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Главный редактор:

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Уважаемые читатели!

Появление многообразия форм собственности на землю требует принципиальных подходов к ее учету. Собственность является юридической концепцией и представляет собой совокупность частных прав владения. Право собственности на землю — это основа для формирования рынка на землю и регулирования рыночных отношений. Сегодня необходимо рассматривать участки земли как особенные объекты права.

Кадастр позволяет идентифицировать земельные участки, обеспечивать гарантии прав их собственникам, быстрые результаты имущественных споров. Он включает подробное геодезическое, географическое, геологическое, экономическое, хозяйственное описание земельных участков, сведения об их юридическом статусе. Как показал анализ на примере городской земли Москвы, примерно 80 % налоговых поступлений — это средства от земельного налога.

Рынок земли имеет широкий смысл, включая реальное право пользования, право аренды, право залога и ипотечного кредитования.

Эти и другие вопросы земельного кадастра и прав собственности на землю рассмотрены в настоящем выпуске журнала.

С наилучшими пожеланиями,
Главный редактор, **Пётр Грабовый**

Dear Readers!

The emergence of various forms of land ownership requires fundamentally new approaches to land registration. Ownership is a legal concept and represents a set of individual rights of possession. Land ownership rights form the basis for the development of the land market and the regulation of market relations. Today, land plots should be regarded as specific objects of legal rights.

The cadastre makes it possible to identify land plots, guarantee the rights of their owners, and facilitate the prompt resolution of property disputes. It includes detailed geodetic, geographical, geological, economic, and land-use descriptions of land plots, as well as information on their legal status. As shown by an analysis of urban land in Moscow, approximately 80 % of tax revenues come from land tax.

The land market is understood in a broad sense and includes the actual right of use, lease rights, pledge rights, and mortgage lending.

These and other issues related to the land cadastre and land ownership rights are discussed in this issue of the journal.

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

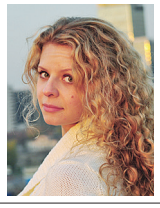
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Yamshchikov A.S.

Quality of the land cadastre institution as a factor in increasing the efficiency of logistics in the investment and construction sector

This paper examines the impact of land cadastre quality on the efficiency of logistics processes in the investment and construction sector. It argues that the land cadastre should be viewed not only as a traditional accounting and registration mechanism, but also as a fundamental element of the information and logistics infrastructure, determining the speed, reliability, and cost of information, documentary, and investment flows at all stages of the construction cycle. The key influences of cadastral data quality are identified: reduced pre-project preparation and approval process times, reduced transaction costs, increased investment attractiveness of territories, and minimized litigation risks and land disputes. Special attention is paid to the problem of cadastral errors, ambiguous land boundaries, and inconsistencies between state information systems, which generate additional logistical losses and increase the duration of the investment and construction cycle. The authors propose a concept for "cadastral logistics maturity of a territory", encompassing five levels — from fragmented to intelligent — at which a digital twin of the territory is created using artificial intelligence, big data, and geospatial analytics. A new scientific concept, "cadastral efficiency rent", is introduced as an additional economic benefit received by developers and investors due to the high quality of cadastral infrastructure. A multi-level model for assessing cadastral and logistics efficiency has been developed, including a system of quantitative indicators of cadastral quality, logistics, economic, and territorial parameters. It is concluded that improving the quality of the land cadastre institution and its integration with urban planning, transport, and infrastructure systems is key to reducing logistics costs, accelerating the investment and construction cycle, and ensuring the sustainable development of urbanized territories.

Keywords: *territorial development, transaction costs, logistics efficiency, spatial development, land management, digitalization of the cadastral register, investment cycle*



Sarchenko Vladimir Ivanovich,
Doctor of Economics, Professor, Professor of the Department of Building Design and Real Estate Expertise; Siberian Federal University (SFU); 79 Svobodny Ave., Krasnoyarsk, 660041, Russian Federation; ID RSCI: 1697-8392, Scopus AuthorID: 57192673087, WoS ResearcherID: AGN-1565-2022, ORCID: 0000-0001-6125-6737; vsarchenko@sfu-kras.ru



Yamshchikov Andrej Sergeevich,
Doctor of Economics, Associate Professor, Professor of the Department of Economic and Financial Security; Siberian Federal University (SFU); 79 Svobodny Ave., Krasnoyarsk, 660041, Russian Federation; ID RSCI: 4472-7067, Scopus AuthorID: 57211160408, ORCID: 0000-0001-7504-6503; AYamshchikov@sfu-kras.ru

In modern conditions, the effectiveness of investment and construction activities is determined not only by the level of development of construction technologies and the availability of financial resources, but also by the quality of institutions that ensure the functioning of the real estate market and land relations.

One of the most important institutions is the land cadastre, which is a system of accounting, registration, description and spatial identification of land plots.

Practice shows that a significant part of the delays in the implementation of investment and construction projects are due to:

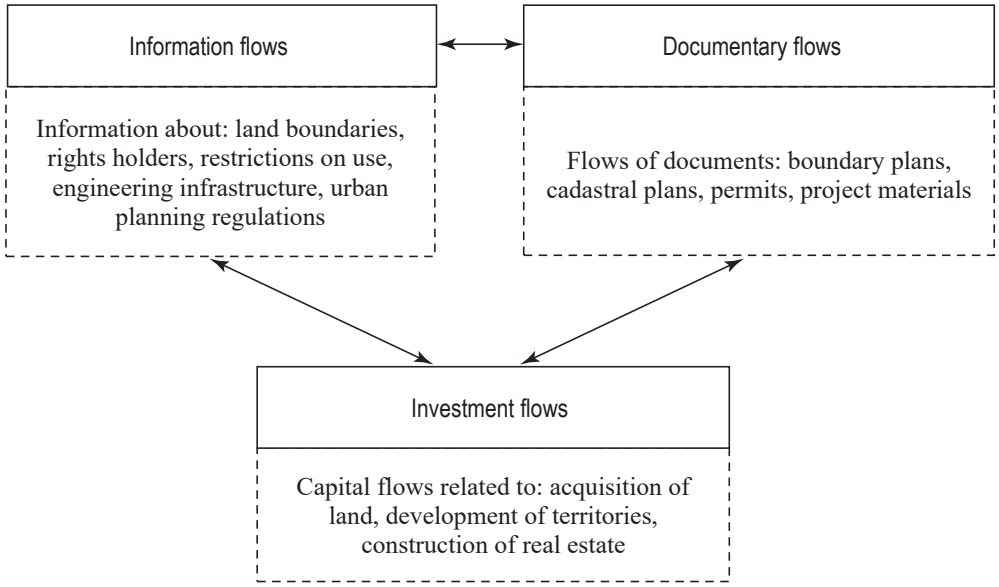
- cadastral accounting errors;
- uncertainty of the boundaries of land plots;
- lack of up – to – date information on the legal status of lands;
- contradictions between different state information systems;
- lengthy approval procedures.

These problems create additional logistical losses, increase project implementation time and reduce the efficiency of using investment capital.

In this regard, there is a need to study the land registry as an independent institutional factor of the logistical effectiveness of investment and construction activities.

The issues of land cadastre quality and its impact on economic processes in the construction sector are at the intersection of several scientific areas: institutional economics, land law, spatial development and logistics. The approach to the cadastre as an information foundation for risk management in investment processes is actively developing in foreign literature. In particular, empirical studies using the example of Poland show that incompleteness, inaccuracy and obsolescence of cadastral data generate legal, technical and financial risks, which leads to delays and increased cost of projects [1]. These findings echo a broader discussion about the quality of services and digital transformation in the real estate sector. Modern approaches to creating urban digital twins also emphasize the need to integrate cadastral, urban planning and transport data to improve the accuracy of management decisions [2, 3].

In the Russian scientific tradition, the land cadastre is traditionally considered as an instrument of state land management, accounting and taxation. In recent years, the focus has shifted towards digitalization and the creation of integrated spatial information systems, such as the National Spatial Data System, which is designed to combine disparate cadastral and other information to improve the effectiveness of spatial planning and investment decisions [4]. However, as the researchers note, problems of standardization, data completeness and interagency integration remain. The logistical aspect in the context of the land registry is presented in works devoted to the selection of land plots for the placement of logistics facilities and the reengineering of logistics processes in construction [5–7].



The logistical nature of the land registry

Nevertheless, there is insufficient systematic analysis of the impact of the quality of the land registry institute on the logistical efficiency of the investment and construction cycle in the existing literature.

Traditionally, the land cadastre is viewed through the prism of: land relations; real estate management; government regulation; taxation; territorial planning. However, in modern conditions, the cadastre should be considered much more broadly — as a key element of spatial and information logistics. From the standpoint of the logistic approach, the land registry ensures the movement of three types of flows (Fig.). Consequently, the quality of the cadastre directly affects the speed and reliability of logistics flows.

It is proposed to consider the cadastre as the core of the spatial information logistics system (Table 1).

The combination of these elements forms the basis of logistical support for investment and construction processes.

The impact of cadastre quality on the efficiency of construction logistics is manifested through five main channels, which together form an environment for the smooth implementation of investment and construction projects. First of all, the high quality of cadastral data directly contributes to reducing time losses at all stages of the object's life cycle: from reducing the time required for pre-design preparation and speeding up the registration of land relations to minimizing the number of interdepartmental approvals. Research shows that the incompleteness and inaccuracy of cadastral data directly correlate with project delays [8]. At the same time, a significant reduction in transaction costs is achieved, since cadastral certainty reduces the cost of expensive legal support, additional engineering surveys, and minimizes the risks of litigation and the need for repeated cadastral work, which ultimately makes the project budget more predictable [9].

Table 1. Information and logistics system of the cadastre

System unit	Key information
Spatial information	coordinates of the plots; borders; topological connections
Legal	ownership rights; encumbrances; easements; usage restrictions
Urban planning	territorial zoning; types of permitted use; building parameters
Infrastructural	transport infrastructure; engineering networks; social facilities
Investment	cadastral value; market value; investment potential of the territory

In turn, the reliability and transparency of cadastral information serve as the foundation for increasing the investment attractiveness of territories: investors make decisions much faster if there is a clear legal regime and clear boundaries of land plots, which accelerates the launch of new facilities. At the same time, a high-quality cadastre increases the sustainability of projects, reducing the likelihood of sudden construction stops, forced changes in design decisions and protracted land conflicts with neighboring land users. Finally, at the macro level, authorities receive a powerful tool to improve the efficiency of territorial management, which is reflected in the ability to accurately predict the development of urban spaces, competently manage the land bank and form long-term programs for the integrated development of territories, where the logistics of construction flows are linked to the overall urban planning strategy [10, 11].

For the purposes of assessment, it is proposed to introduce a new concept — cadastral logistical maturity of the territory. Cadastral logistical maturity refers to the ability of a territory to provide minimal time and transaction costs for investment and construction activities due to the high quality of the cadastral infrastructure. Five maturity levels are proposed (Table 2).

The transition to the fourth and fifth levels involves not only technical modernization, but also institutional changes, including interdepartmental cooperation and unified data standards, which is confirmed by modern research in the field of integrated spatial systems [12, 13].

Table 2. Levels of cadastral logistic maturity of the territory

Number	Level	Characteristic
1	Fragmentary	• lack of up-to-date data; • a large number of errors; • low digitalization
2	Basic	• availability of cadastral registration; • partial digitalization; • limited data integration
3	Functional	• high completeness of information; • stability of registration processes; relatively low costs
4	Integrated	Assumes the unification of: • cadastre; • urban planning systems; • transport systems; • infrastructure platforms
5	Intellectual	A digital twin of the territory is being formed. Used: • artificial intelligence; • big data; • geoanalytics; • predictive modelling

The authors propose a hypothesis of the existence of an inverse relationship between the quality of the cadastre and the duration of the investment and construction cycle. This suggests that improving the quality of the cadastre leads to an acceleration of investment and construction processes [14]. In this regard, a new scientific concept is proposed — cadastral efficiency rent, which is understood as an additional economic effect obtained by participants in investment and construction activities due to the high quality of the cadastral infrastructure. The sources of such rent are:

- reduction of project implementation time;
- reduced transaction costs;
- improving the accuracy of investment decisions;
- reducing judicial risks;
- the growth of capitalization of the territory.

Similar effects are recorded in works devoted to evaluating the effectiveness of digital twins and integrated urban development management systems [15, 16].

One of the main problems of existing research is the lack of a quantitative mechanism for assessing the impact of the cadastral system on the parameters of investment and construction activities. To solve this problem, it is proposed to develop a multilevel model for assessing cadastral and logistical efficiency, which includes the following stages:

1. Formation of the system of indicators (Table 3).
2. Normalization of indicators.

To ensure comparability of indicators, it is proposed to use dimensionless indexes. The calculation is performed according to the formula (1):

$$I_i = (X_i - X_{min})/(X_{max} - X_{min}), \quad (1)$$

where I_i — the normalized indicator;

X_i — the actual value;

X_{max}, X_{min} — boundary values (maximum and minimum, respectively).

Table 3. Groups of indicators for assessing cadastral and logistic efficiency

Group A. Quality of the cadastral system: • percentage of plots with specified boundaries; • number of cadastral errors; • the level of digitalization of cadastral services; • completeness of cadastral information; • average period of cadastral registration	Group B. Logistical indicators: • duration of the coordination procedures; • period of preparation of the land plot for development; • period of passage of licensing procedures; • duration of the investment and construction cycle
Group C. Economic indicators: • investment attractiveness of the territory; • cost of project preparation; • investment volume; • cost of the development project; • internal rate of return of the project	Group D. Territorial indicators: • density of development of the territory; • provision of infrastructure; • quality of the urban environment; • the index of sustainable development of the territory

3. Calculation of the integrated cadastral and logistic efficiency index (ICLE).

It is proposed to calculate the indicator (2):

$$ICLE = \sum_{i=1}^{n} (w_i \cdot I_i), \quad (2)$$

where ICLE — the integrated cadastral and logistic efficiency index;

w_i — weight coefficients (set by experts);

I_i — particular indicators;

Thus, it can be noted that the higher the quality of the land registry institute and the degree of its integration with urban planning, infrastructure and investment systems, the lower the total logistical costs of investment and construction activities, the higher the efficiency of development companies and the sustainability of urbanized areas.

