. System life cycle processes.

systems should be realized. Only with this approach it will be possible to realize the desired result.

3. Manufacturability, usability and maintainability, as well as waste utilization should be envisaged and practically implemented at specific stages of the life cycle.

4. Transition to the next stage of the life cycle of the construction object is necessary only when all the goals of the current stage are achieved [2].

The key concept in this case is the material-spatial environment of an educational organization. This is a set of material objects of the educational environment in a limited space, providing necessary and sufficient conditions for the realization of one or more functions provided by the educational technology in this space [3]. In the functional sense, the university campus is essentially a single material-spatial environment. It is united with the city, with industry, with local business.

In turn, the term "educational environment" is currently also undergoing changes. If initially the educational environment was supposed to be a favorable or well-appointed, providing external and internal conditions for achieving the goals of the educational process, now it is defined as a set of opportunities for personal development arising from its interaction with its social and spatial-subject environment³. In addition, there is a technologization of the concept due to the introduction of modern technologies of learning and development, due to the fact that all subjects of educational activity and external partners interact in the conditions of informatization, as well as other effective organizational and technological mechanisms and tools for this interaction. Thus, we see the educational environment of the university as a complexly organized system, depending on a variety of factors, a significant part of which is material and spatial in nature.

In the conditions of generation of new development goals, the value of educational space as a social system becomes more important [4]. The need for such changes logically follows from the processes that occur in society and economy. The fourth industrial revolution requires the acquisition by specialists of competencies corresponding to the demands of the digital economy [5].

According to the report "University campuses and the city: cooperation for the sake of competitiveness"³, a campus is a set of objects that perform educational, research and innovation, as well as service functions, infrastructural issues of university development, models of interaction between universities and territories of presence. Therefore, let us note once again that the concept of "campus" correlates with the concept of "material-spatial environment".

The elements of the material-spatial environment, which includes the educational process, are the building itself, its premises, structures and design of premises, engineering systems and equipment providing internal microclimate, low-current networks, functional, educational and technological equipment. Accordingly, the material and spatial environment is formed on the basis of the campus as a "object" defined in time and space, and includes subjects (all participants of the educational and scientific process), partners (from the region, business), infrastructure, environment (social and material-spatial) and all the tools and mechanisms of interaction. At the same time, it is

not an established system even for the time being, as its transformations are associated with the constant search and implementation in practice of new technologies and methods of organization of educational and research processes. Thus, speaking about the life cycle of university campus objects, we talk about the life cycle of a multifunctional, dynamic material-spatial environment.

NEW INSTITUTIONAL ENVIRONMENT AS A LIFE CYCLE MANAGEMENT GOAL

Today, higher education organizations are moving towards Education 3.0 and include innovative activities in their agenda (University 3.0). The list of educational technologies that are used in the learning process is noticeably expanding. Many of them have already been described in previous publications. But it is necessary to note the technologies that require the device of special spaces. These are virtual educational laboratories, inverted learning, hybrid formats, collaborative centers, spaces for teamwork, demonstration areas for industrial development of the results of research, development and technological works, laboratories with the possibility of live broadcasting of experiments, AR, VR-labs, additive laboratories, robotized laboratories, etc.

Unfortunately, the existing outdated infrastructure and facilities of many universities do not meet modern requirements, and sometimes are not suitable at all. Meanwhile, in the conditions of implementation of the campus program, or simply reconstruction or overhaul of buildings of other educational organizations, there is an opportunity to provide in advance and justify the necessary parameters for the creation of a modern material and spatial environment.

For example, a specialized material-spatial environment with a practical orientation of educational and scientific processes provides the opportunity to: create and work in appropriate scientific laboratories to test technological hypotheses; expand the network of departments; create collaborative centers, collaborative spaces, digital departments, and advanced engineering schools in simulated, multifunctional spaces; make digital content and live streaming of experiments available to the public; and provide accessibility of digital content and live streaming of experiments to the public.

The effective functioning of the subjects of technological development described above requires a qualitatively new institutional environment, which will include:

- institutions to support their own lines of technology development, including collective use centers for research and development infrastructure, testing and trials;
- contractual forms of integration of research and development and production and technological activities, realization of public-private partnerships;
- digital platforms and information services to ensure networking of subjects of technological development.

If the Concept⁴ defines key educational organizations of higher education and research centers as the driver of technological development of the Russian Federation, then, taking into account the demand for a new institutional environment, it is more accurate to call the concept of modern university campuses as the driver of technological development⁵.

3 University campuses and the city: cooperation for the sake of competitiveness, August 2021. VEB RF University. Center for Strategic Research. URL: <https://www.csr.ru/upload/iblock/3f0/kbpm276p3tau6knldla3d6ozz0fve0e.pdf> (rus.).

4 Concept of Technological Development for the period until 2030. Approved by the Order of the Government of the Russian Federation dated May 20, 2023. No. 1315-r. URL: tatic.government.ru/media/files/KIJ6A00A1K518Aw93NfRG6P8OlbBp18F.pdf (rus.).

5 Standard of Innovative Educational Environment (Campuses) (approved by the Ministry of Science and Higher Education of the Russian Federation on May 8, 2024). URL: <https://www.consultant.ru/cons/cgi/online.cgi?req=doc&base=EXP&n=854557#MN2KbeUroCluLXnY> (rus.).

Based on the definition of innovation projects⁴, the campus can be conditionally equated to an innovation project in general, and in particular — to the environment for creating innovations necessary for scientific and technological development of the country. Since on the basis of the campus it is possible to create a kind of innovation and technology centers aimed at increasing the investment attractiveness of research and development, commercialization of their results, as well as expanding the access of citizens and legal entities to participate in promising scientific and scientific-technical projects.

The following tasks set before the participants of the campus program by the Ministry of Education and Science in the conditions of digitalization of the economy can be highlighted:

- using high technologies (listed in the White Paper) in the educational process: artificial intelligence, VR/AR, blockchain, etc.;
- training of personnel for high-tech industries;
- providing conditions for conducting research and development in priority areas of scientific and technological development of the Russian Federation, the list of critical technologies of the Russian Federation, and other areas of research and development;
- ensuring the implementation of activities within the framework of national and federal projects;
- ensuring conditions for the implementation of indicators of target models of educational organizations;
- ensuring conditions for personnel training in accordance with the goals of the regional socio-economic development strategy and the needs of strategic projects;
- ensuring the possibility of implementing educational programs using practical training together with industry leaders or industrial partners, network educational programs;
- providing opportunities to create RID and high-tech products;
- creating conditions and providing opportunities for testing new technologies and creating university startup projects;
- providing comfortable living and learning conditions;
- ensuring the creation of innovative products, technologies, patents on the basis of the research infrastructure of the campus;
- providing the possibility of creating (placing) on the territory of structural subdivisions of educational organizations together with external partners⁵.

The stakeholders of the campus program are also: city, region, concessionaires, industries and business — all of them should eventually find themselves embedded in a new institutional environment that will contribute to solving the problems of technological development.

SOCIO-ECONOMIC EFFECTS AND ANALYTICAL INDICATORS AS CRITERIA FOR ASSESSING THE EFFECTIVENESS OF LIFE CYCLE MANAGEMENT

According to Annex No. 1 of the Order of the Ministry of Education and Science of Russia No. 293-Z of 26.07.2023⁶ the participants of the campus program should provide a number of socio-economic effects and analytical indicators of national, regional and institutional levels, which are used to assess the effectiveness of the material and spatial environment and management mechanisms of the created campuses. It is necessary to mention here the significant role of the created conditions for cooperation,

additional jobs, etc., as well as the criteria of the top-performing campuses.

It is also worth mentioning the criteria of the top 500 global rankings of universities, correlated with the effects that are declared for analysis and control:

- reputation of the institution in the academic environment;
- reputation among employers;
- employment;
- sustainability. This indicator reflects how much attention universities pay attention to the problems of environment and diversity⁷.

As part of the study, four categories were identified to systematize and evaluate the criteria:

1. Collaboration — the possibility to organize joint projects with partner organizations on campus. Important conditions for the implementation of this cooperation are the provision of material and spatial environment in terms of appropriate spaces and equipment, where it is possible to organize students' project activities, implement commissioned scientific research, etc. (including rent).

2. Jobs — the ability to employ junior scientific and teaching staff in laboratories and other campus units, to conduct retraining programs on "order" from the city or region, and to provide new jobs in some way related to the functioning of the campus in the city or region. An important prerequisite is the reasonable enlargement or modification of spaces for research and development and retraining programs to expand the functions of the campus.

3. Practice-oriented — an opportunity to update some curricula taking into account current technologies and directions of scientific and technological research, to provide orders for research and development of scientific units of the campus under the condition of close cooperation with partner organizations. An important condition is a well-designed material and spatial environment with the necessary equipped spaces for the implementation of programs and research.

4. Prestige — the opportunity to attract students, graduate students and staff to study or work on campus. An important condition is again a comfortable, modern material-spatial environment that provides the necessary conditions for studying, living and working.

From the whole list of relevant socio-economic effects and analytical indicators of national, regional and institutional levels, the following were selected and systematized into four categories (Table). The table also summarizes some proposed ways to achieve the selected effects and indicators.

As it follows from the table, more significant effects and their greater number can be achieved through the creation and management of modern material-spatial environments. But we need to be clear that these are not just new premises, but elements of multifunctional and high-tech environments. This is even more difficult to achieve against the background of the fact that the share of the total area of the commissioned per year total area of teaching and laboratory buildings of educational organizations of higher education, increased more than fourfold over the past three years, and the effective teaching space per student is steadily decreasing [6]. And this trend is inherent in state, municipal and private organizations.

6 On approval of the list of socio-economic effects and analytical indicators of the national, regional and institutional levels and methods for calculating socio-economic effects (analytical indicators) for assessing campuses of the federal project "Creation of a network of modern campuses" : Order of the Ministry of Education and Science of Russia dated July 26, 2023. No. 293-r.

7 Top 500 World Universities By Nation, 2023. URL: tats/stats_unitopnбр_2023.htm (rus.).

Systematization of socio-economic effects and analytical indicators of the Campus Program by category

Cooperation	Workplaces	Practice-orientedness	Prestige
Properly designed material and spatial environment provides conditions for the realization of joint projects with partners	Through new laboratories and projects with partners, there is an opportunity to increase the number of jobs	Partnership projects provide an increase in the number of practical tasks	Attractive MPS and improve campus reputation by ensuring the previous 3 criteria are met
No. 2. Change in the volume of expenditures of campus resident organizations on research and development	No. 3. Change in the number of full-time equivalent researchers	No. 9. Change in the number of employed in high-tech and knowledge-intensive industries	No. 6. Presence in the top 500 global university rankings
No. 3. Change in the number of full-time equivalent researchers	No. 10. Change in the number of outgoing population in the entity in which the campus is located	No. 28. Change in the number of structural units providing practical training for students established with partners	No. 10. Change in the number of outgoing population in the entity in which the campus is located
No. 5. Change in the number of patent and invention applications from campus residents	No. 25. Change in the number of postgraduate students and young scientists	No. 42. Change in the number of students systematically engaged in scientific and research activities	No. 27. Change in the number of students in the youth tourism program
No. 6. Presence in the top 500 global university rankings	No. 42. Change in the number of students systematically engaged in scientific and research activities	No. 44. Change in the number of students who completed final qualification work in the form of startup projects	No. 28. Change in the number of structural units providing practical training for students established with partners
No. 13. Change in the share of products of high-tech and knowledge-intensive industries	No. 43. Change in the share of scientific and pedagogical employees under 39 years of age	—	No. 43. Change in the share of scientific and pedagogical employees under 39 years of age
No. 28. Change in the number of structural units providing practical training for students established with partners	No. 9. Change in the number of employed in high-tech and knowledge-intensive industries	—	—
No. 20. Extrabudgetary funding	—	—	—
No. 25. Change in the number of postgraduate students and young scientists	—	—	—

AN INTERDISCIPLINARY APPROACH TO CAMPUS LIFECYCLE MANAGEMENT

Solutions to the problems described above are certainly found in a variety of areas, ranging from pedagogy to research funding.