The conducted research shows that the land registry should be considered not only as an accounting and registration mechanism, but also as a basic institution of spatial and information logistics in the investment and construction sector. The quality of cadastral information has a direct impact on the speed of investment, information and documentary flows, determining the amount of transaction costs, the duration of the investment and construction cycle and the competitiveness of development projects. Improving the quality of the land cadastre institute is becoming one of the key areas for increasing the efficiency of investment and construction activities and ensuring sustainable development of urbanized territories.

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Качество института земельного кадастра как фактор повышения эффективности логистики в инвестиционно-строительной сфере

В статье исследуется влияние качества института земельного кадастра на эффективность логистических процессов в инвестиционно-строительной сфере. Обосновывается, что земельный кадастр следует рассматривать не только как традиционный учетно-регистрационный механизм, но и как фундаментальный элемент информационно-логистической инфраструктуры, определяющий скорость, надежность и стоимость движения информационных, документарных и инвестиционных потоков на всех этапах строительного цикла. Выявлены основные каналы влияния качества кадастровых данных: сокращение сроков предпроектной подготовки и согласовательных процедур, снижение транзакционных издержек, повышение инвестиционной привлекательности территорий, минимизация судебных рисков и земельных споров. Отдельное внимание уделено проблеме кадастровых ошибок, неопределенности границ участков и противоречиям между государственными информационными системами, которые формируют дополнительные логистические потери и увеличивают продолжительность инвестиционно-строительного цикла. Предложена авторская концепция «кадастровой логистической зрелости территории», включающая пять уровней — от фрагментарного до интеллектуального, на котором формируется цифровой двойник территории с использованием искусственного интеллекта, больших данных и геоаналитики. Вводится новое научное понятие «кадастровая рента эффективности» как дополнительный экономический эффект, получаемый девелоперами и инвесторами за счет высокого качества кадастровой инфраструктуры. Разработана многоуровневая модель оценки кадастрово-логистической эффективности, включающая систему количественных показателей качества кадастра, логистических, экономических и территориальных параметров. Сделан вывод, что повышение качества института земельного кадастра и его интеграция с градостроительными, транспортными и инфраструктурными системами является ключевым направлением снижения логистических издержек, ускорения инвестиционно-строительного цикла и обеспечения устойчивого развития урбанизированных территорий.

Ключевые слова: *территориальное развитие, транзакционные издержки, эффективность логистики, пространственное развитие, управление земельными ресурсами, цифровизация кадастра, инвестиционный цикл*

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Об авторах: **Сарченко Владимир Иванович** — доктор экономических наук, профессор, профессор кафедры проектирования зданий и экспертизы недвижимости; **Сибирский федеральный университет (СФУ)**; 660041, г. Красноярск, пр-т Свободный, д. 79; РИНЦ ID: 1697-8392, Scopus AuthorID: 57192673087, WoS ResearcherID: AGN-1565-2022, ORCID: 0000-0001-6125-6737; vsarchenko@sfu-kras.ru.

Ямщиков Андрей Сергеевич — доктор экономических наук, профессор, профессор кафедры экономической и финансовой безопасности; **Сибирский федеральный университет (СФУ)**; 660041, г. Красноярск, пр-т Свободный, д. 79; РИНЦ ID: 4472-7067, Scopus AuthorID: 57211160408, ORCID: 0000-0001-7504-6503; vsarchenko@sfu-kras.ru;

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Nechyotny N.Yu.
Chubarkina I.Yu.

Current issues in harmonizing territorial planning documents, urban zoning, and USRR data

This paper analyzes the legal and organizational contradictions that arise when reconciling master plans and land use and development rules with data from the Unified State Register of Real Estate (USRR). The relevance of the study stems from the fact that these datasets were created at different times, by different agencies, and using inconsistent technical standards and cartographic bases, which causes the graphic boundaries of territorial zones and settlements to systematically diverge from their cadastral and register descriptions. Such misalignment not only complicates urban planning practice but also creates real obstacles to land turnover, the formation of an investment-attractive environment, and the protection of property rights.
The author analyzes the causes of these discrepancies, among which the absence of a unified coordinate basis and a data-verification methodology when information is transferred between agencies stands out. It is shown that the incompleteness and inconsistency of USRR data generate systemic risks for developers, local self-government bodies, and rights holders, inevitably leading to increased legal uncertainty and higher transaction costs. Particular attention is paid to the specifics of synchronizing accounting and registration systems in the territories of Russia's new constituent entities, where former record-keeping systems have been lost and land-surveying materials are often absent, which requires a special, phased methodology for the geodetically substantiated population of the register.
The study is based on provisions of the Urban Planning Code, related federal acts, and an analysis of existing regional practices. Key directions proposed for overcoming the identified problems include intensifying the inter-system integration of GISOGD, FGIS TP, and FGIS EGRN, as well as the large-scale introduction of comprehensive cadastral works covering not only the fixing of boundaries but also their alignment with approved urban planning documentation. It is concluded that the formation of a unified, harmonized accounting and registration space is impossible without unifying regulatory requirements, digitally consolidating data, and developing special coordination algorithms for regions with special integration conditions. Implementing the proposed measures will help minimize register errors, increase the predictability of urban planning policy, and ensure sustainable territorial development.
Keywords: *territorial planning, urban zoning, USRR, register error, GISOGD, land use and development rules, cadastral registration*



Nechyotny Nikita Yuryevich,
Candidate of Economic Sciences, Associate Professor of the Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; ID RSCI: 801304, Scopus AuthorID: 58825124700, WoS ResearcherID: AAG-6602-2022, ORCID: 0000-0002-2605-8783; osun_kaf@mgsu.ru



Chubarkina Irina Yuryevna,
Candidate of Economic Sciences, Associate Professor of the Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; ID RSCI: 791667, Scopus AuthorID: 57194448794, WoS ResearcherID: AAC-1685-2022, ORCID: 0000-0002-6969-6187; osun_kaf@mgsu.ru

THE LEGAL ARCHITECTURE OF COORDINATION: WHERE THE CONTRADICTIONS ARISE

Three layers of information — territorial planning documents, land use and development rules, and USRR register data — were created at different times, by different agencies, and according to different technical standards. Hence the central difficulty: a system conceived as unified is, in practice, assembled from fragments that fit together poorly.

The Urban Planning Code of the Russian Federation establishes a hierarchy of documents — from territorial planning schemes to master plans and land use and development rules that define the boundaries of territorial zones [1]. The problem is that the boundaries shown on the urban zoning map often exist solely as a graphic appendix to a local self-government regulatory act and do not coincide with the coordinate description entered (or not entered) in the USRR register of boundaries. This discrepancy is not accidental — it is systemic, inherited from an era when cartographic materials were prepared without strict reference to the state coordinate system.

Since January 1, 2021, the legislator has attempted to close this gap: building permits may not be issued in the absence of USRR data on the boundaries of territorial zones for the relevant land plots [2]. The wording is strict, and in theory it should have pushed municipalities to accelerate the entry of data. In practice the effect has been mixed — in a number of regions the pace of filling the register of boundaries has increased, but the absolute figures are still far from full coverage of the country's territory.

The situation in Krasnoyarsk Krai is illustrative: as of January 1, 2025, 1,716 settlements were officially registered, yet only 787 of them currently have officially fixed boundaries. In 2024 alone the USRR was supplemented with boundary data for 253 settlements [3]. The trend is noticeable, but simple arithmetic suggests that even at this pace, fully closing the gap will take years — and until then, land use and development rules will govern space whose administrative contours are not legally fixed in the register.

A similar picture emerges in Chelyabinsk Oblast. According to the regional Rosreestr department and the Roskadastr branch, as of May 1, 2024 the USRR register of boundaries contained 4 borders between constituent entities of the Russian Federation, 43 boundaries of municipal formations, 1,251 boundaries of settlements, and 34,838 zones with special conditions of territory use [4]. The abundance of zones with special conditions of use is not accidental — this type of data creates the largest number of conflicts, since such zones frequently

overlap one another, cross the boundaries of several municipal formations, and require coordination among several federal agencies at once.

A separate puzzle concerns the protection zones of cultural heritage sites. The legislator has provided for a transition period: until January 1, 2028, such zones are considered established even in the absence of USRR data about them, provided the zone itself was established before January 1, 2025 [5]. The provision is reasonable from the standpoint of protecting historical and cultural heritage, but it also preserves a state of legal uncertainty for several more years — a developer working near a cultural heritage site cannot verify the current boundaries of the protection zone through the open register and must apply directly to the municipality's architectural department.

ORGANIZATIONAL AND TECHNOLOGICAL GAPS BETWEEN INFORMATION SYSTEMS

A caveat is in order here: the problem is not purely legal — it is equally technological. Data on territorial planning is prepared and stored in state information systems for urban planning activity (GISOGD) [6], while register data is maintained in the federal state information system USRR (FGIS EGRN) [7]. Formally these systems are supposed to exchange data automatically; in practice, interaction remains fragmentary.

As noted in an analytical publication on the digital transformation of urban planning activity, USRR data is necessary for preparing land use and development rules, territory planning and surveying projects, and urban planning plans for land plots, which is why it is important to ensure interaction between GISOGD and FGIS EGRN [8]. Moreover, the authors explicitly state that it is advisable to establish intersystem interaction between GISOGD and FGIS EGRN that would eliminate duplicate work on placing data about the boundaries of settlements, territorial zones, and zones with special conditions of territory use. The word "advisable" here is notable in itself — years after the launch of digitalization in the urban planning sector, the matter is still framed as a recommendation rather than a completed integration loop.

Duplicated work is not an abstraction. In practice it means that a municipal official enters a territorial zone boundary into GISOGD, and then — often in a different coordinate system or with different precision — the same boundary is described by a cadastral engineer for entry into the USRR register of boundaries [9]. Two descriptions of the same object, prepared independently of one another, rarely coincide exactly. This is the source of register errors, overlapping boundaries, and litigation between neighboring landowners.

The causes of boundary discrepancies are systematically catalogued in the literature on register errors: distortion of land plot characteristics arises from unreliable data entered into the USRR during electronic document transfer, as well as from the difference between "technical" and "register" errors, which require different correction procedures [10]. Technical errors made by the registration authority are corrected through a simplified procedure within a few business days; register errors, however, inherited from incorrectly prepared land-management or urban planning documentation, often require litigation and a repeat geodetic survey.

An inverse relationship can also be observed: the more actively a region carries out comprehensive cadastral works, the less frequently boundary-overlap disputes arise afterward. Saratov Oblast shows a fairly steady dynamic in this respect — in 2026 alone, the regional Roskadastr entered over 200 boundary records, and the press release notes that transparent information about boundaries and zones significantly facilitates real-estate transactions, since buyers and sellers can be confident that there are no unresolved boundary disputes [11]. The statement sounds optimistic, but it is fair only for those plots whose boundaries have already gone through the clarification procedure — and, judging by the Krasnoyarsk and Chelyabinsk statistics, such plots are still a minority.

How specific is this problem to the Russian legal system, rather than being a universal consequence of multi-level territorial governance? The question is partly rhetorical, but the answer matters: a decentralized model, in which master plans are approved by municipalities while cadastral registration is maintained by a federal body, objectively requires more complex synchronization mechanisms than unitary systems of real-estate accounting. This is not a justification for delays, but an explanation of their structural nature.

THE SPECIFICS OF NEW CONSTITUENT ENTITIES AND PROSPECTS FOR DATA HARMONIZATION

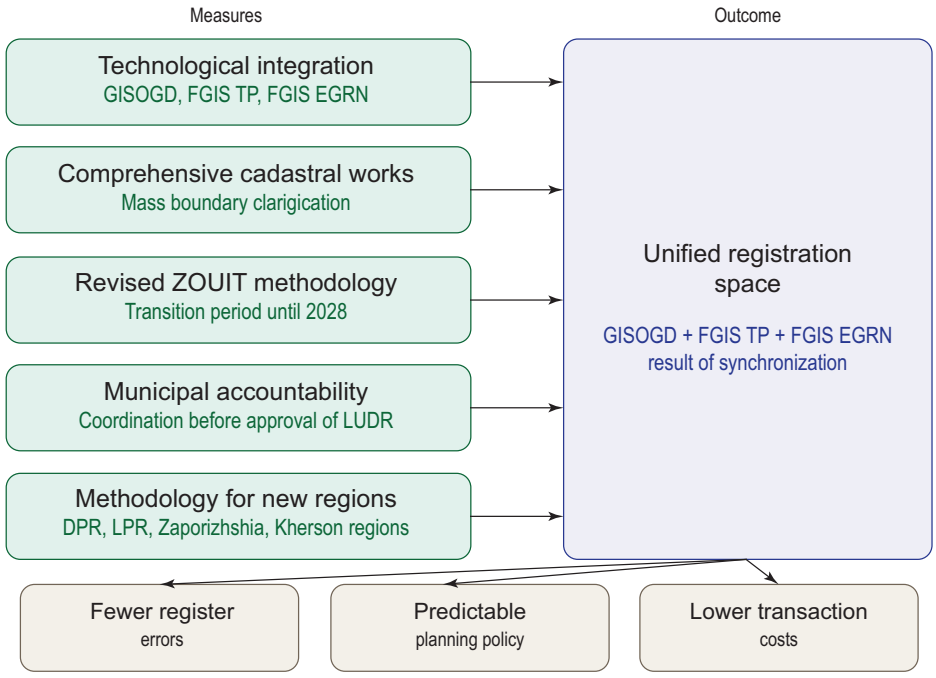
The formation of a unified accounting and registration space in the territories of the Donetsk People's Republic, the Luhansk People's Republic, and the Zaporizhzhia and Kherson regions deserves separate discussion. Integrating these constituent entities into the legal space of the Russian Federation involves not only extending the norms of the Urban Planning Code to them, but also gradually populating the USRR with reliable data on the boundaries



Vakhtina Natalya Sergeevna,
Master's student; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation;
vahtinaaa2003@gmail.com



Voshchanova Veronika Evgenievna,
Master's student, Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation;
Veronikavoshanova2002@mail.ru



Conceptual model for harmonizing territorial planning and USRR data

of settlements, municipal formations, and territorial zones — work that other regions of the country have carried out over decades.