Let us focus on analyzing the impact of the physical and spatial environment on campus program participants and suggest ways to competently and reasonably create and manage it in the context of higher education system development. This requires an interdisciplinary approach: we need to combine knowledge in economics, ergonomics, design, construction, pedagogy, psychology, and operations.

Modern universities are the driver of technological development, but on the way of their development there are various limitations and problems, which can be conditionally divided by the elements of the educational environment: "subjective", "partnership", "infrastructural". Let us consider how the management of the material-spatial environment can contribute to overcoming these limitations.

Overcoming subjective limitations — a well-designed environment covers the needs of students in a comfortable university environment for study and life; it provides conditions for innovation and entrepreneurial activity, conducting relevant research and building a model of technological processes within the university, imitating real production; due to this, there is a probability of new jobs for yesterday's graduates, who will be interested in continuing their scientific activities and work on the campus.

Overcoming partnership limitations — a well-designed environment will allow launching joint projects on campus, which promotes

the transition to the concept of University 3.0, in which the university is engaged in innovative activities in addition to education and science [7].

Overcoming infrastructural constraints - the environment is designed to solve all the infrastructural problems of the campus; the availability of convenient and relevant infrastructure, as well as inclusion in the urban and regional environment is a necessary condition for the sustainable development of the campus and the realization of the stated goals on its site³.

In conclusion, we would like to offer the author's interpretation of the concept "Life cycle of university campus facilities" — it is "the period during which the interrelated development of campus facilities is carried out, integrating its various states, stable in time, for effective and safe functioning, starting from the moment of the need for them and ending with the full completion of work with them".

CONCLUSIONS

Modern higher education organizations must meet the current realities of the life style and the system in which modern specialists work, including those employed in high-tech industries and engaged in the development of critical and end-to-end technologies. And this happens only when holistic education includes training, projects, comfortable life and competence development.

How can the management of the material and spatial environment of campuses approach the solution of the tasks of scientific and technological development? A one-syllable answer to this question is as follows: thanks to it, adaptability and sustainability

are ensured, i.e. there is a clear understanding of which elements of the material-spatial environment are necessary for specific educational or research purposes today, which elements can be replaced, removed or appear later.

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Междисциплинарный подход к управлению жизненным циклом объектов университетских кампусов

Данная статья является продолжением серии публикаций, посвященных программному созданию университетских кампусов, которые являются одним из основных драйверов научно-технологического развития и подготовки высококвалифицированных кадров на сегодняшний день.

В предыдущих публикациях по данному направлению автор исследовал возможности применения в рамках программы развития университетских кампусов «Образовательно-технологических условий» как нового типа инженерных параметров-измерителей материально-пространственной среды, «Образовательно-технологического задания» как нового типа документа, являющегося частью задания на проектирование или частью договора на оказание услуг по управлению или технической эксплуатации объектов капитального строительства кампусов, «Комбинаторной матрицы» как инструмента работы с различными видами требований, а также алгоритмы интеграции «Образовательно-технологического задания» с информационными моделями объектов кампусов.

В настоящей статье автор выявил и проанализировал некоторые особенности определения жизненного цикла объектов капитального строительства университетских кампусов и управления их жизненным циклом. Оценил степень влияния этих особенностей на разные этапы жизненного цикла, зависящих одновременно и от целей национальных проектов в области подготовки кадров, и одновременно от материально-технической базы образовательных организаций высшего образования. Возрастающий акцент данного направления определяется стоящими в настоящий момент перед российской экономикой большими вызовами в области технологического развития. Наука и технологии получают новую роль как основополагающие элементы решения многих национальных и глобальных проблем. В статье также раскрыты отдельные подходы к организации образовательной среды, меняющиеся в условиях перехода от постиндустриальной к информационной экономике.

Ключевые слова: жизненный цикл, управление жизненным циклом, университетские кампусы, материально-пространственная среда, социально-экономические эффекты, аналитические показатели, междисциплинарный подход

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Methodology for calculating the production cycle in industrial real estate construction taking into account ecological aspects

Ecology is a science that encompasses the existing connections between humans and the environment. Ecological relationships are distinguished not only by their diversity but also by their complexity. Their characteristic feature is that many of them cannot be studied using traditional methods. As a result, many types of natural resources suffer irreparable damage. Construction most actively interferes with established natural processes. The most important disruptions to the natural environment during the construction process include: loss of vegetation layer due to large volumes of earthworks; deforestation and clearing of greenery, disturbance of fauna and flora development conditions, as well as the upper soil cover; changes in groundwater levels causing flooding of agricultural land and populated areas. Currently, there is a reduction in landscape disruption, water and wind regimes, damage to soil and vegetation cover, pollution of water and air basins, atmosphere and soil cover, and noise and light effects are being mitigated. During the construction process, violations in the natural environment are restored through reclamation of disturbed lands, preservation and reuse of the humus layer; necessary treatment facilities and air purification installations; creation of protective dams, use of unsuitable and swampy areas for construction development; preservation of the natural regime of rivers and landscape; maintaining proper order in the territory used by construction organizations, construction industry enterprises, and building materials industry; prevention of contamination of the territory with by-products and production waste.

Keywords: *ecological connections, reserve territories, indicators of construction production of the developer-builder, subcontracting plans, industrial complex backlog norm*

I. The GENERAL PART

The construction system, from the perspective of social division of labour, develops in accordance with the nature of the functioning of national economy sectors. Hence, the organization of environmental protection is carried out in two directions: *first*, construction objects of the main industries are equipped with modern technical means ensuring environmental protection; *second*, territorial concentration of construction is implemented, contributing to the widespread use of special large facilities for the protection of the natural environment and the economic use of its components [1].

Increasing complexity in the development of construction leads to more efficient use of local resources and protection of the natural environment. It is necessary to implement progressive forms of organizing associated productions and to rationally locate them, taking into account production and economic connections.

The most significant factor limiting the formation of new construction is land use. The size of the territory for development is strictly limited. In the near future, the possibility of alienating land from agricultural circulation for industrial development will be completely excluded. In connection with this, extensive work is being carried out to identify reserve territories in cities, urban-type settlements, and villages by analyzing the density of residential and industrial development. Inventory data are taken into account in the process of construction preparation. The task of construction is the timely and

complete implementation of all special technical means of environmental protection at facilities [2, 3].

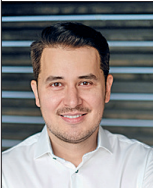
II. LAND RESOURCES AND EFFICIENCY OF THEIR USE FOR DEVELOPMENT

The territorial orientation of construction infrastructure determines the need for rational land use. In order to increase the achieved level of territory use within the boundaries of cities and enterprises, sands, land plots overgrown with shrubs, peatlands, ravine areas, and marshes should be used. Reserve land plots are located in areas inconvenient for construction on uneven terrain, marshes, etc. Construction polygons, bases, warehouses, etc. can be located on these sites in the process of preparing them for development [4].

It is advisable to identify and study reserve territories for construction according to the following methodology. Data on free territories in cities and other settlements that can be used for construction are accumulated in the form of reference catalogs (passports) of reserve sites. The passport of each construction site is developed based on data from schemes and projects of district planning, master plans of settlements, materials from municipal land authorities, state supervision bodies (water, sanitary, etc.), as well as on the basis of schemes of master plans for industrial enterprises and their complexes [5].

Each construction site has specific placement conditions, so the correct choice of construction points significantly affects the efficiency of capital investments.

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The compilation of the list of sites is carried out in two stages. At the first stage, construction sites are identified based on the general labour and other resources of the area under consideration, as well as the existing placement of industry and transport. Sites with an area of over 10 hectares and located no more than 10–15 km from railways, settlements, and water supply sources are considered promising. The area of the certification site should be at least 5 hectares.

For each site, indicators of economic efficiency for development are determined for all possible levels of need for multipurpose resources [6].

The following constraint must be observed:

$$M_{ik} < R_{ik}, \quad (1)$$

where M_{ik} is the set of possible needs for the i -th resource; R_{ik} is the availability of the i -th resource for the k -th site in natural measurements (t, m^3).

Based on the above calculations, the list of sites is ranked by the minimum amount of reduced costs for their preparation and transfer for development.

III. ECONOMICS OF CONSTRUCTION PRODUCTION

The production program is the main part of the work plan for each development company [7].

At the same time, the nomenclature of construction production in development activities is very extensive. The quantitative characteristic of objects being built simultaneously according to several projects is given in units of measurement of their main features: area, capacity, etc. Their natural measurers are: m^2 , t , $pcs.$, etc. The capacity of the created production facilities, for example, a cement plant, is measured in thousands of tons of cement output per year.

The entire volume of construction products can be combined only in monetary terms (in rubles). Estimated prices are used to account for construction products.

The indicator of readiness of construction objects K_{pi} , %, characterizes the level of readiness of the object for commissioning and is determined by the formula:

$$K_{pi} = O_{ki}/O_{mi} \cdot 100 \cdot 100. \quad (2)$$

where O_{ki} is the volume of contract works submitted to the customer from the beginning of construction of the object until the beginning or end of the planned year, thousand rubles; O_{mi} is the estimated cost of construction and installation works of the object, thousand rubles [8].

The indicator of contract work volumes submitted to the customer B_{pi} , %, characterizing the volume of construction and installation works performed for the stage, start-up complex, object and submitted at the beginning or to be submitted at the end of the planned year, in the total estimated cost of construction and installation works of the object, stage, or start-up complex, is determined by the formula:

$$B_{pi} = O_{Bi}/O_{mi} \cdot 100 \cdot 100. \quad (3)$$

where O_{Bi} is the volume of contract works submitted to the customer from the beginning of construction to the beginning of the planned year and to be submitted at the end of the planned year, thousand rubles [9].

The indicator of incomplete construction production Z_{pi} is defined as the difference between the indicators of construction readiness of the object K_{pi} and the indicator of contract work volumes submitted to the customer B_{pi} :

$$Z_{pi} = K_{pi} - B_{pi}. \quad (4)$$

IV. DEVELOPMENT OF The CONTRACTOR'S WORK PLAN BY The DEVELOPER-BUILDER

In accordance with the standards of construction duration, the plan for commissioning production capacities and facilities is broken down by quarters, and title lists are reviewed. Backlog standards serve as the initial basis for planning the volumes of construction and installation works for delivered and transitional construction objects, planning incomplete construction production, and distributing the plan by quarters [10].

When developing the plan for contract construction and installation works, the standards of construction duration, backlog standards for the construction of objects in various industries, and estimated standards are used.

The indicator of the volume of construction and installation works for the construction organization is calculated. This indicator serves as the basis for determining: the consolidated need of this organization for material and technical resources, the size of the wage fund, working capital, and loans. Commissioning and work volumes are established for each object by quarters. A statement of work volumes in natural measurers by objects is attached to the construction production plan [11].

When drawing up the annual production program of a contracting organization, special attention must be paid to creating an optimal construction backlog. In construction, which is characterized by a long production cycle, there is a natural need to create backlogs that ensure the normal functioning of technological processes. Construction backlog is a specific concept that characterizes the degree of preparation of construction conditions and ensuring the continuity of the construction backlog process; it is measured by physical and cost indicators, which are standardized in relation to the natural and sectoral features of construction [12].

In industrial construction, the backlog is determined for individual enterprises, their stages, and start-up complexes.