The task is complicated by the fact that pre-war territorial planning documentation in these territories was prepared according to different technical standards and in a different coordinate system. Transferring such materials into the Russian regulatory framework requires not mechanical copying but full-scale updating — including geodetic work, establishing boundaries in accordance with the requirements of the order on describing the location of territorial zones, and subsequent registration in the federal system. This process naturally takes time; comparable tasks in well-established Russian regions, as the Krasnoyarsk Krai statistics show, take years to resolve even with a fully developed institutional base.

Sequence matters more than speed here. Forcing the entry of approximate, unclarified boundaries can create even more problems than a temporary absence of data in the register — accumulated experience in correcting register errors in regions with a long history of registration (a characteristic example being the case of a gardening partnership in Khabarovsk Krai, which required a special methodology to correct the location of a plot's boundaries) clearly demonstrates the cost of haste. A reasonable strategy for the new regions is the parallel conduct of territorial planning procedures and cadastral registration, synchronized through unified geodetic networks, rather than a sequential, drawn-out filling of the register "on a residual basis".

As for the directions for improvement across the country as a whole, several interrelated lines can be identified (Fig.):

- technological integration of GISOGD, FGIS TP, and FGIS EGRN into a single data-exchange loop, eliminating repeated entry of the same coordinate descriptions by different performers;
- expanding the practice of comprehensive cadastral works, which allow the boundaries of a significant number of land plots within a single cadastral block to be clarified simultaneously, rather than on an application-by-application basis;
- revising methodological approaches to describing zones with special conditions of territory use, taking into account the transition period established until January 1, 2028, in order to avoid "accumulating deferred obligations" to enter data [12];
- strengthening the accountability of local self-government bodies for the timely coordination of the graphic materials of land use and development rules with register data prior to their official approval [13].

None of these points looks revolutionary on its own — all of them essentially develop mechanisms already embedded in the legislation. Their combined effect, however, could change the very logic of interagency interaction: instead of correcting accumulated discrepancies after the fact, preventing their emergence at the stage of preparing documentation. How realistic such a scenario is in the medium term is a question that is difficult to answer unambiguously today; some regions, judging by the pace of filling the register of boundaries, show noticeable progress, while others still lag behind, and there is not yet enough data for a uniform assessment across all constituent entities of the Federation.

Legal scholarship also records a broader systemic effect of the accumulated shortcomings of urban planning legislation: they generate legal uncertainties and risks that are ultimately passed on by developers to end buyers of real estate, while systemic defects in the preparation of urban planning documentation slow the development of municipal territories over time [14]. The formulation is harsh, but it reflects the opinion of specialists who work directly with the practice of preparing land use and development rules, rather than an abstract assessment.

Recent practice also demonstrates the opposite tendency — a strengthening of Rosreestr's oversight functions in providing methodological support to regions in correcting register errors identified through registration actions and citizens' appeals [15]. This indirectly confirms that the problem is recognized at the federal level and response mechanisms are being formed; the only question is the speed of their practical implementation at the municipal level.

CONCLUSION

The analysis shows that the discrepancies between territorial planning documents, urban zoning, and USRR data have a complex nature — legal, organizational, and technological at once. A significant share of settlements and territorial zones in various constituent entities of the Russian Federation still lack legally fixed boundaries in the register, as confirmed by the statistics of Krasnoyarsk and Chelyabinsk Krais for 2024–2025. The absence of fully automatic synchronization between GISOGD, FGIS TP, and FGIS EGRN forces participants in urban planning activity to manually reconcile data from different systems, which naturally increases the risk of register errors.

The practical significance of the findings presented lies in substantiating priority directions for improving accounting and registration practice — from accelerated integration of information systems to the introduction of comprehensive cadastral works as the primary tool for the mass clarification of boundaries. Particular attention is required for the specifics of forming a unified register space in the territories of the Donetsk and Luhansk People's Republics and the Zaporizhzhia and Kherson regions, where the process of populating the USRR with reliable data is at an early stage and requires a methodologically sound, phased approach.

Further research should be focused on the quantitative assessment of the economic consequences of misalignment between register and urban planning data for investment activity in the construction industry, as well as on a comparative analysis of regional practices for populating the USRR register of boundaries with a view to identifying the most effective organizational models.

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Актуальные проблемы согласования документов территориального планирования, градостроительного зонирования и сведений ЕГРН

Статья посвящена анализу правовых и организационных противоречий, возникающих при сопряжении генеральных планов, правил землепользования и застройки со сведениями Единого государственного реестра недвижимости. Актуальность работы обусловлена тем, что указанные информационные массивы формировались в разное время, разными ведомствами и с применением неодинаковых технических стандартов и картографических основ, вследствие чего графические границы территориальных зон и населенных пунктов систематически расходятся с их кадастровым и реестровым описанием. Такая рассогласованность не только осложняет практику градостроительного проектирования, но и создает реальные препятствия для оборота земельных участков, формирования инвестиционно привлекательной среды и обеспечения гарантий прав собственности.

Автором анализируются причины возникновения подобных расхождений, в числе которых выделяется отсутствие единой координатной основы и методики верификации данных при передаче сведений между ведомствами. Доказывается, что неполнота и противоречивость данных ЕГРН порождают системные риски для застройщиков, органов местного самоуправления и правообладателей, неизбежно приводя к повышению правовой неопределенности и росту транзакционных издержек. Особое внимание в работе уделено специфике синхронизации учетно-регистрационных систем на территориях новых субъектов Российской Федерации, где прежние системы делопроизводства утрачены, а материалы межевания зачастую отсутствуют, что требует особой, поэтапной методологии геодезически обоснованного наполнения реестра.

В основе исследования лежат положения Градостроительного кодекса, смежные федеральные акты, а также анализ существующих региональных практик. В качестве ключевых направлений преодоления выявленных проблем предлагаются активизация межсистемной интеграции ГИСОГД, ФГИС ТП и ФГИС ЕГРН, а также масштабное внедрение

комплексных кадастровых работ, охватывающих не только фиксацию границ, но и их увязку с утвержденной градостроительной документацией. Сделан вывод, что формирование единого гармонизированного учетно-регистрационного пространства невозможно без унификации нормативных требований, цифровой консолидации данных и выработки специальных алгоритмов согласования для регионов с особыми условиями интеграции. Реализация предложенных мер позволит минимизировать реестровые ошибки, повысить прогнозируемость градостроительной политики и обеспечить устойчивое развитие территорий.

Ключевые слова: *территориальное планирование, градостроительное зонирование, ЕГРН, реестровая ошибка, ГИСОГД, правила землепользования и застройки, кадастровый учет*

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Об авторах: **Нечетный Никита Юрьевич** — кандидат экономических наук, доцент кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; РИНЦ ID: 801304, Scopus AuthorID: 58825124700, WoS ResearcherID: AAG-6602-2022, ORCID: 0000-0002-2605-8783; osun_kaf@mgsu.ru;

Чубаркина Ирина Юрьевна — кандидат экономических наук, доцент кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; РИНЦ ID: 791667, Scopus AuthorID: 57194448794, WoS ResearcherID: AAC-1685-2022, ORCID: 0000-0002-6969-6187; osun_kaf@mgsu.ru;

Вахтина Наталья Сергеевна — студент магистратуры; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; vahtinaaa2003@gmail.com;

Вощанова Вероника Евгеньевна — студент магистратуры; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; Veronikavoshanova2002@mail.ru.

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Mikhrina T.R.
Gaidin I.A.

Impact of zones subject to special land–use conditions on the cadastral valuation of land plots

The article summarizes the current regulatory provisions and research approaches to accounting for zones with special territorial use conditions in land cadastral valuation. The aim of the paper is to systematize the factors through which such restrictions can affect land value and to compare the approaches presented in Russian and foreign studies. The review covers Russian land legislation, regulatory acts on cadastral valuation, methodological recommendations of Rosreestr, domestic studies of plots located in zones with special use conditions, as well as international studies devoted to land use restrictions, protected areas, territories associated with airports, and other spatial determinants of real estate value. Comparative analysis, thematic classification, and synthesis of literature were used in the work. The review shows that the mere presence of a zone with special use conditions does not determine either the direction or the magnitude of the impact on cadastral value. The result depends on the legal regime, permitted use, the share and configuration of the limited part of the plot, opportunities for development, additional costs, and the local market conditions. Some restrictions may reduce the value of the directly affected plot, while proximity to natural, historical, or infrastructure facilities may create a separate positive or negative locational effect. The obtained results confirm the need for a differentiated approach to zones with special use conditions and for market-based justification of adjustments in state cadastral valuation.
Keywords: *cadastral value, state cadastral valuation, land plot, zones with special conditions for territorial use, land use restrictions, mass valuation, pricing factors, real estate market*



Mikhrina Tatiana Romanovna,
Master's student of the Department of construction organization and real estate management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation;
ORCID: 0009-0004-5566-2164;
tanyamikhrinacom@gmail.com



Gaidin Ivan Alekseevich,
Master's student of the Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation;
ivan.gaydin.03@mail.ru

The cadastral value of a land plot is used for property taxation, calculating certain payments, and in other cases established by law. Therefore, the reliability of the results of the state cadastral valuation largely depends on how correctly the characteristics of the object that are actually relevant to the market are taken into account. For land plots, such characteristics include, among other things, usage restrictions that arise when zones with special conditions for the use of territories (ZSCUT) are established.

ZSCUT are established to address publicly significant tasks: ensuring the safe operation of engineering and transport facilities, protecting the population, preserving the natural environment, conserving cultural heritage, and for other purposes. As a rule, the land plot itself is not seized from the right holder, but the scope of its permissible use may change significantly. Depending on the type of zone, restrictions affect construction and reconstruction, earthworks, the placement of certain facilities, agricultural use, and other forms of economic activity [1].

From the perspective of cadastral valuation, different types of special use zones and special protection zones cannot be considered economically homogeneous. The protection zone of a linear facility, the sanitary protection zone, the water protection area, and the cultural heritage protection zone differ not only in their legal grounds but also in the nature of their impact on the land plot. The same restriction may have a different impact on value depending on the permitted use and the intended development of a particular property.

The connection between the zone of special use and the cadastral value is directly enshrined in the legislation on state cadastral valuation. Federal Law No. 237-FZ provides for consideration of information about whether a land plot is located within the boundaries of such a zone in terms of its possible impact on the value [2]. The methodological guidelines of Rosreestr also allow for taking into account land rights restrictions caused by the zone of special use and applying reasonable adjustments to plots with individual characteristics [3]. Thus, regulatory regulation focuses the appraiser not on automatic cost reduction, but on the preliminary determination of the fact and magnitude of the cost effect.

The scientific literature considers the impact of ZSCUT on the value of land as a complex problem in which legal restrictions are related to the spatial characteristics of the site and its economic use. In domestic studies, infrastructural constraints are analyzed through the category of negative externalities and their possible reflection in the value of land [4]. A separate area is related to the assessment of the protection regimes of cultural heritage sites and their impact on the use of land [5].

The purpose of this paper is to summarize the existing approaches to assessing the impact of land use and land management zones on the cadastral value of land plots. The focus is on the regulatory grounds for accounting for such zones and the main channels through which they affect value, which arise when using the relevant factors in mass valuation.

MATERIALS AND METHODS

The review was carried out in stages. First, a database of sources was compiled, including regulatory documents and scientific publications directly related to land use restrictions and their

cost-related consequences. When selecting sources, the following factors were taken into account: thematic relevance, the presence of a description of the method used, and the possibility of correlating the authors' conclusions with the tasks of state cadastral valuation.

The regulatory section was supplemented with documents necessary to verify the legal status of the information describing the zone of special land use and its restrictions. Federal Law No. 218-FZ was used in relation to information about the registered boundaries of the zone and restrictions on the use of real estate [6]. Federal Law No. 342-FZ was taken into account when analyzing the transitional features of establishing protected areas and land use restrictions and entering the relevant information into state registers [7].

Scientific publications were grouped by subject matter: infrastructure and environmental restrictions, protection of cultural heritage, territories of transport facilities, and spatial external effects. The sources were compared based on the nature of the restriction, the mechanism of its possible impact on value, the assessment method used, and the state of the market. To link these approaches with the tools of mass valuation, an additional study of correlation-regression analysis of real estate was considered [8]. The work is of a review nature: foreign results are used to compare economic mechanisms and methods, rather than to directly transfer the adjustments obtained by the authors to Russian practice.

RESULTS

ZSCUT in the state cadastral valuation system. Land legislation establishes various types of ZSCUT to protect the population, ensure the safe operation of facilities, and safeguard the environment and cultural heritage [1]. Restrictions within the boundaries of such zones relate to the use of land and real estate, as the relevant activities may contradict the objectives of the established regime. The economic rationale for the property owner is to preserve the object itself while potentially reducing the number of permissible ways to use it.

Federal Law No. 237-FZ refers the information and location of the site in the ZSCUT to the information to be considered when determining the cadastral value [2]. The guidelines establish an exception to the general approach to encumbrances: restrictions on land rights that arise in accordance with land legislation, including as a result of the establishment of ZSCUT, can be taken into account in the assessment [3]. If the site has features that are not typical for the main set of objects, appropriate reasonable adjustments may be applied.