The main indicators of the regulatory backlog are: readiness of the construction object for commissioning; intermediate commissioning of technological stages and work packages; remainder of the regulatory backlog at the end of the quarter.

The readiness of the object (U_g , %), is determined by the ratio of the volume of capital investments realized from the beginning of construction to the end of the quarter, K_g to its estimated cost:

$$U_g = K_g/S_s \cdot 100. \quad (5)$$

The intermediate commissioning of technological stages and work complexes at the end of the quarter M_k , %, is determined by the ratio of the estimated cost of their part to be commissioned for the period from the beginning of construction to the end of the given quarter M , to their total estimated cost S_e :

$$M_k = M/S_s \cdot 100. \quad (6)$$

The remainder of the regulatory backlog is the difference between the readiness of the object U_g and the intermediate

commissioning of fixed assets for this object M_k . The absolute value of the backlog at the end of the quarter is expressed by the difference between the volume of capital investments realized since the beginning of construction and the cost of fixed assets put into operation during this period.

When compiling operational, tactical, and strategic planning of capital investments for industrial construction and non-production facilities, the backlog can be determined using the following methodology: the backlog is calculated by the capacity of the enterprise or facility, the commissioning of which will ensure the implementation of the normative duration of their construction; the norm of backlog readiness; the relative size of incomplete construction. The value of the backlog by the capacity of enterprises or construction objects, the completion of which will allow putting them into operation in accordance with the normative terms of construction duration. The norm of the backlog by capacity is equal to the product of its average annual size, envisaged for commissioning over a number of years, by the average normative duration of construction of enterprises in the backlog. The ratio of the difference between the total design capacity of enterprises under construction and their commissioned capacity to the capacity planned for commissioning in the upcoming period by industry [13]. The indicator of the readiness of the construction backlog reflects the volumes of capital investments that should be realized in the normative terms for backlog construction sites. It is defined as the ratio of capital investments that should be mastered on backlog objects to the estimated cost of these objects without the cost of previously commissioned main stages. The norm of object readiness N_g is equal to:

$$N_g = \frac{K_o - K_f - K_p}{S_o - S_f - S_p} \cdot 100, \quad (7)$$

where K_o , K_f and K_p are capital investments, respectively total at the date of determining the backlog, realized on commissioned funds from the composition of backlog construction, on auxiliary and service objects from backlog construction; S_o , S_f , S_p are the estimated cost, respectively full at the date of determining the backlog, of commissioned funds from the backlog and other objects [14].

The backlog for capital investments is expressed by the following relationship:

$$Z_k = (B_1G_1 + B_2G_2 + B_3G_3 + B_4G_4)/100, \quad (8)$$

where Z_k is the backlog according to the estimated cost of residential buildings planned for delivery next year, %; B_1 , B_2 , B_3 and B_4 are the distribution of the total area of housing commissioned respectively by quarters of the year, %; G_1 , G_2 , G_3 and G_4 are the readiness of houses by the end of the year, ensuring their commissioning in the corresponding quarters, %.

The backlog for the total area of houses Z_p , %, is determined by the formula:

$$Z_p = \sum (B_1 + B_2 + \dots + B_{i-1})/S, \quad (9)$$

where B_1 , B_2 , ..., B_{i-1} are the total area of houses put into operation during 1, 2, ..., months, starting from the first month, ml; $(i-1)$ is the duration of construction of one house, months; S is the total area of houses put into operation in the calculated period, ml.

The volume of incomplete construction production for works performed by own forces at the end of the planning period, $Q_{own.e.p.p}$, is determined by the formula:

$$Q_{own.e.p.p} = Q_{own.b.p.p} + Q_{own.c.w} - Q_{own.c.p}, \quad (10)$$

where $Q_{own.b.p.p}$ is the volume of incomplete construction production for works performed by own forces at the beginning of the planning period; $Q_{own.c.w}$ is the volume of contract works performed at the construction of an enterprise or object in the planning period by own forces; $Q_{own.c.p}$ is the volume of commercial construction products for the enterprise or object, performed by own forces, to be delivered to the customer in the planning period.

The total volume of incomplete construction production for the enterprise under construction, the start-up complex, or the object at the end of the planning period $Q_{total.e.p.p}$ is determined by the formula:

$$Q_{total.e.p.p} = Q_{total.b.p.p} + Q_{own.c.w} + Q_{sub} - Q_{total.c.p}, \quad (11)$$

where $Q_{total.b.p.p}$ is the total volume of incomplete construction production at the beginning of the planning period; $Q_{own.c.w}$ is the volume of contract works performed at the construction of an enterprise or object in the planning period by own forces; Q_{sub} is the volume of commercial construction products accepted in the planning period $Q_{total.c.p}$ of construction products planned to be delivered to the customer in the planning period.

The total volume of incomplete construction production recorded on the balance sheet of the contracting organization at the end of the planning period $Q_{total.b.e.p}$ is determined by the formula:

$$Q_{total.b.e.p} = Q_{total.e.p.p} - Q_{w.p}, \quad (12)$$

where $Q_{w.p}$ is the estimated cost of construction and installation works performed at the beginning of the planning period under general and direct contracts (including the volumes of work performed by subcontracting organizations) and delivered to the customer.

V. SYSTEM OF INDICATORS OF The VOLUME OF CONSTRUCTION PRODUCTION PRODUCTS

The system of cost indicators of the volume of construction products used in the planning and accounting of construction production is formed based on economic, organizational, and other features of capital construction. These primarily include the structure of construction activities, the measure of participation in production, forms of specialization, the system of contractual relations, sources of financing, forms of subordination, territorial placement, features of the technology of construction production, etc. [15].

Taking into account the features of the organization and functioning of capital construction noted above, the system of indicators of the volume of construction production products is formed according to the following main characteristics:

1. By stages of construction activity:
 - produced construction products;
 - commercial construction products.
2. By the nature of contractual relations:
 - construction products under general contracts;
 - construction products under direct contracts;
 - construction products under subcontracts.
3. By sources of financing at the expense of:
 - state capital investments;
 - public-private partnership funds;
 - specialized funds;
 - population funds;

- funds from authorized regional and territorial sources of financing.

4. By the nature of participation in cooperative construction production:

- construction products produced by the contractor's own forces;
- construction products of involved organizations;
- construction products produced economically.

5. By subordination and territorial placement of products produced by own forces (under subcontracting agreements), for organizations subordinate to:

- their association, construction groups;
- other construction groups.

6. By subordination to the territorial placement of products of involved organizations, subordinate to:

- their association, construction groups;
- other construction groups.

The results of the work of the developer-builder, as well as construction production as a whole, are characterized by a system of product indicators, in which construction activities are considered as a single process of production and implementation (delivery to customers) of construction products. In accordance with this economic content, two subsystems of indicators are formed — the volume of produced products and the volume of commercial construction products (delivered to customers), having different economic meanings and purposes. Indicators of the volume of produced products characterize the volume of construction production (gross volume of construction and installation works) regardless of the sale of products. Indicators of the volume of commercial construction products are used to assess the final result of the production activities of construction companies.

When building large industrial, transport, and other complexes, dozens of subcontracting organizations participate in the order of production cooperation. At the same time, subcontractors are responsible only for the works entrusted to them, while general contractors are responsible for all works at the facility and the construction site as a whole, i.e., for works performed both by their own forces and by subcontracting organizations. The peculiarities of production relations between construction organizations, the nature of the functions they perform in joint construction find expression in the system of construction product indicators.

When determining the value of the total volume of commercial construction products, the finished products of the developer-builder are taken as a basis.

The stage and complex of works in the composition of this indicator are accounted for:

- the cost of works on start-up complexes and objects delivered to customers under direct contracts;
- the cost of completed complexes of works (on site improvement; works not included in the start-up complex) on previously delivered special objects to the customer;
- the cost of completed construction and installation works delivered to the general contractor at enterprises and objects under construction under subcontracting agreements;
- the cost of completed technical stages delivered to the general contractor at objects under construction;
- the cost of works on completed capital repairs of buildings and structures;
- the cost of other contract works.

VI. FINAL PART

When calculating construction organizations for a finished object, the estimated cost for the object is included in the commercial construction products after the complete completion of its construction in the volume and composition of works provided for by the project and estimate, and its delivery to the customer. The cost of works on technological stages and complexes of works is included in the commercial construction products of the organization after their complete completion in the volume and composition provided for by the estimate.

The composition of realized construction products differs from the composition of commercial construction products for the corresponding period in that the realized construction products do not include: the volume of works on unfinished objects and completed but not delivered to the customer objects, volumes of works delivered to the customer, the construction of which was not provided for by the plan; the estimated cost of sold products, the proceeds from which did not arrive at the settlement account by the end of the planning period.

When determining the volume of realization of construction products, the full cost of works on completed objects is taken into account, regardless of when they were started, and not just the cost of works performed in the reporting period. For example, if some works on the object were not completed in the preceding period, then the estimated cost of works on them will not be accounted for in the organization for this period in the realized products. In the next reporting period, after the completion of all works on the object and its acceptance by the customer, the estimated cost of works of this object (including the result of the previous year) will be credited to the realized construction products. For example, the total volume of works delivered to customers for the reporting period amounted to 16,707 million rubles. The volume of works on completed and delivered to the customer objects approved for this reporting year will amount to: $12,500 + 1,134 + 915 + 1,120 = 15,792$ million rubles. The realized products did not include: the volume of completed but not delivered to the customer works on the boiler house — 440 million rubles, the volume of works delivered to the customer on a residential house, the construction of which was not provided for by the plan of the given year — 915 million rubles.

The fulfillment of the plan for the realization of construction products in the reporting year was: $15,792/16,232 = 97.3\%$.

When calculating the volume of these works, double counting of individual and accepted types of works should be avoided.

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Методика расчета производственного цикла при строительстве промышленной недвижимости с учетом экологических аспектов

Экология — это наука, охватывающая существующие связи между человеком и окружающей средой. Экологические связи отличаются не только разнообразием, но и сложностью. Их характерная особенность заключается в том, что многие из них не поддаются изучению традиционными методами. В связи с этим многим видам природных богатств наносится непоправимый ущерб.

Строительство наиболее активно вмешивается в сложившиеся природные процессы.

К важнейшим нарушениям природной среды в процессе строительства относятся: потери растительного слоя в связи с выполнением больших объемов земляных работ; вырубка зеленых насаждений и леса, нарушения условий развития фауны и флоры, а также верхнего покрова почвы; изменение уровня грунтовых вод, вызывающее подтапливание сельскохозяйственных угодий и населенных мест.

В настоящее время уменьшаются нарушения ландшафта, водного и ветрового режима, повреждение почвенного и растительного покрова, загрязнение водного и воздушного бассейнов, атмосферы и почвенного покрова, погашаются шумовые и световые эффекты. В процессе строительства восстанавливаются допущенные нарушения в природной среде путем рекультивации нарушенных земель, сохранения и повторного использования гумусового слоя; необходимых очистных сооружений и воздухоочищающих установок; создания защитных дамб, использования под строительную застройку негодных и болотистых местностей; сохранения природного режима рек и ландшафта; наведения надлежащего порядка на территории, используемой строительными организациями, предприятиями строительной индустрии и промышленности строительных материалов; предотвращения загрязнения территории попутными продуктами и отходами производства.

Ключевые слова: экологические связи, резервные территории, показатели строительного производства, деоператор-застройщика, планы подрядных работ, норма задела промышленных комплексов

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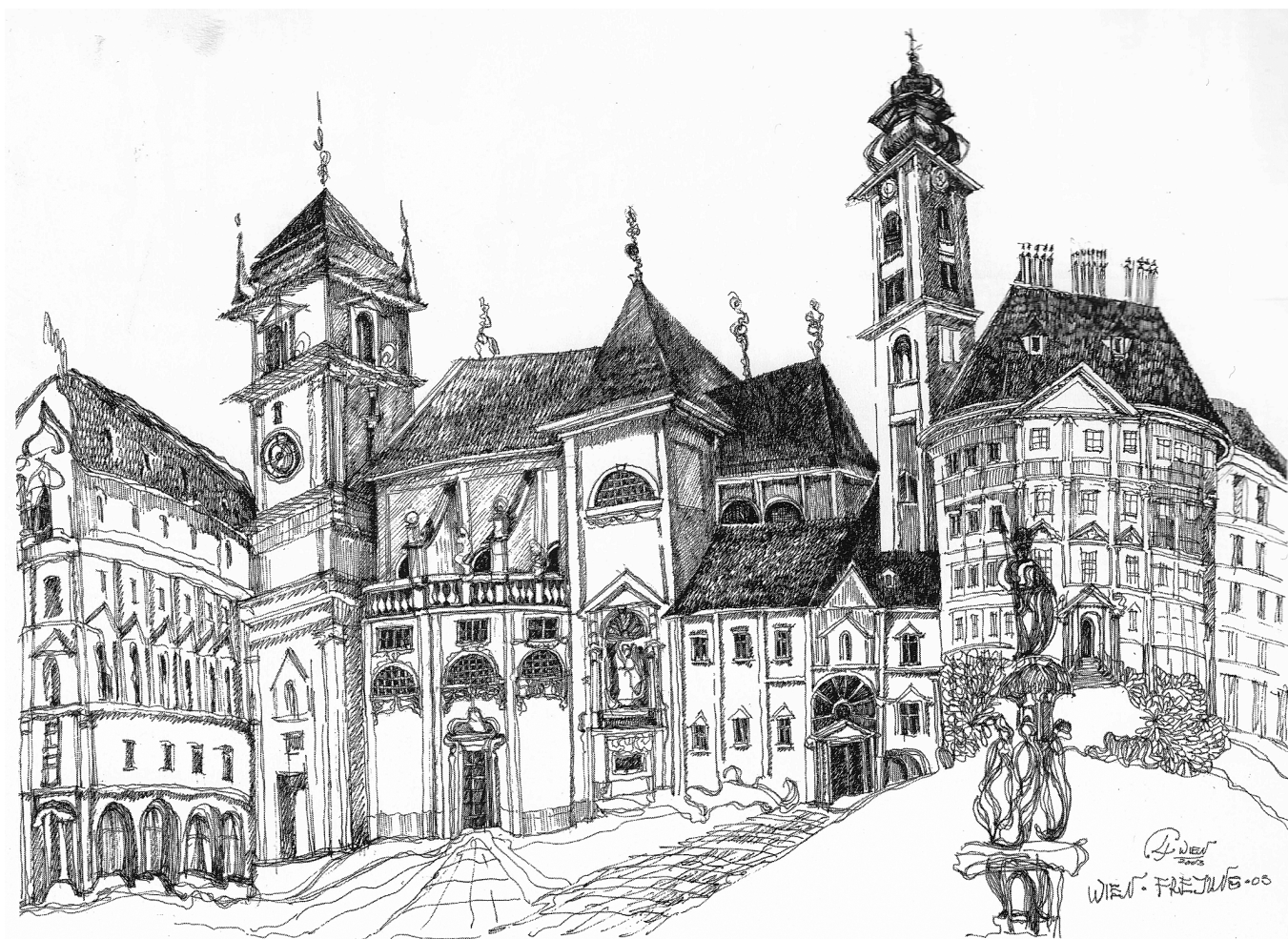
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Вена. Площадь Фрайанг. Л.И. Павлова. Рисунок, тушь, перо.

UDC 332

Models of integrating social and transport infrastructure in housing construction in remote regions: the experience of the republic of Tyva

This paper provides an in-depth analysis of the integration of social and transport infrastructure in housing construction, using the Republic of Tyva as a case study. The region's unique geographical and socioeconomic conditions necessitate a thorough evaluation of modern infrastructure planning and implementation strategies for Russia's remote territories. This study examines contemporary challenges and barriers associated with improving access to social services, ensuring high-quality service provision, establishing transport connectivity, and fostering sustainable regional development. Special attention is given to innovative models and methodologies that facilitate the efficient operation of various infrastructure types under current conditions. The paper analyzes successful projects and initiatives implemented in Tyva, assessing their impact on living standards and the development of residential construction. Key factors contributing to effective infrastructure integration are explored, including financial mechanisms, private investment participation, and partnerships with local governments. Particular emphasis is placed on environmental sustainability and the responsible management of natural resources throughout the development of both transport and social infrastructure. Additionally, the study examines methods for optimizing logistics processes and strategically planning the location of social infrastructure facilities to enhance accessibility for diverse population groups. A comprehensive set of recommendations is provided to improve infrastructure integration and planning processes, ensuring more efficient resource utilization and advancing key social and economic indicators at the regional level. The findings of this research are valuable for professionals in urban and regional planning, infrastructure project management in remote areas, and government authorities responsible for territorial development strategies.

Keywords: infrastructure integration, residential development in the Republic of Tyva, social and transport infrastructure, regional development in remote areas, and architectural planning

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The housing construction industry in remote regions of Russia, such as the Republic of Tyva, faces distinct challenges due to its unique geographical features, extreme climatic conditions, and specific economic and social factors. The effective development of such territories requires a comprehensive approach that integrates social and transport infrastructure systems to ensure comfortable living conditions for the population while improving their overall quality of life. Modern infrastructure integration models play a crucial role in facilitating sustainable territorial development, enhancing transport accessibility, and providing essential social services to residents.

The Republic of Tyva, as a regional center in Asia, experiences significant transport constraints alongside underdeveloped social infrastructure. These factors have a substantial impact on the pace of housing construction and the overall standard of living within the region. This paper examines contemporary approaches to infrastructure integration, focusing on housing development in the Republic of Tyva. The study evaluates existing models, assessing their effectiveness and proposing optimization strategies for infrastructure projects to achieve sustainable development under regional conditions.

THEORETICAL CONCEPTS OF INFRASTRUCTURE INTEGRATION

The integration of social and transport infrastructure comprises a set of complex and multidimensional measures aimed at creating favorable

conditions for both population needs and regional development. Various infrastructure integration approaches are highlighted in academic literature, including functional, spatial, and institutional integration. Functional integration involves the coordinated operation of different infrastructure systems to deliver comprehensive services to the population. Spatial integration is based on the strategic planning of infrastructure facility distribution to maximize accessibility and usability for residents. Institutional integration entails collaboration between government agencies and private entities to ensure the effective management of infrastructure projects.

Modern infrastructure integration models align with the principles of sustainable development by balancing economic growth with social and environmental considerations. In isolated regions such as the Republic of Tyva, infrastructure integration serves as a key mechanism for overcoming geographic isolation, improving quality of life, and stimulating economic development. The successful development and implementation of integration models require careful consideration of regional characteristics, including geographical conditions, demographic trends, and levels of socio-economic development.

THE UNIQUE CHARACTERISTICS OF THE REPUBLIC OF TYVA AND THEIR IMPACT ON INFRASTRUCTURE INTEGRATION

The Republic of Tyva stands out among Russian regions due to its strategic geographical

► location, rich cultural heritage, and complex socio-economic landscape. Its position in Central Asia presents significant accessibility challenges, as the region lacks a railway network and faces severe climatic conditions, including harsh winters in mountainous terrain. As of 2024, more than 70 % of the region's roads fail to meet compliance standards, exacerbating transport limitations [1].

The social infrastructure system in Tyva also encounters multiple challenges. The shortage of medical facilities is particularly pronounced, with an average of 1,500 residents per doctor in remote areas, exceeding the national average [2]. According to the Ministry of Education, over 40 % of schools in the region require major renovations as of 2024 [3]. Additionally, the limited availability of cultural and sports facilities constrains both recreational opportunities and the overall development prospects of the local population.

Despite these challenges, the Republic of Tyva continues to implement infrastructure projects aimed at regional development. The reconstruction of the Kyzyl – Erzin highway was completed in 2024, reducing travel times by 30 % and improving accessibility for more than 20,000 residents [4]. The planned construction of the Kyzyl – Abaza highway, which will connect Tyva with neighboring regions, is expected to create new economic opportunities. In the healthcare sector, a multifunctional medical centre is set to be launched in Kyzyl in 2025, projected to serve over 50,000 people annually, according to forecasts by the Russian Ministry of Healthcare.

The sustainable development of Tyva requires an infrastructure integration strategy that considers the region's distinctive characteristics. To achieve this, the region must actively attract investment, develop strategic plans based on modern research, and implement innovative technologies. The introduction of digital solutions, including smart city systems and automated monitoring technologies, will significantly enhance resource efficiency and improve service quality.

CONTEMPORARY INFRASTRUCTURE INTEGRATION MODELS FOR REMOTE REGIONS AS PART OF THEIR DEVELOPMENT FRAMEWORK

The effective integration of social and transportation infrastructure in the remote regions of the Republic of Tyva requires the adoption of cutting-edge technological solutions. The "smart city" concept represents a modern model that utilizes digital technologies to manage urban operations, particularly in the areas of transportation, energy supply, and social services. The implementation of data monitoring and analysis systems allows for a rapid response to changing population needs while optimizing resource allocation.

A key example of successful infrastructure integration in Tyva is the development of a unified transportation and logistics system, incorporating automated traffic management and transport flow monitoring. This initiative has resulted in a 25 % reduction in travel time and a 15 % increase in road safety, contributing to residential development and overall improvements in the population's quality of life [5].

In the social sector, initiatives focus on the expansion of telemedicine and distance education, helping to bridge gaps in healthcare and educational services in remote areas. In 2024, Tyva introduced remote medical consultation services, providing over 10,000 residents in isolated regions with access to qualified medical care [6]. The development of distance learning platforms is also progressing, ensuring that students and schoolchildren can receive quality education regardless of their location. In fact, academic performance levels in rural schools improved by 12 % in comparison to 2023 [7].

The integration of social and transportation infrastructure in Tyva also encompasses public space development and urban improvement projects. In 2024, the federal programme "Comfortable Urban Environment" invested in the renovation of parks and public squares in Kyzyl and other major settlements, enhancing social engagement and improving the overall quality of the urban environment [8]. These urban development initiatives not only transformed the appearance of settlements but also created attractive conditions for investment in residential construction.

Achieving long-term positive outcomes from infrastructure integration requires careful consideration of local population needs and regional environmental factors. Sustainable infrastructure development must incorporate environmental technologies and natural resource management strategies as core decision-making principles. In Tyva, the deployment of renewable energy projects, including solar and wind power facilities, has reduced dependence on centralized electricity sources and contributed to environmental sustainability [9].

The development of remote infrastructure necessitates a comprehensive, integrated approach to implementation. Modern technological advancements and innovative models not only enhance the quality of life for residents but also stimulate economic growth by creating jobs and attracting investment to the region. A well-developed infrastructure framework supports sustainable community development, enabling adaptability to changing conditions while maintaining high living standards for local populations.

CHALLENGES AND BARRIERS TO INFRASTRUCTURE INTEGRATION IN THE TUVAN REGION

Despite the successful implementation of certain projects, the Republic of Tyva faces multiple systemic issues that hinder the effective integration of its social and transportation infrastructure. The primary challenge today revolves around insufficient financial support for infrastructure initiatives. In 2023, funding allocated for essential infrastructure projects in Tyva covered only 60 % of the required maintenance costs necessary for the region's sustainable development. This funding shortfall impedes both the modernization of existing infrastructure and the implementation of new construction projects.

Another significant challenge stems from the complex topographical conditions of the region. The combination of mountainous terrain and harsh climatic conditions substantially increases both the cost and duration of infrastructure construction projects. The Kyzyl – Abaza highway project, initially scheduled for completion in 2025, has already faced delays due to complex engineering challenges and additional environmental assessments [10].