For practice, the conclusion follows from this: the presence of a ZSCUT in itself should not turn into a universal cost-reducing feature. The assessment should determine whether a particular regime has an independent impact on the market attractiveness of the site and whether this impact is confirmed by the data of the segment in question. In the absence of such confirmation, the adjustment can only artificially change the result of the cadastral assessment.

The main source of information about the zones is the Unified State Register of Real Estate (USRRE), which records their boundaries, details of solutions, and usage restrictions. Combining these data with the contours of land plots can be performed in GIS and is convenient for mass assessment. At the same time, the spatial intersection is only the starting point of the analysis: two sites with the same share of the ZSCUT territory may differ markedly in terms of the remaining possibility of development and actual use.

The main mechanisms of the impact of ZSCUT on the value of land plots

Summarizing the publications allows us to identify several main mechanisms of the impact of ZSCUT on the cost. The first is related to the reduction of acceptable use cases: if the regime excludes the most demanded development scenario, the economic opportunities of the site decrease. This is especially noticeable where the price depends on the possibility of construction or the intensity of use.

The second mechanism is related to the parameters of the development. The restriction may reduce the area suitable for development, introduce requirements regarding height and setbacks, or worsen the layout scheme; therefore, not only the area of the zone matters, but also its position within the plot. The third mechanism generates additional costs for approvals, protective measures, surveys, and changes to design solutions. Even if the permissible use is maintained, the increase in costs and the time required for development can affect the price.

The fourth mechanism is related to the uncertainty of the project implementation: the risk of complications in obtaining approvals and permits can reduce demand and affect price expectations. In a mass assessment, such an effect is especially difficult to separate from other characteristics of an object.

At the same time, the legal effect of the ZSCUT must be separated from the independent influence of the regime-forming object and the surrounding territory. For engineering infrastructure, this distinction is especially important because of the combination of usage restrictions and possible location



Beliakov
Sergei Igorevich,
Doctor of Economic Sciences, Associate Professor, Professor of Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; ID RSCI: 587836, Scopus AuthorID: 39763951700, ORCID: 0000-0001-5179-737X; BelyakovSI@mgsu.ru



Orlov
Alexandr Konstantinovich,
Candidate of Economic Sciences, Associate Professor, Associate Professor of Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; ID RSCI: 400958, Scopus AuthorID: 57192545943, WoS ResearcherID: AAH-8610-2019, ORCID: 0000-0003-1800-5478; orlovak@mgsu.ru

Generalized characteristics of the impact of certain types of land use and land management zones on the cadastral value of land plots

Zone group	Typical restrictions	Possible impact on the cadastral value	Factors that need to be separated
Security zones of engineering and transport facilities	Restrictions on construction, earthworks, and other work, safety requirements	Reduction in cost due to loss of opportunity, fragmentation of the plot, or additional expenses	The positive effect of infrastructure provision and transport accessibility
Sanitary protection and near-airfield areas	Restrictions on certain types of use, requirements for the placement of facilities, and development parameters	Possible discount for residential, recreational, and other sensitive types of use	Noise, emissions, and the availability of transport infrastructure
Water protection and environmental protection zones	Limitations of economic activity and development intensity	From a neutral to a negative effect on the burdened part of the plot	Proximity to water and green spaces, recreational appeal, risk of flooding
Cultural heritage protection zones	Restrictions on construction, reconstruction, height limitations, and architectural solutions	Reduction with a significant limitation on the scope of application; the effect depends on the segment	The value of the historical environment, its centrality, and its tourist appeal
Several intersecting ZSCUT	The totality of various prohibitions and requirements	The risk of a more significant limitation on use, but not necessarily the total amount of individual discounts	Duplication of prohibitions and the overall residual potential for use

advantages. In natural areas, the legal regime operates simultaneously with noise and other physical effects, which also affect real estate prices [9]. A similar principle applies to natural and historical territories: the characteristics of the surrounding environment should be considered separately from the restriction itself.

The influence of individual groups of land use and land management zones. The direction and intensity of the cost effect depend primarily on the purpose of the zone and on how the restrictions affect the actual or potential use of a particular site. The main patterns identified in regulatory sources and scientific publications are summarized in Table.

Protected areas of engineering infrastructure in Russian studies are often considered through the concept of negative infrastructural externalities. E.N. Bykova links the possibility of cost reduction with restrictions on activity, violation of the spatial integrity of the site and other consequences of the presence of a regime-forming facility [4]. At the same time, the infrastructure itself is capable of improving the quality of the location, therefore, when analyzing prices, it is necessary to separately take into account the inconveniences of the security regime and the advantages of the proximity of communications.

For sanitary protection and airfield areas, the impact is formed by several circumstances at once: restrictions on sensitive uses by the physical impact of the facility itself. Batog and co-authors show that changes in housing prices near regional airports are simultaneously associated with noise levels and land-use restrictions [9]. In relation to cadastral valuation, this confirms the need to distinguish between the legal regime and the characteristics of the environment.

Water protection zones particularly clearly demonstrate the divergent nature of the factors. The work by D.A. Shapovalov and co-authors examines the impact of water protection restrictions on cadastral value [7]. At the same time, being located near water can increase the attractiveness of a plot, while the legal regime simultaneously restricts certain types of economic use [10]. As a result, the observed price reflects a combination of at least two different effects.

A similar situation is typical for protection zones for cultural heritage sites. I.S. Dyachkova examines the impact of protection regimes on commercial land [5], and, together with K.M. Karadzhyan, on plots for individual housing construction [6]. Restrictions on construction parameters can reduce the potential for development, but the influence of the historical environment should be taken into account separately from the legal regime itself. The same issue is examined in I.S. Dyachkova's English-language work, using data from a low-activity market of individual housing construction participants [11, 12].

Approaches to quantitatively assessing the impact of ZSCUT in Russian literature

Russian publications show that the method of accounting for ZSCUT is largely determined by the market saturation and the quality of the source data. E.N. Bykova's study examines a differentiated approach: with a sufficient number of observations, the impact of restrictions can be identified using statistical methods; in conditions of a shortage of transactions, comparisons of encumbered and unencumbered plots, as well as qualimetric and expert-analytical procedures, may be used [4]. The analysis includes not only the mere fact of the zone's presence but also the spatial characteristics of the plot.

Further development of this area is linked to the automation of assessing infrastructure constraints. E.N. Bykova and co-authors examine the use of information technologies to take into account negative externalities when determining land value and draw attention to the need to align the choice of method with the state of the market. For state cadastral valuation, this conclusion is particularly significant, since one model is applied to a large number of objects, and the volume of available market data varies across different segments [13].

I.S. Dyachkova's study presents various approaches to assessing the impact of protecting cultural heritage sites: the use of fuzzy set theory, analysis of individual housing plots, and a comparative approach for a low-activity market. This shows that the choice of method depends on the nature of the restrictions and the availability of market data. For mass cadastral valuation, it is preferable for the existence of a value effect to be statistically confirmed. With a sufficient specimen of plots with a certain type of restriction, the relevant factor can be tested in the model simultaneously with location, area, permitted use, and other characteristics. If there are not enough observations, a single dummy variable may turn out to be unstable. In this case, it becomes more justified to aggregate homogeneous groups or to consider atypical objects separately.

The work by I.F. Gareev and T.A. Akhmatgaliev is not directly focused on ZSCUT, but it is of interest for this topic as an example of the development of regression tools for mass valuation and the use of large datasets on real estate [8]. It is only possible to isolate the independent effect of a specific restriction in a model where other significant price-forming characteristics are simultaneously controlled.

DISCUSSION

Foreign studies on land-use restrictions and spatial effects

There is no direct analogue of the Russian ZSCUT category in foreign law, but the international literature contains a significant body of research on land-use restrictions, conservation easements, protected open space, zoning regulations, and other land-use regulation regimes. Their value for the topic under consideration lies primarily in the methods for identifying how restrictions and environmental characteristics are reflected in real estate prices.

Anderson and Weinhold link the value effect of conservation easements to the loss of rights to future development and land use [14]. The very principle of this approach is important for the analysis of land use and zoning regulations: it is not the formal presence of a restriction that matters, but the economic value of the use scenarios that become unavailable. The more significant the lost development potential, the higher the likelihood of a noticeable impact on the value.

Studies of open spaces reveal another side of the issue. Geoghegan shows that the characteristics of open space can be capitalized into the value of residential real estate [15]. Irwin and Bockstael emphasize the difficulty of separating spatial external effects from other location factors and point to the problem of endogeneity [16]. For land use planning, this means that a change in price cannot be automatically linked to the legal regime if there is an object nearby that in itself affects the attractiveness of the territory.

Yoo and Ready examine the impact of agricultural conservation easements on the value of neighboring houses, taking into account spatial autocorrelation and territorial heterogeneity [17]. Zhang and co-authors document the dependence of the effect of forest conservation easements on the spatial location of the objects [18]. These results show that the model parameters must be calibrated locally, and transferring coefficients between territories without re-verification may lead to erroneous conclusions.

Taken together, foreign publications confirm two points that are important for Russian cadastral valuation. Land-use restrictions can indeed be reflected in the market price, but the magnitude and even the direction of the effect depend on a combination of the legal regime, the lost use potential, the spatial environment, and the characteristics of the local market. Therefore, a single adjustment applied outside of the analysis of a specific segment does not agree well with the results of the studies reviewed.

Methodological problems of accounting for ZSCUT in mass assessment

Based on the results of the review, a number of problems can be identified that directly affect the quality of ZSCUT accounting in the state cadastral assessment. The first concerns the source data. One contour of the zone in the Unified State Register of Real Estate (USRRE) is not enough: for economic interpretation, it is necessary to know the current regime, the date of its establishment and the content of specific restrictions. Spatial information without a legal context does not allow determining the consequences for the use of the site.

The second problem is related to partial overlap. The share of the plot area within the boundaries of the land use zone is important, but it does not fully characterize the effect. For land intended for development, the position of the limited part, the preservation of a rational construction footprint, access roads, and utility connections may be decisive. For agricultural land, technological integrity and the ease of processing the remaining territory are more important. Therefore, the same percentage of overlap can be accompanied by different cost outcomes.

The third problem arises when several zones overlap. If different regimes prohibit the same action in the overlapping territory, the sequential application of several downward adjustments will lead to the repeated accounting of the same consequence. In such a situation, it is necessary to analyze the residual set of actually available ways to use the site, rather than the number of registered ZSCUT themselves.

The fourth problem is the lack of market observations. For rare types of zones and low-activity segments, a statistically stable coefficient may be unattainable. Under such conditions, Bykova considers comparative and expert-analytical methods for assessing the impact of restrictions [4]. Dyachkova proposes a methodological approach focused on addressing the situation of a lack of direct market observations [5]. Overall, the use of such methods requires a transparent description of the underlying assumptions and caution to ensure that the expert assessment does not create an impression of excessive precision.

The fifth problem is related to the choice of the indicator through which the influence of the zone is introduced into the model. This could be a binary feature, the share of overlap, the type of legal regime, the distance to the regulatory object, or another characteristic. The most informative option depends on the segment: for residential development, it is more important to limit construction parameters, for agricultural land — to preserve technological integrity, for commercial land — the permissible intensity of use.

Finally, it is necessary to take into account the limitation itself and the characteristics of the environment separately. Combining cadastre, GIS, and market information seems promising. The possibilities of automating spatial constraint analysis are considered by Bykova and co-authors [13], and the development of regression tools for mass assessment is considered by Gareev and Akhmetgaliev [8]. Spatial methods can be used to calculate additional variables, while statistical analysis can determine whether they are reflected in prices.

CONCLUSIONS

A synthesis of regulatory sources and scientific publications shows that the impact of land use zones on cadastral value cannot be described by a single universal coefficient. Differences in the purposes for establishing zones, the composition of prohibitions, and the consequences for land use mean that the same fact of a plot being within the boundaries of a land use zone may have different economic significance.

The most significant characteristics include the type and severity of the regime, the permitted and actual use of the plot, the area and configuration of the restricted part, the possibility of major construction, the resulting additional costs, and the state of the local market. The impact of the framework-forming object and the surrounding territory should be considered separately, as it may not align in direction with the effect of the restriction itself.

Russian literature describes statistical, comparative, expert-analytical, and qualimetric methods for accounting for restrictions. The choice between them is determined by market activity and the quality of the initial data. Foreign studies complement this picture, showing the significance of lost use potential, spatial heterogeneity, and external effects in assessing the consequences of land-use regulation.

For state cadastral valuation, a step-by-step approach appears to be the most consistent: first, the content and spatial scope of the restriction are established, then its impact on the actual possibilities for using the plot is determined, after which the presence of a value effect is verified based on market data. If there is insufficient information, atypical objects require a separate analysis. The use of pre-defined universal discounts in such conditions increases the risk of distorting the cadastral value.

Further improvement of the accounting of land use and zoning restrictions is primarily related to improving the quality of information about zone regimes, developing GIS analysis, and accumulating market data on plots subject to various types of restrictions. Expanding such a database will make it possible to more accurately identify the independent effect of land use and zoning restrictions and to increase the validity of the results of state cadastral valuation.

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Влияние зон с особыми условиями использования территорий на определение кадастровой стоимости земельных участков

В статье обобщены действующие нормативные положения и исследовательские подходы к учету зон с особыми условиями территориального пользования при кадастровой оценке земли. Цель статьи — систематизировать факторы, посредством которых такие ограничения могут влиять на стоимость земли, и сравнить подходы, представленные в российских и зарубежных исследованиях. Обзор охватывает российское земельное законодательство, нормативные акты о кадастровой оценке, методические рекомендации Росреестра, отечественные исследования участков, расположенных в зонах с особыми условиями использования, а также международные исследования, посвященные ограничениям землепользования, охраняемым территориям, территориям, связанным с аэропортами, и другим пространственным детерминантам стоимости недвижимости. В ходе работы применялись сравнительный анализ, тематическая классификация и обобщение литературы. Обзор показывает, что само по себе наличие зоны с особыми условиями использования не определяет ни направление, ни величину влияния на кадастровую стоимость. Результат зависит от правового режима, разрешенного использования, доли и конфигурации ограниченной части участка, возможностей для развития, дополнительных затрат и конъюнктуры местного рынка. Некоторые ограничения могут снижать стоимость непосредственно затронутого участка, в то время как близость к природным, историческим объектам или объектам инфраструктуры может создавать отдельный положительный или отрицательный локационный эффект. Полученные результаты подтверждают необходимость дифференцированного подхода к зонам с особыми условиями использования и рыночного обо-

снования корректировок при государственной кадастровой оценке.