Labour shortages further exacerbate infrastructure development difficulties. The shortage of skilled professionals in the region's construction sector slows down project completion times. According to Rosstat (2024), employment levels in Tyva's construction sector are 20 % below the national average, necessitating the recruitment of workers from other regions, which in turn increases project costs.

The lack of coordination between different levels of government and limited project management transparency complicates the integration process. Inadequate cooperation among federal, regional, and municipal authorities leads to overlapping responsibilities and inefficient resource allocation. This issue is particularly evident in the social sector, where newly constructed facilities often lack corresponding transportation infrastructure, thereby limiting service accessibility for the local population.

Environmental concerns also pose a significant obstacle to infrastructure integration. As transportation networks and residential developments expand, environmental risks such as water contamination and ecosystem degradation become increasingly pressing. The successful implementation of environmentally friendly technologies and ongoing environmental monitoring requires additional financial and organizational support [11].

FUTURE PROSPECTS FOR INFRASTRUCTURE DEVELOPMENT IN THE REPUBLIC OF TYVA

Effective planning and integration of infrastructure, along with attracting external investments, play a crucial role in the development of Tyva's social and transportation systems. The successful implementation of innovative technologies is a key factor in enhancing both the sustainability and efficiency of regional development. Infrastructure expansion is a strategic priority that not only improves the quality of life for the local population but also strengthens Tyva's integration into Russia's economic framework.

1. Transportation Infrastructure Development

As part of the federal programme "Comprehensive Development of Transport Infrastructure in the Republic of Tyva (2024–2030)", more than 500 km of new roads will be constructed, expanding the regional highway network by 20 % [12]. A key project involves the Kyzyl – Krasnoyarsk motorway and the Kyzyl – Kuragino railway link, which will create the necessary conditions for establishing logistics centres, increase regional cargo traffic by 25 %, and reduce production costs by 15 % [13].

The reconstruction of Kyzyl Airport, scheduled to begin in 2024, includes extending the runway to 3,200 meters and modernizing passenger terminals. These upgrades will enable the region to accommodate large aircraft, including Boeing 737 and Airbus A320, thereby improving air transport accessibility.

Additionally, the development of river transportation on the Yenisei River includes port infrastructure upgrades in Tura and Teele, increasing overall freight capacity by 30 %.

2. Social Infrastructure Enhancement

In 2024, as part of national healthcare and education modernization projects, Tyva will see the construction of three new medical centres and five educational facilities. A multi-profile medical centre equipped with advanced diagnostic technology will be built in Kyzyl, alongside two new schools and a 300-seat early childhood education centre.

Sports and cultural infrastructure will also undergo significant improvements. A new sports complex with an Olympic-standard swimming pool will be constructed, while existing cultural institutions, including the Tuvan Musical and Dramatic Theater, will be renovated. These measures aim to enhance healthcare and education accessibility, ultimately increasing the region's Human Development Index (HDI) by 10 % toward its target level by 2030 [14].

3. Investment and Public-Private Partnerships

Infrastructure expansion is impossible without private investment, making public-private partnerships (PPP) a cornerstone of Tyva's development strategy. In 2023, the region launched a PPP Coordination Centre, which facilitates cooperation between government agencies and private businesses. As a result, the number of joint investment projects has increased by 15 % [15].

To further stimulate investment, the regional government offers tax incentives, including a profit tax reduction to 13.5 % and a five-year exemption from property tax. In 2024, Tyva plans to attract multi-billion-ruble investments for the construction of a logistics and trade centre in Kyzyl, expected to create 500 new jobs.

4. Implementation of Modern Technologies

The adoption of digital technologies is central to improving infrastructure efficiency. Smart city systems, automated monitoring platforms, and digital mapping tools for transportation planning will be introduced across the region, optimizing resource distribution and enhancing service delivery standards [16].

A special focus is placed on energy-efficient technologies and low-carbon construction, ensuring environmental sustainability. The "Digital Tyva" project is driving regional internet connectivity expansion, with the goal of providing 95 % of residents with high-speed internet via fiber-optic networks by 2027.

RECOMMENDATIONS FOR OPTIMIZING INFRASTRUCTURE INTEGRATION

A comprehensive approach that aligns regional characteristics with modern infrastructure development trends is essential for maximizing the efficiency of social and transportation infrastructure integration in the Republic of Tyva. The key recommendations are as follows:

1. Development of Comprehensive Infrastructure Strategies

Long-term planning must be based on current demographic trends, economic demand projections, and future growth forecasts. Strategic plans should incorporate the region's geographical challenges, including remote and mountainous areas, to optimize resource allocation and reduce costs. The use of statistical data from Rosstat and regional authorities will allow for more accurate planning. A comprehensive transportation development strategy could reduce logistics costs by 20 % while improving overall accessibility [17].

2. Promotion of Private Investment and Public-Private Partnerships (PPP)

To stimulate private sector participation, tax incentives, simplified administrative procedures, and stability guarantees must be established. The successful PPP model in Krasnoyarsk Krai, which has significantly improved transport services, serves as an example for Tyva. The creation of special economic zones should be encouraged to attract business investment, aiming to increase private capital inflows by 25 % by 2027 [18].

3. Implementation of Innovative Technologies and Digital Solutions

The adoption of smart infrastructure technologies, such as automated monitoring systems for roads and buildings, along with digital project management tools, will enhance budget transparency and operational efficiency. The deployment of intelligent lighting systems and smart traffic management solutions is projected to reduce energy consumption by 15 % and travel times by 10 %.

4. Development of Human Capital for Infrastructure Projects

Expanding the qualified workforce in the construction and infrastructure sectors requires targeted education and training programmes. Efforts should focus on recruiting skilled specialists from other regions while simultaneously strengthening local expertise through vocational training and internship programmes. Collaborating with leading Russian universities to establish specialized departments within Tyva's educational institutions will be essential. These measures aim to increase the number of skilled workers by 30 % across the region by 2030.

5. Consideration of Environmental Factors

All infrastructure projects must undergo mandatory environmental impact assessments to minimize ecological risks. Sustainable construction techniques, including the use of energy-efficient materials and renewable energy sources, should be prioritized to ensure eco-friendly development. Special attention should be given

► to preserving Tyva's unique ecosystems while accounting for the region's climatic conditions. The adoption of green technologies is expected to reduce regional carbon emissions by 12 % over the next decade.

6. Expansion of Logistics Infrastructure

Strengthening the transportation and logistics network through the development of transport hubs and modern logistics centres will lower freight costs and improve regional accessibility. The integration of multimodal transport corridors and the modernization of warehouse complexes will facilitate a 20 % increase in freight traffic while reducing delivery times by 15 % [19].

7. Adoption of International Best Practices

The study and adaptation of successful global infrastructure models will accelerate regional development. Scandinavian sustainable construction techniques can provide valuable insights for Tyva, given its challenging climate. Additionally, Canada's and Switzerland's infrastructure management strategies should be examined for their resilience to climate-related challenges. Implementing these approaches will enhance the durability and adaptability of Tyva's infrastructure in response to environmental conditions.

The integration of social infrastructure, transportation, and residential development within the Republic of Tyva is crucial for ensuring the region's long-term sustainability. A comprehensive approach — incorporating strategic planning, investment mobilization, innovation adoption, and human capital development is essential for the success of infrastructure projects.

Infrastructure development delivers two key benefits: the enhanced quality of life for the population and improved economic performance, alongside better transportation services and job creation. Environmental safety and sustainable development principles must be prioritized to ensure that the benefits of these projects are long-lasting. The implementation of infrastructure projects is projected to reduce regional unemployment by 5 % and increase the regional GDP by 15 % by 2030.

This study provides valuable insights for urban planners, regional development experts, and infrastructure project managers, as well as government officials involved in the development of territorial strategies. Future research in the region should focus on evaluating the effectiveness of implemented infrastructure projects and their impact on the socio-economic development of the Tyva population, while also seeking new methods of optimizing infrastructure projects tailored to the region's challenging climatic conditions.

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Модели интеграции социальной и транспортной инфраструктуры в жилищном строительстве удаленных регионов: опыт Республики Тыва

В статье представлен глубокий анализ интеграции социальной и транспортной инфраструктуры в жилищном строительстве с использованием Республики Тыва в качестве примера. Уникальные географические и социально-экономические условия региона требуют тщательной оценки современных стратегий планирования и реализации инфраструктуры для

удаленных территорий России. В исследовании рассматриваются современные проблемы и барьеры, связанные с улучшением доступа к социальным услугам, обеспечением качественного обслуживания, установлением транспортной связи и содействием устойчивому региональному развитию. Особое внимание уделяется инновационным моделям и методологиям, которые способствуют эффективному функционированию различных типов инфраструктуры в текущих условиях.

В статье анализируются успешные проекты и инициативы, реализованные в Тыве, с оценкой их воздействия на уровень жизни и развитие жилищного строительства. Рассматрива-

ются ключевые факторы, способствующие эффективной интеграции инфраструктуры, такие как финансовые механизмы, участие частных инвесторов и партнерства с местными органами власти. Особое внимание уделено экологической устойчивости и ответственному управлению природными ресурсами в процессе развития как транспортной, так и социальной инфраструктуры. В дополнение исследуются методы оптимизации логистических процессов и стратегического планирования расположения социальных объектов с целью улучшения доступности для различных групп населения.

Дается комплекс рекомендаций для улучшения интеграции инфраструктуры и процессов планирования, направленных на более эффективное использование ресурсов и повышение ключевых социальных и экономических показателей на региональном уровне. Результаты данного исследования будут полезны для специалистов в области градостроительства и регионального планирования, управления инфраструктурными проектами в удаленных районах, а также для государственных органов, ответственных за разработку стратегий территориального развития.

Ключевые слова: интеграция инфраструктуры, жилищное строительство в Республике Тыва, социальная и транспортная инфраструктура, региональное развитие в удаленных районах и архитектурное планирование

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Current trends in import substitution of construction materials and equipment in the Russian Federation

This paper investigates the current directions of import substitution in the Russian construction sector. Against the background of economic instability and international sanctions in recent years, the task of building up the potential of domestic production of construction materials and equipment has become increasingly important. The paper discusses the key areas of import substitution, including the development of high-tech construction materials production, strengthening support for Russian manufacturers, as well as the introduction of innovative technologies. Currently, the issue of import substitution for companies in the construction sector is very important. Co-operation with domestic suppliers for a number of materials required for production is being actively developed. Russian manufacturers of raw materials, equipment and components understand perfectly well that now is a unique time for them, when many market segments and niches are being freed up and they can replace foreign suppliers who are leaving. At the same time, one of the negative consequences of the sanctions has manifested itself in the fact that many enterprises have decided to temporarily reduce their investment programmes and abandoned plans to modernize or expand their production capacities. There are also difficulties in supplying equipment components from abroad. Previously, a significant part of equipment was purchased in the European Union countries, for example, in Italy. Currently, most of the alternative supplies are from China. Special attention is paid to analyzing government policies aimed at stimulating local producers, as well as assessing the prospects for sustainable growth and self-sufficiency of the construction industry. In general, the current prospects of domestic producers are positively assessed. The purpose of the paper is to highlight the current trends of import substitution of construction materials and equipment in the Russian Federation, find problems and propose solutions. **Keywords:** construction industry, construction materials, equipment, import substitution, production, economy, instability

Import substitution has long been a serious problem for Russia. Analysis of statistical data shows that many industries in the country are largely dependent on imported goods and services, as a result of which there is a deterioration of the economic situation due to the strengthening of sanctions policy of Western countries. Solving the problem of import substitution is of crucial importance, as it directly affects the growth, development and defence capability of the national economy. Dependence on imports has been formed for many years, and for many industries a significant part of the volume of realized products is produced using imported materials and equipment.

The purpose of this research is to study the actual directions of import substitution in the production of construction materials and equipment in the Russian Federation. The problem of dependence on imports is analyzed from the standpoint of both the production of materials and construction equipment. It should be noted that the growing gap between the economy's need for innovative solutions and the capabilities of domestic R&D forces to rely on foreign technologies, especially in the field of technological equipment. At the same time, attempts to replace imported components with domestic ones face a number of significant challenges (Table 1).

Table 1. Opportunities and limitations of import substitution in the construction industry

Potential opportunities	Existing constraints
Reducing dependence on external supplies of materials and technologies	Lack of necessary production capacity for mass production
Ensuring sustainability of domestic production and its competitiveness	Lack of investment and high capital costs for modernization of the industry
Development of new jobs and support for the domestic market	High level of technological backwardness in some areas of production
Improving the environmental situation through the introduction of new, environmentally friendly technologies	Shortage of qualified specialists in new areas of production
Development of domestic scientific and technical potential	Limited support from the state for small and medium-sized enterprises
Improving the level of quality and standardization of domestic construction materials	Dependence on imported components for complex production facilities

Import substitution in the construction sector should be considered as the creation of conditions for equal competition of domestic producers with foreign companies. Active development of this direction and the formation of new competitive industries can lead to a profound restructuring of the economy, contributing to the emergence of new industries and the growth of demand for local equipment, raw materials and construction materials [1]. Such a vector will not only accelerate scientific and technological progress, but also allow domestic research and development to reach the world level. Moreover, high-tech industries focused on import substitution should strive not only to meet domestic needs, but also to enter global markets, thus ensuring their export potential and strengthening the country's international position.

Given the current geopolitical and economic situation, the task of import substitution of a number of goods and technologies is becoming increasingly important for the Russian Federation [2]. Trade restrictions from other countries, as well as the shortage of imported raw materials, components and spare parts have led to the need to search for domestic substitutes [3]. This scenario, combined with changes in logistics, has led to an increase in the cost of construction materials and increased dependence on imports for some products.

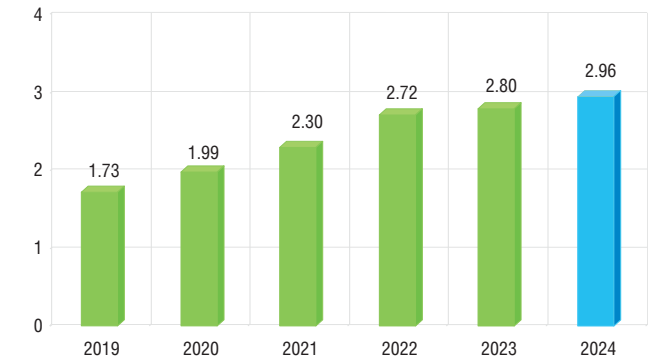
The plan for the development of the construction industry and housing construction in Russia for the period until 2030 and further until 2035 emphasizes the importance of shifting from imported construction materials and equipment to increasing local production in Russia [4]. Studies in more than 50 regions of the Russian Federation show that most of them do not actually face problems of shortage of construction materials and equipment, even despite the withdrawal of foreign manufacturers from the market.

About 85 % of applied construction materials are produced from resources that are available in significant quantities in the country. Among the various types of construction, premium real estate is particularly vulnerable today, as most of the fittings for special works, plumbing fixtures and high quality equipment are supplied from abroad. For example, the country has established production of construction chemicals, but the equipment used for production is supplied from European companies. Also, the production of sanitary ware, ceramic products and facing bricks. are heavily dependent on imported equipment. there is still a lot of work to be done to localize these production lines and expand the capacity in production, installation, design and, most importantly, high quality service.

According to official sources, the current situation with import substitution in the construction industry is quite good. According to the Ministry of Construction of Russia, most materials for large construction projects are produced locally, but imported materials still lead in the medium and high price range [5]. Many types of engineering systems are still imported, including air conditioning systems, ventilation systems, pumps, fire-fighting equipment, public address systems, shut-off and regulating equipment, plumbing and automated control systems.

As for basic building materials such as concrete, glass, pipes and some metal products, the construction market has everything it needs from Russian suppliers. Construction goods are also supplied from countries such as Belarus, Kazakhstan, China, Turkey and Iran, and parallel imports also take place.

In the period from 2019 to the present, there is an average annual growth rate of 12.8 % in monetary terms for the production of construction materials.



Dynamics of the volume of construction materials output in Russia (2019–2024), trillion rubles [6]

In the first half of 2024, the Russian construction industry recorded a significant growth in the output of materials, namely the total value increased by 5.6 % compared to the same period last year. At the same time, the actual volumes were even more impressive, with the production of wood panels increasing by 20 %, wall blocks by 15 %, ceramic tiles by 9 %, and the output of sheet glass increasing by 7 %. There was also strong growth in the crane market segments, as well as in the production of wood and concrete panels (Figure).

At the beginning of 2024, about 80 % of the lift equipment market was occupied by domestic products. Thus, in the first half of the year, four factories in Moscow produced more than 6,000 lifts, and they can produce about 25,000 units per year. Significant progress has also been made in the development of high-tech equipment, namely Karacharovsky, Shcherbinsky and MEL plants have certified their lifts to achieve speeds of up to 4 m/s, which is optimal for use in multi-storey residential buildings.

To mitigate the impact of sanctions, the relevant departments of the Russian government represented by the Ministry of Construction, Ministry of Industry and Trade and various industry groups are implementing a set of measures [7].

The National Association of Builders “NOSTROI” together with the Ministry of Construction of Russia launched an online platform, which is a catalogue presenting a wide range of domestic construction materials and equipment capable of replacing imported analogues [8]. At the same time, the Ministry of Construction formed a list of Russian software for urban planning, and the Ministry of Industry and Trade initiated the Import Substitution Exchange, which helps to find the necessary spare parts and components.

The federal budget for 2023–2025 has allocated 872.8 million rubles for the target programme, and 16 banks with a total loan portfolio of 65 billion rubles, designed for 513 potential borrowers, have been selected for its implementation. As of April 2023, 38 special loans for the amount of 2.86 billion rubles have been issued, and 32 loan agreements for 3.39 billion rubles are still under consideration [9]. The need for import substitution mainly concerns the introduction of advanced technologies and construction equipment. Currently, government agencies are working on these problems by teaming up with institutions, research centres and small businesses.

At present, it seems necessary to improve the monitoring and analysis of the construction industry by focusing on critical areas requiring government attention. Preliminary analysis of import substitution programmes can be organized according to several criteria: identification of problem areas (technological, technical, informational, personnel); cataloguing of materials, raw

► materials, structures, units, machinery, equipment and mechanisms that are scarce in the domestic construction market; assessment of innovative and scientific and technical potential of organizations and their components; study of potential diversification opportunities. Systemic solution of the tasks faced by the construction industry in the field of import substitution will allow for an in-depth analysis of projects and programmes, which will allow to adequately assess their effectiveness [10].

Self-regulatory organizations in the field of design and construction should also actively participate in import substitution initiatives to ensure the involvement of all industry participants in this process. It is recommended to create a centralized federal body that will take over the coordination of import substitution measures, paying special attention to improving the efficiency of R&D and supporting mutually beneficial cooperation with technologically advanced friendly or neutral countries.

At the current stage, the priority task of federal and regional authorities is not just operational substitution of imported products for construction enterprises, but the definition of strategic directions

that can create a synergistic effect and build the necessary technological chains within the country. For the highlighted problems, it seems reasonable to consider specific measures of solutions, shown in Table 2.

The main objective of modernization of the construction sector is to provide targeted support measures. The management of innovation and import substitution at the state, industry and corporate levels is not always properly coordinated. There is a gap in the goals and motivation of efforts in this area, and there are no standardized performance indicators [11].

So, the study shows that in recent years, the construction industry has been developing under significant sanctions pressure under the acute need for import substitution of various construction materials, machinery, equipment and technologies. These challenges necessitate fundamental structural transformations aimed at improving the sustainability and competitiveness of domestic construction.

Among the key areas of transformation are:

1. Institutional and regulatory support.

Table 2. Ways of solving import substitution problems in the construction industry, with examples of solutions

Problem	Solutions
Warranty repair of foreign equipment and components	Develop and implement quality standards for domestic equipment. Example: Germany introduced a programme of certification and support for local manufacturers to improve product quality. Creation of a government programme aimed at subsidizing manufacturers of domestic components similar to foreign ones. Attracting investment in the development of domestic analogues of foreign components
Problems with the implementation of Russian software in construction	Introduction of state support programmes for local software development focused on the needs of the construction sector. Active co-operation with educational institutions and business structures to improve the skills of specialists in digital technologies used in construction. Formation and promotion of accelerator programmes to stimulate the development of startups in the field of innovative construction technologies
Increase in delivery times and production costs due to the need to create new logistics chains	Use of multimodal transport, as practiced in the US, to optimize logistics routes. Developing and implementing regional logistics hubs to reduce delivery time and costs. Application of modern technologies in supply chain management, such as blockchain and logistics automation systems
High costs of domestic transport, especially to northern regions	Development and implementation of subsidies for transport companies operating in hard-to-reach regions. Use of alternative modes of transport, such as air transport for small consignments of materials, which can reduce delivery times to remote regions
State support measures are available only to large enterprises	Introduction of a system of tax incentives and subsidies for medium and small enterprises, as it is practiced in EU countries. Creation of specialized funds and grants for small construction companies to participate in import substitution programmes. Development of educational and consulting programmes for small enterprises on how to obtain state support
Lack of investors to organize production of construction materials in the constituent entities of the Russian Federation	Organize specialized economic clusters for the production of construction materials, providing tax incentives and developed infrastructure. Attract private capital through venture capital financing or loan programmes backed by state guarantees. Actively support the development and implementation of innovative technologies that can significantly reduce production costs
Division of import substitution management functions between different bodies and centres	It is proposed to form a single federal body responsible for coordinating the import substitution process in the country, similar to the Chinese model, where a centralized agency manages all areas of industrial policy. At the same time, it is necessary to create a universal digital platform that would unite data on the import substitution process and be available to all stakeholders
Lack of a unified information space on construction import substitution	Creation and implementation of a unified information platform for all market participants, as it was implemented in South Korea for the construction sector. Introduction of a cataloguing and monitoring system for all types of import substitution, which will make it possible to track material shortages and provide access to up-to-date information

First of all, it requires the development and implementation of modern legislative initiatives and regulatory mechanisms that stimulate domestic production. This includes revision and adaptation of existing regulations, creation of favourable conditions for investment, as well as introduction of state support instruments such as subsidies, tax incentives and grant programmes. Such measures will make it possible to offset the negative impact of sanctions and ensure stabilization of the industry.

2. Technological modernization and innovative development.

A strategically important direction is the integration of advanced scientific and technological developments into production processes. Active co-operation between research institutes, higher education institutions and industrial enterprises is necessary for the formation of innovative potential. The development of domestic analogues of imported technologies and materials will be a key element of import substitution, allowing to increase production efficiency and reduce technological dependence.

3. Digitalization and information support.

Effective information interaction between construction market participants facilitates the rapid exchange of analytical data, best practices and research results. The creation of specialized digital platforms will not only optimize management processes, but also increase transparency in supply chains and logistics, which is an important factor of competitiveness.

4. Development of international partnership.

Establishing constructive partnerships with allied countries with a high level of technological development remains a priority. Conclusion of bilateral and multilateral agreements in the field of technology exchange, joint research and investment will allow to diversify the sources of raw materials and equipment, as well as to ensure a stable supply of advanced innovations.