Ключевые слова: *кадастровая стоимость, государственная кадастровая оценка, земельный участок, зоны с особыми условиями использования территории, ограничения в землепользовании, массовая оценка, ценовые факторы, рынок недвижимости*

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Об авторах: **Михрина Татьяна Романовна** — магистрант кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; ORCID: 0009-0004-5566-2164; tanyamikhrinacom@gmail.com;

Гайдин Иван Алексеевич — магистрант кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; ivan.gaydin.03@mail.ru;

Беляков Сергей Игоревич — доктор экономических наук, доцент, профессор кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; РИНЦ ID: 587836, Scopus AuthorID: 39763951700, ORCID: 0000-0001-5179-737X; BelyakovSI@mgsu.ru;

Орлов Александр Константинович — кандидат экономических наук, доцент, доцент кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; РИНЦ ID: 400958, Scopus AuthorID: 57192545943, WoS ResearcherID: AAH-8610-2019, ORCID: 0000-0003-1800-5478; orlovak@mgsu.ru.

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Zaytseva L.I.

Identifying markers of conflict potential in the context of seamless implementation of construction projects

The paper focuses on the analysis of specific conditions that lead to an increase in the number of disputes and the escalation of conflicts among participants in investment and construction activities, which the author has identified as markers of conflict potential. The main goal of identifying these markers is to launch a mechanism for managing disputes and disagreements in projects based on mediation approaches. It is particularly noted that each stage of project implementation is characterized by certain markers of conflict potential, both at the external and internal levels. The following types are identified: regulatory (amendments in legislation), geopolitical (escalation of international relations), organizational and managerial (management processes within the corporation), communication (interaction among project participants), contractual (legal framework of the project), informational (platform solutions), production and technological (continuity of the process), as well as markers of judicial and non-judicial settlement of disputes. It is concluded that the proposed markers are mutually reinforcing, and their impact on the project implementation process is not equal. At the same time, a preventive component of the activities of specialized commissions has been identified, which consists in identifying and analyzing the designated markers of conflict potential in order to modify contractual obligations if necessary. It is precisely this format of expert support for projects that best aligns with modern concepts of a horizontal model of cooperation. The conclusions and results obtained can contribute to the development of constructive partnerships in the implementation of projects and the adoption of preventive measures to significantly reduce the level of conflict in investment and construction sector.

Keywords: *markers of conflict potential, the mechanism of managing disputes and disagreements, expert support, the level of conflict potential*



Zaytseva Larisa Igorevna,
Associate Professor of the Department of Project Management and Business Administration RANEPA, Candidate of Law, Associate professor, Head of Judicial Practice, Accounting and Statistics Department; Arbitration Court of Moscow Region; 82 Vernadskogo av., Moscow, 119571, Russian Federation; ID RSCI: 1027747, Scopus AuthorID: 57194457897, WoS ResearcherID: JZE-4102-2024, ORCID: 0000-0002-8325-4342; Zaytseva-li@ranepa.ru

INTRODUCTION

Currently, amid external challenges and crises, flexible horizontal models of cooperation based on the use of conciliation mechanisms and effective management of disputes and disagreements in project implementation are becoming particularly relevant. The developments used in this field, such as the PMBOK Extension for the construction industry, the standard forms of contracts drafted by the International Federation of Consulting Engineers (FIDIC) [1], GOST 71177–2023 [2], etc., are based on mediation approaches aimed at reducing conflict in both economic activity as a whole and the construction industry (taking into account that construction disputes are among the most amenable to mediation), and, as a result, the creation of a framework for ensuring a favorable business climate, taking into account the certain inequality of project participants.

The selection of specific methods for resolving disagreements and the activation of a dispute and disagreement management mechanism in practice should be carried out in the event of certain conditions that lead to an increase in conflict potential [3]. We define these specific conditions as markers of conflict potential. They are, in a sense, signals that prompt the participants in the project cycle to analyze and choose the most effective method of dispute resolution.

Let us clarify that each stage of project implementation is characterized by certain conflict-generating factors, both at the external and internal levels. They have varying degrees of significance, indicating the possibility of the emergence and escalation of economic contradictions among the project participants.

MATERIALS AND METHODS

Based on the analysis of various approaches, we can identify the following types of markers:

- *regulatory* (external level — amendments in legislation). The relevant legal norms may be aimed either at easing the current procedure for conducting investment and construction activities, shortening the investment cycle, and removing administrative barriers [4], or at tightening the position of developers (for example, regulating the processes of integrated development of territories [5], including those related to the creation of infrastructure facilities, strengthening the supervisory component regarding self-regulatory organizations, a moratorium on the accrual of penalties, the validity of which expired in 2026, etc.) [6];
- *geopolitical* — that is, markers at the external level related to the escalation of international relations and directly to the sanctions regime. An analysis of judicial practice has shown that the most common situations leading to an increase in conflict potential are: breach of contract terms caused by disruptions in supply chains due to sanctions, payment freezing by a correspondent bank, actions of a foreign counterparty, etc. [7]. Moreover, the existing judicial practice demonstrates a selective approach to

classifying sanctions as circumstances that exempt from liability or allow for the termination of a contract [8]. Sanctions are not automatically recognized as force majeure, and parties are required to prepare and provide a detailed justification for their position [9]. Sanctions restrictions that are not recognized in Russia, due to which foreign counterparties fail to fulfill their obligations, are not considered force majeure circumstances [10]. For contracts concluded after the imposition of sanctions, it is necessary to prove that the specific sanction affecting the project was still unforeseen, and that all reasonable alternative ways of implementation, including parallel imports, were indeed exhausted and proved to be impossible;

- *organizational and managerial* markers relate to the internal level, which pertains to the administration processes within the corporation. They are reflected, among other things, in the concept of corporate social responsibility as an integral part of sustainability of a construction company's operations [11], as well as in the ESG principles (Environmental, Social, Governance), which predetermine the focus on reducing conflict throughout the entire project cycle [12, 13];
- *communication* markers related to both external and internal levels of management. An important role is played by the project participants' interaction plan, which makes it possible to ensure comprehensive project coordination and the involvement of all key players already at the initial phase [14]. It is also important to develop a negotiation strategy (avoiding this process is unacceptable), to create a system of early notifications, and so on. Regarding the manifestation of the marker at the external level, the most destructive factors may be a negative image of the project participant (for example, publications in the media, inclusion in the register of unfair suppliers, information about the initiation of bankruptcy proceedings in open sources, etc.);
- *contractual* markers (legal dimension) that characterize the choice of contractual strategy and the use of project-oriented provisions in the agreement (and, more broadly, the concept of relational contracts — that is, a type of long-term agreement based on trust, common goals, and flexible rules of interaction between the parties) [15, 16];
- as the analysis has shown, it is advisable to identify markers of *judicial and non-judicial settlement*. The external level characterizes the creation of conditions for applying a certain format of interaction when disputes arise. Thus, in the Russian Federation, for a long period of time, judicial proceedings served as the main method of resolving disputes, which, among other things, affected the level of conflicts. An important external factor aimed at promoting non-judicial settlement was the substantial increase (by more than 50 times in terms of monetary claims) in the amount of the state fee when filing a claim in arbitration courts. At the same time, the results of 2025 demonstrated a positive trend in the number of economic disputes in general, and construction disputes in particular, but this trend remains insignificant for now.

Markers at the internal level, in turn, relate to the willingness of economic entities to use ADR. Thus, according to a study conducted by Pravo.ru in 2015, only 25 % of respondents (representatives of the business community) are ready to use mediation to resolve conflicts [17]. This method is still positioned as a procedure with a high psychological and organizational threshold. Moreover, special emphasis is placed on the mediator's lack of industry-specific expert knowledge [18]. In this regard, examples are already emerging of companies (such as Gazpromneft Expert Solutions) that do not engage external specialists but instead develop an internal mediation service:[1]

- *information* markers. Unified databases and information platforms are becoming particularly important, as they make it possible to combine data on the construction sector across the entire territory of Russia in a single digital environment, making it as transparent and accessible as possible for all market participants. For example, in November 2025, a federal law was signed that provides for the creation of a unified resource for cultural heritage objects in order to effectively integrate them into economic circulation. Other examples include: GISOGD (State Information System for Urban Planning Activities), EISZhS (Housing Construction System), FGIS TsS (Federal Pricing System), and others. It is clear that such resources can save time and ensure predictability and transparency in interaction;
- *production and technological* markers that characterize the continuity of the work production process, supply chains, the use of innovative technologies in the implementation of a specific project, the preparation and adjustment of estimates, etc.

RESULTS

The development of a mechanism for managing disputes and disagreements in a project should be carried out not only based on the categories of potential disputes, but also taking into account the specified factors; this reflects the principle of adaptability of such mechanism.

In general, when conditions arise that exacerbate contradictions and serve as markers of conflict potential, the designated mechanism should be activated immediately. At its core is the selection of effective methods for resolving disputes.

It is important to emphasize that the proposed markers are mutually reinforcing. Thus, the sanctions regime influences the modification of contractual models both in terms of drafting sanctions clauses and in terms of assessing the consequences of imposing sanctions on certain goods, counterparties, payments, as well as mechanisms for amending, terminating, or exempting from liability, etc.

Communication markers, in turn, have a direct impact on the production and technological component (conflicts with other project participants can lead to supply disruptions, missed deadlines, uncoordinated additional work, the absence of a well-thought-out import substitution strategy, etc.) [19].

Thus, the assessment of conflict-related markers for the purpose of using the dispute and disagreement management mechanism in the project should be comprehensive. Since conflict potential reflects the system's propensity to generate future disputes, the preventive component and the focus on conflict prevention become particularly important.

For example, regulatory and geopolitical markers are far from always capable of generating insurmountable consequences for the successful implementation of a project. Moreover, they do not depend on the will of the project participants. Organizational, management, and communication markers, in turn, may indicate the possibility of a significant escalation of contradictions, which cannot be overcome without structural changes [20].

[1] URL: https://research.pravo.ru/story/259258/

In other words, each marker has a different degree of significance for managing disputes and disagreements in the project. To take into account all possible consequences, the most in-demand format is expert support for the project, which makes it possible to consider all possible factors, both external and internal, that could affect the successful completion of the project.

Global experience has demonstrated the extreme relevance of such a format as the creation of independent commissions for the prevention and resolution of disputes at the initial stage of project implementation. The preventive component of such commissions' activities precisely consists in identifying and analyzing the designated markers of conflict potential in order to modify contractual obligations if necessary [21].

In this regard, it is important to understand that even if participation in a project does not result in losses at a given moment, a low profit margin does not allow for sustainable operation under conditions of high cyclical dynamics, uncertainty in the foreign economic environment, and the target structure of social development. Studies of various aspects of the sustainability of production and economic activity have convincingly demonstrated that the alignment of economic interests is the foundation for the growth of business activity, without which sustainable development is impossible [22]. Specialized commissions are precisely aimed at ensuring the sustainability and alignment of the interests of all project participants. The main task of their work is to monitor the project at all stages of its life cycle, coordinate the actions of its participants, and conduct an early assessment of the impact of emerging negative factors that may become critical to the project's objectives.

CONCLUSION

The practice of investment and construction activities aimed at implementing projects and carried out in contractual formats has convincingly demonstrated that, in the absence of systemic solutions to resolve the disagreements among the participants, delays in achieving the final project goals are inevitable.

Fragmentary and non-systemic attempts to change the established order not only fail to resolve the contradictions but exacerbate them, especially if negative experience is gained from using the adopted norms and rules.

That is why, to ensure relatively seamless project implementation, a comprehensive analysis of conflict markers is necessary, both at the external and internal levels. Identifying regulatory, geopolitical, organizational and managerial, communication, contractual, informational, production and technological markers, as well as markers of judicial and non-judicial dispute resolution, will make it possible to launch a mechanism for managing disputes and disagreements and to use the potential of a wide range of methods not only for resolving but also for preventing conflicts.

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Выявление маркеров конфликтогенности в контексте бесшовной реализации строительных проектов

Статья посвящена анализу специфических условий, приводящих к увеличению количества и эскалации противоречий участников инвестиционно-строительной деятельности, которые детерминированы автором как маркеры конфликтогенности. Подчеркивается основная цель их выявления — запуск механизма управления спорами и разногласиями в проекте на основе медиативных подходов. Особо отмечено, что каждый этап реализации проекта характеризуется определенными маркерами конфликтогенности как на внешнем, так и на внутреннем уровнях. Выделены следующие их виды: регуляторные (изменения в законодательстве), геополитические (обострение международных отношений), организационно-управленческие (процессы управления внутри корпорации), коммуникационные (взаимодействие участников проекта), контрактные (договорная обвязка проекта), информационные (платформенные решения), производственно-технологические (непрерывность процесса), а также маркеры судебного и внесудебного урегулирования разногласий. Сделан вывод, что предлагаемые маркеры носят взаимообуславливающий характер и их влияние на ход реализации проекта не равнозначно. При этом обозначена превентивная составляющая деятельности специализированных комиссий, которая заключается в выявлении и анализе обозначенных маркеров конфликтогенности с тем, чтобы при необходимости модифицировать контрактные обязательства. Именно такой формат экспертного сопровождения проектов в наибольшей степени соответствует современным концепциям горизонтальной модели сотрудничества. Полученные выводы и результаты могут способствовать развитию конструктивного партнерства при реализации проектов и принятию превентивных мер для существенного снижения уровня конфликтности в инвестиционно-строительной сфере.