To implement a comprehensive import substitution mechanism, it is proposed to create an integrated model of interaction between the state and business, which involves the formation of a specialized fund to support import substitution projects in construction. Such a fund will be aimed at financing experimental and design developments, research and implementation of domestic innovative technologies. At the same time, special attention should be paid to the synergy between public institutions and private structures, which will ensure a prompt response to dynamically changing foreign economic conditions and sanctions challenges.

Therefore, a systemic approach that combines institutional regulation, technological modernization, digitalization and international cooperation is a viable strategy for creating an effective

organizational and economic mechanism for import substitution in the construction industry. The implementation of this strategy will not only reduce dependence on imported components, but also create conditions for sustainable development and increase the competitiveness of the domestic construction complex in the context of global economic and geopolitical challenges.

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Современные тенденции импортозамещения строительных материалов и оборудования в Российской Федерации

Данная статья исследует современные направления импортозамещения в российском строительном секторе. На фоне экономической нестабильности и международных санкций в последние годы становится все более важной задача наращивания потенциала отечественного производства строительных материалов и оборудования. В статье рассматриваются ключевые направления импортозамещения, включая развитие производства высокотехнологичных стройматериалов, усиление поддержки российских производителей, а также внедрение инновационных технологий.

В настоящее время вопрос импортозамещения для компа-

ний строительного комплекса является очень актуальным. Активно развивается сотрудничество с отечественными поставщиками по ряду необходимых для производства материалов. Российские производители сырья, оборудования и комплектующих прекрасно понимают, что сейчас для них уникальное время, когда многие рыночные сегменты и ниши освобождаются, и они могут заменить уходящих иностранных поставщиков.

В то же время одно из негативных последствий санкций проявилось в том, что многие предприятия решили временно сократить свои инвестиционные программы и отказались от планов по модернизации или расширению производственных мощностей. Существуют также трудности с поставками комплектующих для оборудования из-за рубежа. Ранее значительная часть оборудования закупалась в странах Европейского Союза, например в Италии. В настоящее время большая часть альтернативных поставок приходится на Китай.

Особое внимание уделяется анализу государственной политики, направленной на стимулирование местных производителей, а также оценке перспектив устойчивого роста и самообеспечения строительной отрасли. В целом позитивно оцениваются текущие перспективы отечественных производителей.

Цель статьи — выделить современные тенденции импортозамещения строительных материалов и оборудования в Российской Федерации, найти проблемы и предложить пути решения.

Ключевые слова: строительная отрасль, строительные материалы, оборудование, импортозамещение, производство, экономика, нестабильность

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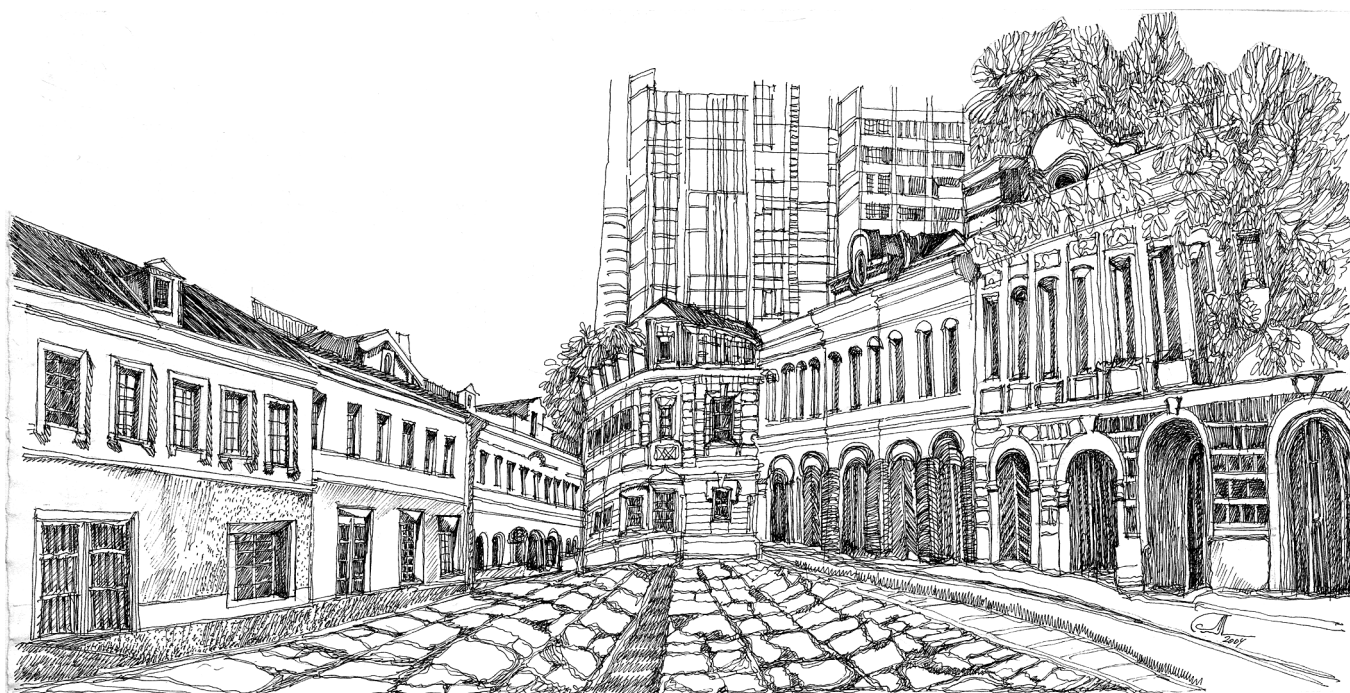
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Key aspects of implementing the concept of closed-loop economy in the construction industry

The paper considers the environmental situation in the country and the implementation of the concept of a closed-loop economy in the construction sector. The focus is on the sustainable use of resources, waste minimization and the use of secondary materials. The main types and volumes of world waste that have the greatest impact on the environment are presented, and it is noted that the construction sector occupies a leading position in terms of annual volumes, which proves the relevance of this study. The closed-loop economy helps to rethink existing approaches to the design, construction and operation of real estate. The paper presents key aspects of the approach to the formation of a closed-loop economy at various stages of the implementation of an investment and construction project, such as planning and design, preparation for construction, construction, operation and end of the life cycle. Particular attention is paid to the use of recyclable and environmentally friendly materials, as well as the application of technologies that make it possible to reuse construction waste. The paper also considers examples of successful practices and innovative approaches used in Russian and international projects aimed at increasing sustainability and reducing the environmental burden. Examples of the implementation of closed-loop economy projects in Russia, such as eco-industrial parks, which include a new approach to the implementation of recycling and waste disposal, are considered. The problems that the construction industry faces during implementation are emphasized, the main ones being the lack of a legal framework, the creation of incentive programmes for stimulation and the need to improve the skills of personnel. In conclusion, the importance of the closed-loop economy programme and the effectiveness of its implementation are highlighted.

Keywords: closed-loop economy, secondary raw materials, environmental situation, federal project, construction

The issue of the environmental situation in Russia is becoming more and more relevant every year. Measures are being taken at the state level to support environmental protection and sustainable development of the country. For example, the national project “Ecology” is currently being implemented¹ [1], which is aimed at radically improving the environmental movement and stimulating the health improvement of Russians. In addition, the goals and objectives in the field of environmental protection fixed at the legislative level by the Decree of the President² [2] are taken into account. As part of the implementation of environmentally friendly projects, it is also necessary to note the importance of following the concept of closed-loop economy.

The project of closed-loop economy implies the application of a fundamentally new approach to production, consumption and economic activity on the basis of renewable solutions and environmentally sustainable business models. Closed-cycle economy approaches are especially relevant in the context of the implementation of the national project “Ecology”¹, the goals and targets of which are presented in Fig. 1 [1].

The goals set by the national project are oriented towards improving the quality of water supply and the health of water bodies, ensuring a balance between the loss and recovery of flora, and reducing pollution, including through effective waste management.

Approximately 33 billion tonnes of waste are generated annually in the world [2]. For clarity, let us

present five main types of waste that have the maximum impact on the environment and note their approximate volume (Fig. 2).

Thus, it can be concluded that construction and demolition account for the maximum share of waste, accounting for 30 per cent of the world's waste. The construction and demolition of buildings consumes about 1/3 of all materials consumed in the world and generates about 40 % of harmful CO₂ emissions due to inefficient energy saving of resources [3]. Consequently, the construction industry as a whole has an enormous environmental responsibility. If we consider in more detail the types of wastes of IV–V hazard classes in the field of construction, the most common ones include concrete waste, soil during construction works and scrap of asphalt and concrete pavements [4]. In order to reduce the indicators of harmful impact on the environment, managers of the world's enterprises strive to use more rational management methods, as well as to implement new environmentally friendly technologies. As a consequence, there is a growing tendency to reorient production towards the use of secondary resources and raw materials, particularly in the construction industry, which confirms the relevance and necessity of this study.

The concept of the circular economy is a model based on the principles of sustainable development, aimed at minimizing waste and maximizing the use of resources. The basic idea is that instead of the traditional linear model “extraction – production – consumption – utilization”, the closed-loop economy

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1 Federal media outlet “Ecology of Russia”. URL: <https://ecologyofrussia.ru/> (Accessed on 11.11.2024).
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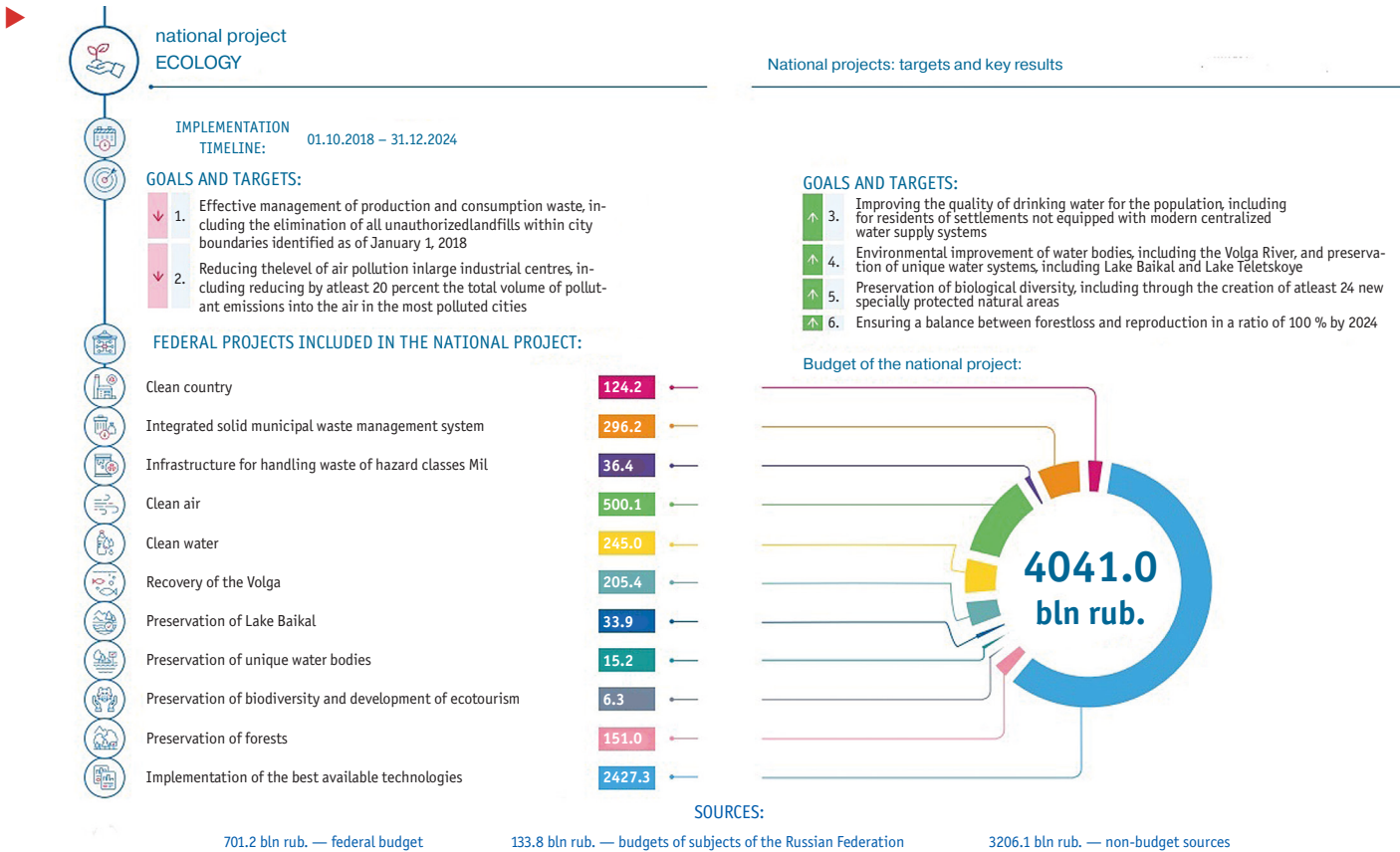


Fig. 1. National Project "Ecology"¹

focuses on the creation of so-called "closed" cycles where products, materials and resources are reused, recycled or recovered [5]. For the construction sector, especially important is the measure of using non-toxic, modern, durable, renewable materials (as construction waste belongs to the 4th and 5th class of hazard); improving the energy efficiency of buildings; recycling of materials after dismantling; use of modular structures suitable for assembly and disassembly (Fig. 3) [6].

One example of an architectural initiative inspired by the concept of the circular economy is the construction of the CNAD National Art, Crafts and Design Centre³. This centre is located on the island of Cape Verde in the city of Mindelo. Because of the island location, all goods were brought into the country using containers and barrels. The architects, inspired by the ideas, decided to take the lids from the containers as a basis and use them as industrial parts in the construction. The lids became a colourful facade in the project (Fig. 4, 5) [7]. As a result of using all kinds of colours, they create not only a unique external appearance, but also act as a double ventilated facade (Fig. 6), which provides passive control of the internal temperature and does not require air conditioning. They can be rotated, which allows the indoor light and airflow to be regulated.

One of the examples of the implementation of closed-loop economy projects in Russia can be called eco-industrial parks. Ecoprom-parks are a new approach to the implementation of waste recycling and utilization⁴. Such sites will house resident companies, and production will be carried out in a closed system. Waste and other

by-products will be realized in a new production cycle. Ecoprom-parks will become a place where the full cycle of waste utilization and production of products from secondary raw materials will be implemented. Glavgosexpertiza in the report for 2023 indicated that 7 positive conclusions on eco-industrial parks were issued [8]. In 2024, the construction of such parks began in the Moscow, Chelyabinsk, Leningrad, Novosibirsk regions and Stavropol Krai. It is planned that in total the enterprises will be able to process over 850 tonnes of waste per year [9]. The construction of eco-industrial parks will provide an opportunity to reduce emissions into the atmosphere and reduce the burden on the environment, as well as become a promising investment in the economy of the regions.

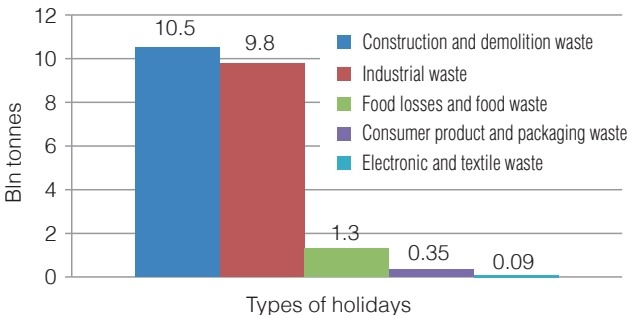


Fig. 2. Annual volume of major waste streams in the world

³ Official website of the National Centre for Handicraft, Art and Design (CNAD National Art, Crafts and Design Centre). URL: <https://cnad.cv/en/> (Accessed 12.11.2024).

⁴ Circular economy: how the project for the construction of eco-industrial parks is being implemented in Russia | FAU "Glavgosexpertiza of Russia". URL: <https://gge.ru/press-cent-er/news/ekonomika-zamknutogo-tsikla-kak-v-rossii-realizuyetsya-proekt-po-stroitelstvu-ekopromparkov/?ysclid=m3h4fw7d1y821595962> (Accessed 11.11.2024).

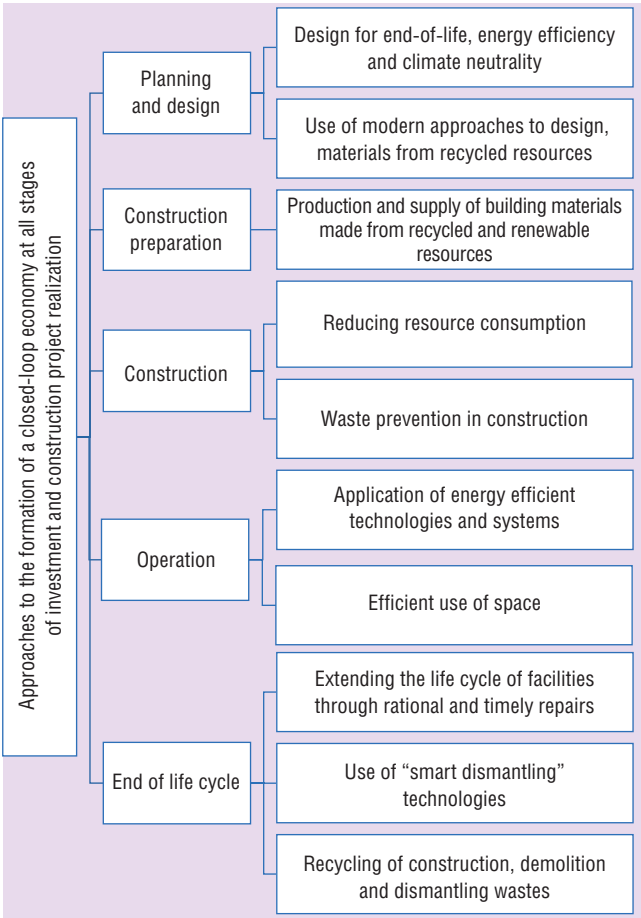


Fig. 3. Approaches to the formation of a closed-loop economy

At the moment, the transition to a closed-loop economy is hampered by a number of problems. For example, the legislation of the Russian Federation has no normative regulation of construction waste, which leads to the lack of a system of standards and certification of materials from secondary resources. In this regard, it is the state that can become the main initiator of the introduction of measures to stimulate the use of new construction materials [10]. Economic incentives and state support measures will make it possible to implement construction projects using secondary resources and raw materials. In addition, it is important to develop a monitoring system for waste management, thanks to which it will be possible to increase the level of control over the formation, transport and disposal of construction waste. Implementation of the described approach has many positive effects not only for companies in the construction industry, but also for the environment. Thus, it will be possible to provide recycling of up to 85 % of construction waste of all types and reduce up to 20 % of the share of waste sent to landfills [11]. These improvements will also affect the partial substitution of investments in traditional production methods for new technologies for the use of recycled materials, which will potentially lead to the stimulation of research and development in the field of secondary production, as well as the emergence of new recyclable products.

In conclusion, we would like to note the obvious advantages of the closed loop programme, which justify the expediency of its application. The use of secondary resources and raw materials in the construction industry will allow to significantly reduce the volume of waste, increase the efficiency of materials use, and will also have a positive impact on business development in this area.

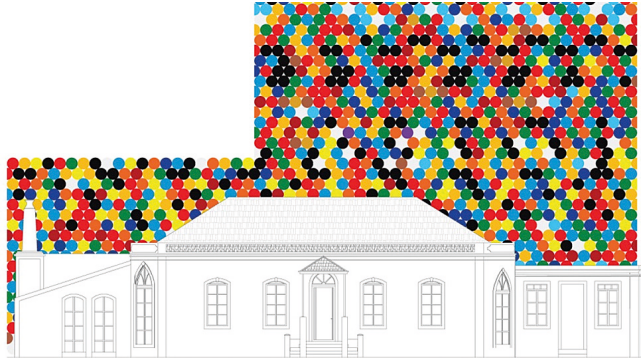


Fig. 4. Project visualization

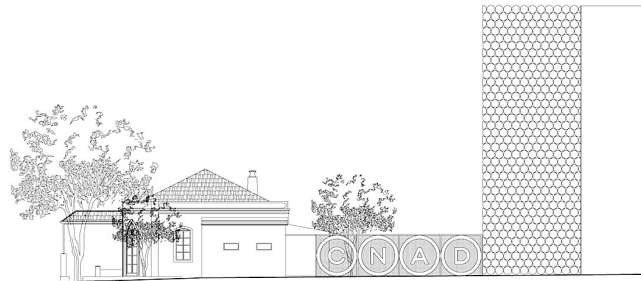


Fig. 5. Visualization of the project. Addendum

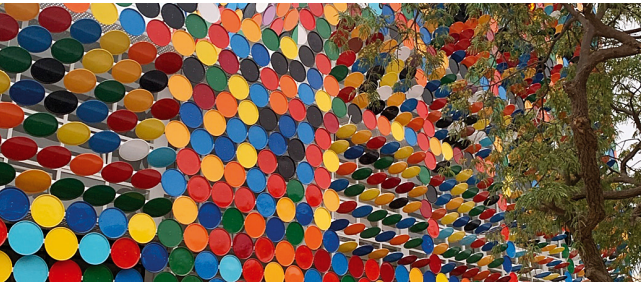


Fig. 6. Exterior view of the building facade

An integrated approach to the implementation of the closed-loop economy programme will make it a means of achieving sustainable development and environmental protection on a planet-wide scale.

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Ключевые аспекты реализации концепции экономики замкнутого цикла в сфере строительства

В статье рассмотрены вопросы экологической ситуации в стране и реализация концепции экономики замкнутого цикла в сфере строительства. Акцентируется внимание на устойчивом использовании ресурсов, минимизации отходов и использовании вторичных материалов. Представлены основные виды и объемы мировых отходов, оказывающие максимальное влияние на экологию, и отмечено, что по количеству годовых объемов лидирующую позицию занимает сфера строительства, что доказывает актуальность данного исследования. Экономика замкнутого цикла помогает переосмыслить существующие подходы к проектированию, строительству и эксплуатации объектов недвижимости. В статье представлены ключевые аспекты подхода к формированию экономики замкнутого цикла на различных стадиях реализации инвестиционно-строительного проекта, таких как планирование и проектирование, подготовка к строительству, строительство, эксплуатация и окончание жизненного цикла. Особое внимание уделяется использованию перерабатываемых и экологически чистых материалов, а также применению технологий, благодаря которым становится возможным повторное использование строительных отходов. Также в статье рассматриваются примеры успешных практик и инновационных подходов, применяемых в российских и международных проектах, направленных на повышение устойчивости и снижение экологической нагрузки. Рассмотрены такие примеры реализации проектов экономики замкнутого цикла в России, как экопарки, включающие новый подход в реализации обротки и утилизации мусора. Подчеркиваются проблемы, с которыми сталкивается строительная отрасль при реализации, основными из которых можно отметить: недостаток правовой базы, создание льготных программ для стимулирования и необходимость повышения квалификации кадров. В заключении отмечается важность программы экономики замкнутого цикла и эффективность ее реализации.

Ключевые слова: экономика замкнутого цикла, вторичное сырье, экологическая ситуация, федеральный проект, строительство

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