Ключевые слова: *маркер конфликтогенности, механизм управления спорами и разногласиями, экспертное сопровождение, уровень конфликтности*

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Об авторе: **Зайцева Лариса Игоревна** — доцент кафедры управления проектами и предпринимательства РАНХиГС, кандидат юридических наук, доцент, начальник отдела обобщения судебной практики, учета и статистики; **Арбитражный суд Московского округа**; 119571, г. Москва, пр-т Вернадского, д. 82; РИНЦ ID: 1027747, Scopus AuthorID: 57194457897, WoS ResearcherID: JZE-4102-2024, ORCID: 0000-0002-8325-4342; Zaytseva-li@ranepa.ru.

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Zakharova Yu.V.
Sitekova A.A.

Improving the methodology for determining the cadastral value of land plots designated for individual housing construction by incorporating local factors

This paper addresses the improvement of the state cadastral valuation methodology for land plots designated for individual housing construction (IHC). The relevance of the topic stems from the persistent imbalance between cadastral and market values of such properties, which is particularly pronounced in territories with harsh natural and climatic conditions, including the Arctic and equivalent regions. The study analyzes the current regulatory framework — Federal Law No. 237-FZ of July 3, 2016 and the Methodological Guidelines approved by Order of Rosreestr No. P/0336 of August 4, 2021 (as amended on September 15, 2025). It is established that the indicative list of pricing factors (Appendix No. 3 to the Methodological Guidelines) does not contain mandatory requirements for accounting for natural-landscape, environmental, and socio-economic characteristics of territories, which creates prerequisites for a subjective approach in selecting factors and leads to economically unjustified results. The analysis also covers amendments introduced by Federal Laws No. 243-FZ of July 23, 2025 and No. 513-FZ of December 28, 2025. The study systematizes local factors affecting the value of IHC land plots: relief, soil types, freezing depth, pollution levels, noise exposure, proximity to recreational zones, district prestige, infrastructure development, and for northern territories — the presence of permafrost, climatic severity, and seasonal transport accessibility. International experience in accounting for such factors in the USA, European countries, Canada, and Scandinavia is summarized. A cadastral value calculation model with a system of adjustment coefficients is proposed and tested on a conditional example of a plot in a northern settlement. The research results can be used to improve the methodological support of state cadastral valuation.

Keywords: *cadastral value, individual housing construction land plots, mass appraisal, local factors, pricing factors, northern territories, permafrost, differentiation coefficients*



Zakharova Yulia Vladimirovna,
Master's student of Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; zzakh4rowa@yandex.ru



Sitekova Amina Askerbievna,
Master's student of Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; sitekova_amina@mail.ru

INTRODUCTION

The cadastral value of land plots in the Russian Federation serves not only as the tax base for calculating land tax but also as a key instrument for regulating property relations. In the context of reforming valuation activities, as established by Federal Law No. 237-FZ of July 3, 2016 [1], the issue of objectivity in the cadastral valuation of individual housing construction (IHC) lands becomes particularly acute.

The existing mass appraisal methodology, relying on a limited set of pricing factors, does not fully reflect the diversity of local territorial characteristics. As a result, the cadastral value of plots in prestigious areas is often underestimated, while in territories with complex natural and climatic conditions, it is overestimated relative to market prices. For northern and Arctic regions, where ignoring engineering-geological conditions (permafrost, soil types) and climatic constraints leads to a significant imbalance, this problem is especially relevant.

The methodological content of mass appraisal remained unchanged: the indicative list of pricing factors (Appendix No. 3 to the Methodological Guidelines [2]) remains open-ended and does not contain mandatory requirements for accounting for natural-landscape, environmental, and socio-economic factors. At the same time, the amendments introduced in 2025 — Federal Law No. 243-FZ of July 23, 2025 [3] and Federal Law No. 513-FZ of December 28, 2025 [4] — mandated the use of the federal state geographic information system in cadastral valuation.

The aim of this study is to develop proposals for improving the cadastral valuation methodology for IHC land plots by expanding the system of pricing factors through comprehensive consideration of local territorial characteristics, including the specifics of northern regions.

The legal regulation of state cadastral valuation is built on a hierarchy of federal laws and subordinate acts. The fundamental document is Federal Law No. 237-FZ of July 3, 2016 [1] "On State Cadastral Valuation". The law established a centralized model: the authority to determine cadastral value is transferred to specialized state budgetary institutions established by the constituent entities of the Russian Federation. The law regulates the frequency of valuation campaigns — no more than once every three years (for cities of federal significance — no more than once every two years) and no less than once every five years — and also provides for pre-trial mechanisms for challenging results.

In 2025, significant novelties were adopted. Article 6 of Law No. 237-FZ [1] was supplemented by Federal Law No. 243-FZ of July 23, 2025 [3] with a provision on the mandatory use of the federal state geographic information system in cadastral valuation in the constituent entities of the Russian Federation (with the exception of cities of federal significance). These provisions come into force on January 1, 2026. Federal Law No. 513-FZ of December 28, 2025 [4] introduced state monitoring of cadastral valuation and adjusted the rules for applying cadastral value data.

The methodological level of regulation is determined by Order of Rosreestr No. P/0336 of August 4, 2021 [2], which approved the Methodological Guidelines on State Cadastral Valuation. The current version was introduced by Order of Rosreestr No. P/0327/25 of September 15, 2025 [5], which adjusted the procedure for applying mass appraisal methods. Certain provisions come into force on January 1, 2026.

According to paragraph 3 of the Methodological Guidelines, mass appraisal methods are used to determine cadastral value — the construction of unified models for groups of properties with similar characteristics. If their application is impossible, the valuation is performed individually [2].

Mass appraisal involves grouping properties and applying comparative, cost-based, and (or) income-based approaches. The main methods include: statistical (regression) modelling, the typical (reference) property method, and modelling based on the specific cadastral value indicator (SCVI).

Order of Rosreestr No. P/0327/25 of September 15, 2025 clarified the procedure for modelling based on SCVI, allowed the determination of a property's location through conditional territorial units, and supplemented the list of sources of information on pricing factors with data from the federal state geographic information system [5].

According to Part 2 of Article 14 of Federal Law No. 237-FZ [1], pricing factors are characteristics of a property that affect its value. For land plots, these include information on being within zones with special conditions of use, land category, permitted use type, and area.

The indicative list of factors for land plots is set out in Appendix No. 3 to the Methodological Guidelines and includes: general information (land category, use type, area, elongation coefficient); encumbrances (water protection zone, construction restriction zone, etc.); development parameters; and additional characteristics for agricultural use (land type, standard yield, soil granulometric composition) [2].

However, the list is open-ended — the specific set of factors is determined by the budgetary institution independently. The main limitations include: the absence of a closed list creates a risk of subjectivity in factor selection; insufficient consideration of local characteristics (environmental, natural-landscape, socio-economic); aggregation problem — models for enlarged groups of municipalities do not account for the specifics of individual settlements; weak integration of spatial data, despite the introduction of mandatory GIS use from 2026.

Local factors are understood as qualitative and quantitative characteristics of a plot's location that can be identified during territorial zoning and have a significant impact on its value. Unlike macroeconomic factors, they capture the specifics of a particular territory.

The scientific literature highlights ecological criteria, infrastructure provision, landscape aesthetics, and transport accessibility. For IHC plots, particular importance is attached to prestige of location, social homogeneity, safety, and proximity to natural objects.

A classification is proposed: natural-landscape; ecological; transport accessibility and engineering infrastructure; socio-economic; and specific factors of northern territories.

The terrain determines the complexity of planning, site preparation costs, and drainage organization. Plots with level terrain have a higher unit price [6].

According to the Methodological Guidelines, when assessing agricultural land, soil fertility and the influence of natural factors should be considered [2]. Soil and ground quality determine the need for foundation reinforcement and drainage works. With increasing erosion, salinization, and alkalization, the cadastral value can decrease by more than 90 % [7].

Proximity to water bodies has a dual effect: aesthetic appeal increases value, but water protection zones impose use restrictions.

Ecological factors are capitalized in market and cadastral value. As the distance from the pollution source increases, the cadastral value rises: the monetary change ranges from 6,448 to 9,212 rubles [7]. Air pollution can reduce value by 5–10 % [8].

Noise pollution, especially near highways and airports, negatively affects the attractiveness of an area. Proximity to industrial zones and waste disposal sites reduces value, while the presence of recreational zones (parks, squares) positively affects it [9].

Proximity to roads and public transport stops positively affects value. According to the Methodological Guidelines, a plot is considered provided with access roads if a road approaches any of its boundaries, allowing entry [2]. Ignoring individual indicators of transport accessibility is recognized as a significant deficiency [10].

The main factors affecting cadastral value are the level of socio-economic development of the territory, location, and engineering amenities. For IHC lands, prestige of location, social homogeneity, and safety are significant. Proximity to schools, kindergartens, medical facilities determines the quality of daily life [11].

The presence of permafrost, soil types, and seasonal thawing depth determine construction



Kurakova Oksana Anatolyevna,
Candidate of Economic Sciences, Associate Professor at the Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; ID RSCI: 9622-8481, Scopus AuthorID: 57192659689, WoS ResearcherID: 0000-0001-7512-8576; kurakovaoa@mgsu.ru



Kulakov Kirill Yurievich,
Doctor of Economic Sciences, Professor at the Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; SPIN-code: 9158-4154, AuthorID: 360164, ScopusID: 57130861000, WoS ResearcherID: AFG-8212-2022, ORCID: 0000-0003-2081-7045; kkulakov@bk.ru

technology (pile foundations, ground thermal stabilization) and operational costs. In agroclimatic subzones of Siberia with continuous permafrost, the median cadastral value of permafrost-taiga soils is 0.4 rubles/m², and of lowland bog soils — 0.5 rubles/m² [7]. The sum of active temperatures (Δt > 10 °C) in such territories does not exceed 1,300 °C. Northern territories are also characterized by the absence of year-round roads, seasonal transport accessibility (winter roads, river transport), and high costs of "northern delivery" of materials [8].

The current Indicative List (Appendix No. 3 [2]) includes four groups of factors, oriented primarily toward formal accounting characteristics. The proposed system supplements them with natural-landscape, ecological, socio-economic, and northern factors. The difference is the systematic consideration of the spatial nature of factors, which requires the use of GIS technologies [12].

The need for expansion is due to the fact that the current list does not cover a number of characteristics affecting market value. Ignoring significant factors leads to overestimation or underestimation of cadastral value [13]. For IHC lands, the ecological situation, prestige of the district, safety, and developed social infrastructure are of particular importance. For northern territories, natural-climatic conditions radically affect construction and operational costs, but are practically not taken into account in the existing methodology.

In the United States, valuation is decentralized and carried out at the county level using mass appraisal methods (mass appraisal) and hedonic modelling. Socio-economic characteristics are considered: income levels, education, crime rates, quality of school districts, and environmental conditions. Computer-assisted mass appraisal systems (CAMA) are actively used [13].

In Germany, the basis is standard land values (Bodenrichtwerte) determined for valuation zones. Factors such as state of development, soil quality, and plot shape are considered. In Great Britain, valuation for tax purposes (Council Tax) takes into account "locality" — a territory characterized not only by housing stock but also by associated infrastructure and amenities. In Sweden, location-based factors derived from value areas are used. In the Netherlands, the WOZ valuation is based on property characteristics and sales data in the same area [14].

In Finland, when classifying agricultural land for taxation, the influence of climate on productivity is considered: in the northern zone, productivity is only one-fifth of that in the southwest. In Norway, slope, plot size, and weather conditions are taken into account [14]. Canada integrates climate risks into property valuation. For northern territories, the consideration of permafrost and its degradation, seasonality of transport accessibility, and heating costs is critical [15].

The Chinese system is based on state ownership of land. Prices are determined through public auctions for land use rights. Local governments set starting prices based on a periodically published state land price list, updated every three years [14].

Foreign experience confirms that accounting for local factors is standard practice. Particularly indicative is the experience of Canada and the Scandinavian countries, where natural-climatic conditions similar to those in Russian northern territories are taken into account as mandatory pricing factors.

It is proposed to supplement Appendix No. 3 to the Methodological Guidelines [2] with the following groups of factors: natural-landscape (relief, soil types, freezing depth, proximity to water bodies); ecological (pollution, noise, proximity to industrial zones and waste storage, presence of recreational zones); socio-economic (prestige, safety, infrastructure); northern (permafrost, climatic severity, seasonal accessibility).

To account for local factors, a system of adjustment coefficients is proposed. The cadastral value of an IHC land plot is determined by the formula:

$$CV = A \cdot \text{UPKS} \cdot K_{ecol} \cdot K_{trans} \cdot K_{infr} \cdot K_{prest} \cdot K_{north},$$

where A — plot area;

UPKS — basic specific cadastral value indicator;

K_{ecol} — ecological comfort coefficient (0.7–1.3);

K_{trans} — transport accessibility coefficient (0.8–1.2);

K_{infr} — infrastructure provision coefficient (0.8–1.2);

K_{prest} — territory prestige coefficient (0.7–1.5);

K_{north} — integral northern coefficient (0.1–0.7), accounting for permafrost, soil types, climatic severity, and logistics costs [8].

Hedonic models of cadastral value are built using the least squares method. It is proposed to include an expanded set of local factors in these models using spatial analysis. Starting from January 1, 2026, valuation will be carried out using unified software based on the Federal State Information System "Unified Digital Platform 'National System of Spatial Data", which allows integrating data on local factors directly into the modelling process [3].

For northern territories, it is proposed to develop separate mass appraisal models that take into account engineering-geological conditions, climatic constraints, and transport accessibility. The values of K north are determined based on zoning according to the severity of conditions using GIS data.

The introduction of local factors will require expanding data sources (ecological and geocryological maps), increasing the role of GIS specialists, and automating processes. This will reduce the gap between cadastral and market values, ensure fair differentiation of taxation, and account for regional specifics.

The cadastral value of an IHC land plot with local factors is determined by the formula:

$$CV = A \cdot \text{UPKS} \cdot K_{ecol} \cdot K_{trans} \cdot K_{infr} \cdot K_{prest} \cdot K_{north},$$

for K_{north}, an integral indicator is used:

K_{perm} (soil type/permafrost, 0.3–1.0) · K_{clim} (climatic severity, 0.5–1.0) · K_{acc} (transport accessibility, 0.4–1.0).

Consider a plot of 1,000 m² in a northern settlement with permafrost, located 200 km from the regional center. The base SCVI set for this group of municipalities is 500 rubles/m².

Calculation without local factors:

$$CV = 1{,}000 \cdot 500 = 500{,}000 \text{ rubles}.$$

Calculation with local factors:

K_{ecol} = 0.9 (moderate pollution);

K_{trans} = 0.8 (no year-round road);

K_{infr} = 0.85 (no central water supply and sewerage);

K_{prest} = 0.8 (non-prestigious area);

K_{north} = 0.4 (permafrost, harsh climate, high cost of material delivery).

$$CV = 1{,}000 \cdot 500 \cdot 0.9 \cdot 0.8 \cdot 0.85 \cdot 0.8 \cdot 0.4 = 97{,}920 \text{ rubles}.$$

Thus, accounting for local factors allowed adjusting the cadastral value from 500,000 to 97,920 rubles, which significantly brings it closer to the real market price of the plot under these conditions.

CONCLUSION

The conducted research allows us to formulate the following main conclusions.

The current methodology for cadastral valuation of IHC land plots, based on the Indicative List of pricing factors (Appendix No. 3 [2]), does not fully account for the local characteristics of the territory. The open-ended nature of the list and the absence of mandatory requirements for including natural-landscape, environmental, and socio-economic factors create risks of a subjective approach.

The local factors that significantly affect value include: natural-landscape (relief, soil types, freezing depth, proximity to water bodies); environmental (pollution, noise, proximity to industrial zones, recreational zones); transport and infrastructure; socio-economic (prestige, safety, infrastructure). For northern territories, engineering-geological conditions, climatic constraints, and logistics costs are critical.

Foreign experience — particularly the practice of Canada and Scandinavian countries, where climatic and geographical factors are considered mandatory pricing factors — confirms the need to adapt a similar approach in Russia.

A calculation model with a system of adjustment coefficients (K_{ecol}, K_{trans}, K_{infr}, K_{prest}, K_{north}) is proposed. Testing on a hypothetical example confirmed its practical applicability.

The practical significance of the study lies in the possibility of using the proposed recommendations in improving the Methodological Guidelines [2]. Further research should be directed toward developing methodological recommendations for determining coefficient values for various types of territories and creating geospatial data layers with permafrost, climatic, and ecological maps for automated accounting of local factors in cadastral valuation.

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Совершенствование методики определения кадастровой стоимости земельных участков индивидуальной жилой застройки с учетом локальных факторов территории

В статье рассмотрены вопросы совершенствования методики государственной кадастровой оценки земельных участков, предназначенных для индивидуальной жилой застройки (ИЖС). Актуальность темы обусловлена сохраняющимся дисбалансом между кадастровой и рыночной стоимостью таких объектов, что особенно характерно для территорий со сложными природно-климатическими условиями, включая арктические и приравненные к ним регионы. Проведен анализ действующей нормативно-правовой базы: Федерального закона от 3 июля 2016 г. № 237-ФЗ и Методических указаний, утвержденных Приказом Росреестра от 04.08.2021 № П/0336 (в редакции от 15.09.2025). Установлено, что примерный перечень ценообразующих факторов (Приложение № 3 к Методическим указаниям) не содержит обязательных требований по учету природно-ландшафтных, экологических и социально-экономических характеристик территорий, что создает предпосылки для субъективного подхода при отборе факторов и ведет к экономически необоснованным результатам. Также рассмотрены изменения, внесенные Федеральными законами от 23 июля 2025 г. № 243-ФЗ и от

28 декабря 2025 г. № 513-ФЗ. Систематизированы локальные факторы, влияющие на стоимость земельных участков ИЖС: рельеф, типы грунтов, глубина промерзания, уровень загрязнения, шумовое воздействие, близость к рекреационным зонам, престижность района, развитость инфраструктуры, а для северных территорий — наличие многолетней мерзлоты, климатическая суровость и сезонная транспортная доступность. Обобщен зарубежный опыт учета подобных факторов в США, странах Европы, Канаде и Скандинавии. Предложена модель расчета кадастровой стоимости с системой корректирующих коэффициентов, апробированная на условном примере участка в северном поселении. Результаты исследования могут быть использованы при совершенствовании методического обеспечения государственной кадастровой оценки.

Ключевые слова: *кадастровая стоимость, земельные участки под индивидуальное жилищное строительство, массовая оценка, местные факторы, факторы ценообразования, северные территории, вечная мерзлота, коэффициенты дифференциации*

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Об авторах: **Захарова Юлия Владимировна** — магистрант кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; zzakh4rowa@yandex.ru;

Ситекова Амина Аскербиевна — магистрант кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; sitekova_amina@mail.ru;

Куракова Оксана Анатольевна — кандидат экономических наук, доцент кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; РИНЦ ID: 9622-8481, Scopus AuthorID: 57192659689, WoS ResearcherID: 0000-0001-7512-8576; kurakovaoa@mgsu.ru;

Кулаков Кирилл Юрьевич — доктор экономических наук, профессор кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; SPIN-код: 9158-4154, AuthorID: 360164, ScopusID: 57130861000, WoS ResearcherID: AFG-8212-2022, ORCID: 0000-0003-2081-7045; kkulakov@bk.ru.

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Romanenko M.I.
Boldyrev E.S.

Development of the housing market amid challenging economic conditions in real estate development

The state of the real estate market is one of the indicators of the level of socio-economic development of territories. The market's ability to respond flexibly to global changes ensures the reliability and resilience of its indicators in the face of challenges and threats. Four major periods in the country's history represented turning points for the real estate market, significantly affecting its rate of development and, consequently, its legal and regulatory framework. This article analyses the effects of the financial and economic crises of 1998, 2008–2010, 2014–2015, and 2022 on the real estate market. The distinctive features of market functioning during each period are examined, and the causal relationships between them are identified. Particular attention is given to 2014 and 2022: their effects are compared, development patterns are identified, and the effectiveness of government support measures is assessed. The study also considers the sanctions imposed in 2022, which increased economic pressure on the Russian market, resulted in the suspension of numerous construction projects, and increased the number of unfinished developments. Recent developments in the real estate and mortgage markets are also examined. More restrictive conditions for purchasing apartments have driven up residential rents and increased rental yields. Based on the results obtained, market support measures are proposed that could facilitate its recovery. An analysis of the economic outlook makes it possible to formulate short and medium-term development strategies and identify effective ways of restoring depressed market segments. The paper emphasizes the importance of government support and stabilization measures amid continuing crises and high uncertainty.
Keywords: *economic crises, real estate market, investment, demand, supply, mortgage loans*



Romanenko Maria Igorevna,
Associate Professor, Candidate of Economic Sciences, Associate Professor of the Department of Economics, Organization and Management of Production; Penza State University of Architecture and Construction; 28 German Titov St., Penza, 440028, Russian Federation; AuthorID: 757101, Scopus AuthorID: 57214679876, WoS ResearcherID: AAZ-9685-2021, ORCID: 0000-0003-3243-9205, SPIN-code: 6563-8022; romanenko.masha@yandex.ru



Boldyrev Egor Sergeevich,
Master's student, Group 24ST1m, Department of Building Structures; Penza State University of Architecture and Construction; 28 German Titov St., Penza, 440028, Russian Federation; ORCID: 0009-0000-7562-5636; egr-b@yandex.ru

Economic crises significantly impact the real estate market, causing property price fluctuations, changes in supply and demand dynamics, and investment and construction challenges. Key crisis indicators include production decline, financial shortages, business failures, disrupted business ties, rising unemployment, and decreased economic performance, living standards, and well-being [1, 2].

To develop anti-crisis measures, predict economic trends, ensure guarantees for market participants (developers, investors, buyers), and minimize negative consequences, it is crucial to study the interconnection between financial and economic phenomena and their impact on the real estate market.

The main causes of the 1998 crisis included the collapse of the short-term government bond market, which led to financial collapse and the inability to service external debt. The decline in global oil prices reduced budget revenues and exacerbated the country's economic situation. The crisis manifestations in the real estate market were multifaceted. The main phases of the August crisis are presented in Table 1.

This period was characterized by a significant stratification of cities in terms of housing prices, indicating a growing gap in effective demand between different population centres. The average property cost in cities with dollar-denominated prices (excluding Moscow) decreased by 19 %, in cities with ruble-denominated prices by 56 %, and across the entire group of cities, including Moscow — by 21 %.

The primary impact was felt by the secondary housing market, as there were few new buildings, and project financing and mortgages were virtually non-existent. As a result of government stabilization measures, including the adoption of laws and the development of mortgage lending, the market was able to stabilize, and price declines stopped as

Table 1. The main phases of the 1998 August crisis in the Russian real estate market

Crisis phase	Period	Events, characteristic features	Main changes in the real estate market
False start	End of August	Ruble devaluation, expectations of rising housing prices, short-lived rush demand	In major cities, dollar prices increased by 5–10 %; in other cities, prices stabilized or increased
Stagnation	Early September	Ruble devaluation, depreciation of housing certificates	Sales on the primary market came to a standstill; the number of transactions decreased by 40–60 % in major cities
Recovery from Shock	End of September	Decline in dollar prices, discount sales of luxury housing	The number of transactions began to increase, but did not reach pre-crisis levels. Price growth in cities with ruble-denominated prices
Depressive Stabilization	October – November	Final segmentation of markets into ruble-denominated and dollar-denominated segments	In cities with dollar-denominated prices, the decline in prices continued; in ruble-denominated cities, prices rose and the volume of transactions increased

early as 1999. From 2002, there was a noticeable increase in housing prices, both in dollar and ruble terms. The market fully recovered only in 2002.

The decline of the global economy, which began in 2008 with the crisis in the USA mortgage and stock markets, subsequently led to a decrease in liquidity in several countries and a fall in oil prices [3]. The primary real estate market, which had been actively developing thanks to large-scale development projects and the attraction of loans from foreign banks, found itself in a difficult situation.

The sharp reduction in the availability of credit forced many construction companies to freeze projects and even declare bankruptcy. This resulted in a decrease in housing commissioning volumes, from 64.1 million square meters in 2008 to 59.8 million square meters in 2009.

The decline in prices in the secondary real estate market was also significant. In Moscow, the number of transactions in 2008 fell from 6–7 thousand per month to 2–2.5 thousand. This was caused by a decrease in the purchasing power of the population and general economic instability. The fall in oil prices, which is a key source of income for the Russian economy, exacerbated the crisis, leading to a reduction in budget revenues and investment in various sectors, including construction.

The pace of investment in construction slowed down. In the first quarter of 2008, it reached 28.9 %, in the second quarter it fell to 18.2 %, in the third — to 9.5 %, and in November it grew by only 6.3 % compared to November of the previous year. This slowdown was caused by rising unemployment and declining household incomes, which negatively affected the solvency of buyers. In the primary market, new classifications of real estate emerged, based on price levels, the average area of lots, and quality characteristics.

The Russian government took a number of measures to restore the market. Programmes were launched to support mortgage borrowers and construction companies, and the Central Bank reduced rates, providing banks with additional liquidity. From January 1, 2009, the corporate income tax rate was reduced from 24 % to 20 %, which helped to reduce the tax burden on enterprises and preserve some jobs [4].

The Central Bank of Russia issued a subordinated unsecured loan to Sberbank in the amount of at least 500 billion rubles, which could be repaid within 10 years. These measures, aimed at supporting the economy during the crisis, along with the use of state financial reserves and the improvement of conditions in external markets, contributed to positive changes in the Russian economy.

The market recovery took several years, but the measures taken allowed for the preservation of jobs and support for the construction industry.

The currency crisis of 2014–2015, triggered by sanctions and the devaluation of the ruble, had a significant impact on the real estate market in Russia. One of the main problems was the speculative (panic) demand: people began to massively purchase real estate in order to preserve their savings from depreciation, which temporarily drove up its value. Subsequently, this led to a decrease in the number of sales and a decline in price levels. In addition, sanctions and the fall of the ruble led to a significant reduction in the purchasing power of Russians, which negatively affected demand for real estate [5, 6].

The foreign currency mortgage segment suffered particularly severely: by the end of 2015, the exchange rate of the US dollar reached approximately 70 rubles, which doubled mortgage repayments while borrowers' salaries remained unchanged. The mortgage market also experienced significant growth. According to the Bank of Russia, more than 1 million mortgage loans were issued for a total amount of 1.76 trillion rubles, which significantly exceeded the 2013 level. The share of mortgage loans in the total volume of lending to individuals rose to 20.4 %.

However, at the end of 2014, interest rates on mortgage loans rose sharply, reaching 13.16 %, which mirrored the level seen at the end of 2010. The average mortgage rate in 2014 stood at 12.65 %.

Despite this, the quality of the mortgage portfolio continued to remain at a high level, although the percentage of mortgage loans with overdue payments exceeding 90 days rose to 2.1 %.

To combat the consequences of the crisis, the Government implemented several important measures. At the first stage, insurance policies for apartments during the construction period were introduced, but this mechanism failed to prove effective due to manipulations by developers. Therefore, under Federal Law No. 214-FZ[1], the escrow account mechanism was introduced. This allowed protecting the funds of equity participants until the completion of construction, significantly reducing risks and increasing confidence in new buildings.

In early 2015, demand for real estate plummeted sharply, as available funds had already been invested, and high mortgage interest rates (16–21 %) made loans unattractive. Prices reached their lowest point at the end of 2015 and the beginning of 2016. To stimulate demand, the Government launched a state-supported mortgage programme. From March 2015 to March 2016, this programme provided loans for the purchase of housing in new buildings at a rate not exceeding 12 % which contributed to positive sales dynamics and price stabilization in the real estate market.

Despite the crisis, developers sought not only to erect buildings but also to improve the quality of residential areas, including the construction of kindergartens, schools, and outpatient clinics. This enhanced the attractiveness of real estate and the quality of life for buyers.

The global economic crisis of 2022 was triggered by the expansion and tightening of Western sanctions, which led to a depreciation of the ruble and an acceleration of inflation. This compelled the Central Bank of Russia to sharply raise the key interest rate. The departure of many suppliers and related businesses from the Russian market exacerbated the situation, intensifying economic instability and reducing the availability of goods and services [7].

Firstly, the suspension of construction materials supplies led to a price increase of more than 20 %, which raised the cost of construction and, consequently, housing.

Secondly, wealthy Russians began to view luxury apartments as a means of capital preservation, which resulted in a surge in demand for expensive new buildings and high-quality secondary housing in central Moscow.

Sanctions also complicated the sale of commercial real estate to foreign investors, negatively impacting the market. As a result, the investment attractiveness of a quarter of Russia's regions declined, altering the structure of supply and demand in the residential segment [8, 9].

Despite the economic crisis, in 2022, there was a 36 % increase in real estate transactions across the country compared to the previous year, reaching a level of 494 billion rubles. This trend was linked to the strengthening of state support and the exit of international companies. However, the number of foreign investors remains negligible, which also affects the market structure [10, 11].

[1] On Participation in Shared Construction of Apartment Buildings and Other Real Estate Objects and on Amendments to Certain Legislative Acts of the Russian Federation : Federal Law, dated December 30, 2004, No. 214-FZ (latest revision).

In 2022, changes in the key rate of the Central Bank of Russia had a significant impact on the real estate market. Initially (on February 28), the rate was raised to 20 %, making mortgage loans less accessible. This led to a sharp decline in housing demand, particularly for new apartments, and a drop in prices. The tightening of lending conditions was accompanied by an increase in the down payment requirement and a reduction in the number of mortgage applications at major banks.

The rate hike also affected the cost of project financing, making construction more expensive and consequently raising housing prices. Developers and financial institutions sought solutions by introducing preferential mortgage programmes, but high interest rates continued to limit the number of transactions [12, 13].

On April 11, the rate was reduced to 17 %, which slightly revitalized the market, but the level remained sufficiently high to restrain demand. The reduction to 14 % on May 4 improved the conditions for mortgage lending, contributing to increased interest and price stabilization. A further decrease to 11 % on May 27 boosted interest in housing and triggered a slight price increase.

The reduction to 9.5 % on June 10 notably improved mortgage affordability, contributing to a further price rise. The decrease to 8 % on July 22 led to a noticeable increase in interest, and the final reduction to 7.5 % on September 16 supported the market by improving lending conditions and housing demand. These changes in rates played a key role in stabilizing the real estate market amid economic difficulties and sanctions, gradually increasing credit accessibility and supporting price stability [14, 15].

An analysis of the real estate market's reaction to the 2022 events reveals similarities with the 2014 crisis [16, 17]. A comparative characteristic of the impact of the 2014 and 2022 crises on the real estate market is presented in Table 2.

In 2023–2024, sanctions continued to impact the real estate market in Russia. In Moscow and St. Petersburg, the cost of premium housing increased by 15–20 % in 2023 due to limited supply and the interest of wealthy citizens. The volume of commercial transactions decreased by 30 % due to the departure of foreign companies and a decline in business activity.

In 2024, the real estate market in Russia is facing serious difficulties. High apartment prices and expensive mortgages with rates exceeding 20 % have led to a decline in demand. Property owners prefer to rent out their housing rather than sell it. Purchasing new housing also remains problematic. In October, prices for new buildings in most major Russian cities rose, with the cost per square meter increasing by 0.7 %, reaching 138.4 thousand rubles. Housing rental has become the only accessible option for those who do not own property, although rent also increased in the second half of 2024: the average rental price in Moscow amounted to 111 thousand rubles per month; in St. Petersburg — 56 thousand rubles; in other cities — 43 thousand rubles[2].

High mortgage rates, economic instability, and limited supply of new buildings are intensifying the pressure on the real estate sector. These factors create difficulties for both buyers and tenants.

One of the key measures to counter the crisis was the cancellation of mass preferential mortgages, which was intended to reduce demand and cool down the market. The conditions of the "Family Mortgage" programme were revised: the 6 % rate now applies to families with children where there is at least one child under six years old, a child with a disability, or two minor children. The parameters of the IT mortgage were also adjusted: the rate was increased from 5 to 6 %; the maximum loan amount was set at 9 million rubles, excluding IT specialists in Moscow and St. Petersburg. To stimulate private housing construction, the escrow account mechanism was extended, and a pilot programme of credit subsidies at a rate of up to 1 % was introduced.

However, the situation worsened with the cancellation of the "Family Mortgage" programme at 6 % per annum and the preferential mortgage at 8 % per annum starting from the third quarter of 2024. Due to high demand for these programmes, financing was exhausted, and banks temporarily suspended the issuance of preferential mortgage loans. Under conditions of reduced subsidized programmes and rising market mortgage rates up to 20 %, people have few options left for financing home purchases.

Thus, the impact of the economic crisis on the real estate market in Russia in 2022–2024 was heterogeneous. In 2022, prices for liquid apartments and the premium segment rose, but by the end of the year, a decline in prices for secondary housing and new buildings began. In 2023, economic instability caused an increase in prices for luxury housing and a decrease in the volume of commercial transactions. In 2024, the high level of mortgage rates and economic instability reduced demand and prices for new buildings [18].

The cancellation of preferential mortgage programmes exacerbated the situation, as banks suspended the issuance of preferential loans. The increase in the key rate of the Central Bank of the Russian Federation will reduce demand in the primary and

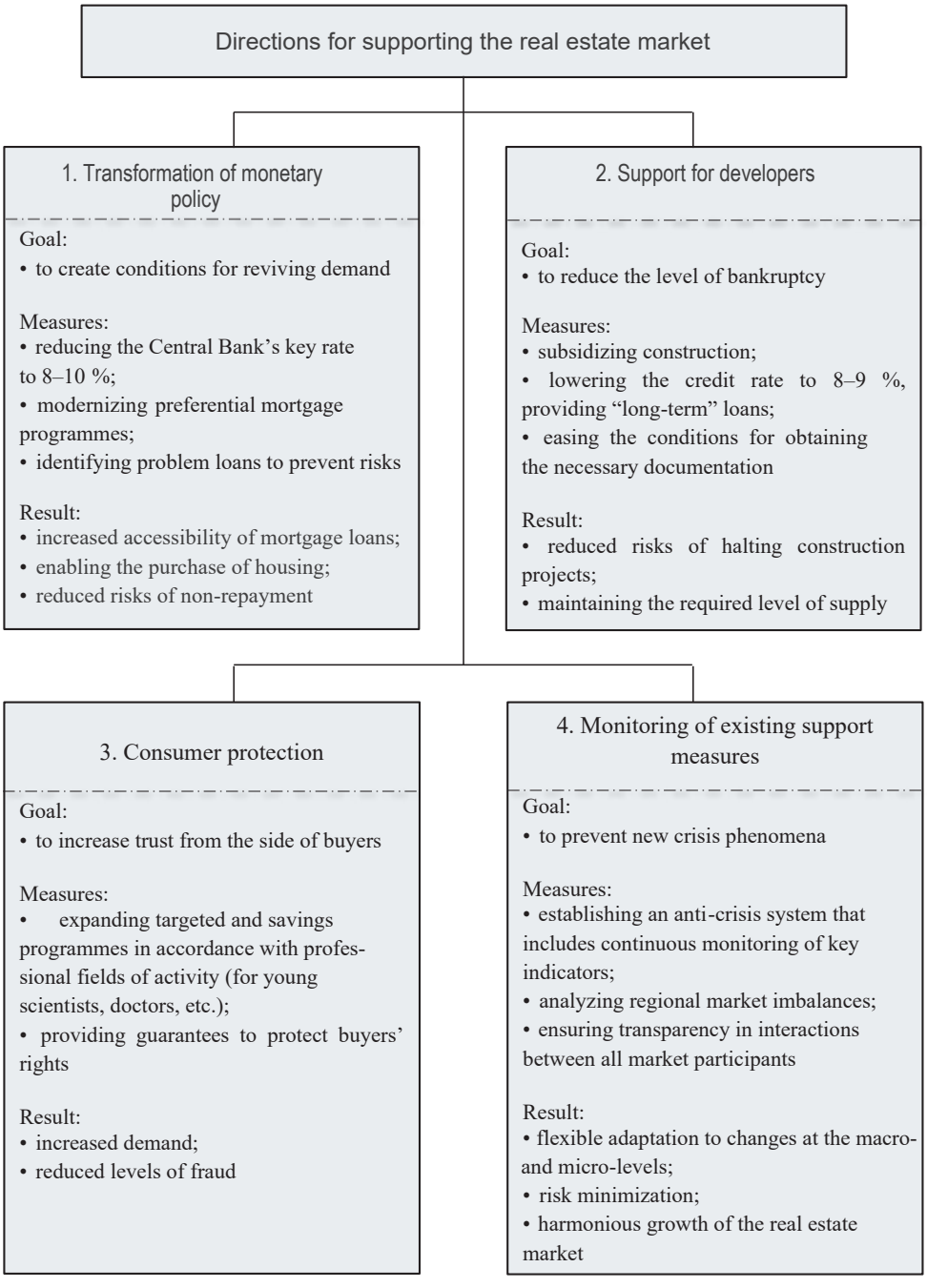
[2] Housing Rental Market Review for Q3 2024. October 31, 2024. URL: https://dom.rf/analytics/rental-housing-report/516776/ (rus.).

Table 2. Comparative Characteristic of the Impact of the Crises of 2014 and 2022 on the Real Estate Market

Parameter	2014 Crisis	2022 Crisis
Causes of the Crisis	Global economic recession, foreign policy decisions, decline in oil prices	Market overheating, start of the special military operation, partial mobilization, sanctions
Exchange Rate (Ruble)	Sharp weakening against foreign currencies	Sharp weakening against foreign currencies
Central Bank Key Rate	Increase from 9.5 to 17 % p.a.	Increase from 9.5 to 20 % p.a.
Demand for Housing	Panic buying, rise in housing prices	Decline in demand and prices
Mortgage Loans	Reduced mortgage affordability, drop in the volume of issued loans	Reduced mortgage affordability, shift in demand towards secondary housing
Housing Prices	Increase in new construction costs, decline in ruble prices amid falling living standards	Decline in housing prices, discounts up to 30 %
Construction Rates	Decline in construction rates	Excess supply, decline in sales rates
Market Reaction	Reduction in demand, decrease in construction rates	Decline in demand, excess supply, price reduction
Debt Burden of Developers	480–500 billion rubles	Over 3 trillion rubles

Table 3. Impact of Financial and Economic Crises on the Real Estate Market of the Russian Federation

Year	Crisis	Causes	Impact on the Real Estate Market	Government Measures
1998	Economic crisis in Russia	Financial instability, cessation of lending by foreign banks	A 30 % decline in real estate prices in dollar terms, suspension of development projects	Absence of state support
2008–2010	Financial and economic crisis in Russia	Global financial crisis, decline in demand	Reduction in construction volumes, project freezes, drop in secondary housing prices	Anti-crisis measures: support for systemically important enterprises, subsidies for improving housing conditions
2014–2015	Currency crisis in Russia	Decline in oil prices, sanctions against Russia, weak ruble	Drop in real estate prices, reduction in the number of rooms in new apartments	Preferential mortgage programmes, support for the construction sector
2022	Economic crisis in Russia	Sanctions, increase in the key rate to 20 %	Decline in demand and prices for housing, rise in construction costs	Reduction of the key rate, subsidization of mortgage rates, extension of the "Family Mortgage" programme until 2030



Directions for supporting the real estate market

secondary markets, especially in the mass segment. Developers will be forced to reduce costs and simplify layouts. The rise in mortgage rates made loans difficult to access, which in turn reduced interest in purchasing housing. These factors, together with the cancellation of preferential mortgages and the growing requirements for the down payment, create difficulties in the real estate market, necessitating comprehensive measures of state support and adaptation by developers.

Based on the results of this study, a comparative analysis of the causes of global economic crises and their consequences for the real estate market of the Russian Federation was conducted, as well as measures to overcome these crises (Table 3).

Thus, each financial and economic crisis had a distinctive impact on the real estate market at different historical moments. In 1998, the crisis led to a significant drop in prices and suspension of projects. In 2008, the global financial crisis caused a reduction in construction volumes and a fall in secondary housing prices. In 2014, the currency crisis resulted in price drops and a decrease in the number of rooms in new apartments. In 2022–2024, sanctions and the high key rate led to a decline in housing demand, while the cancellation of preferential mortgage programmes exacerbated the situation, pushing mortgage rates up to 20 %.

Local trends and changes in preferential programmes have had an impact on the sector under consideration. In 2025–2026, the dynamics are mixed. There is an increase in prices for real estate purchases and rentals, with demand focused on studios and one-bedroom apartments. Analyzing the structure of transactions, secondary housing sales without mortgages have become the leaders.

In order to stabilize the market, it is necessary to implement additional measures of state support for buyers and developers, taking into account the mistakes made during previous crisis periods. This includes the implementation of proposed directions for market stimulation, which encompass: new state programmes; reduction of interest rates; development of alternative mechanisms for purchasing housing (Fig.).

Thus, the proposed recommendations are aimed at taking into account the mistakes of past crisis periods and establishing a reliable, stable mechanism for the development of the real estate market. This mechanism is designed to achieve a balance between supply and demand, increase the level of investment attractiveness, ensure comprehensive territorial development, and reduce the pressure on the industry.

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Развитие рынка жилья в сложных экономических условиях возведения объектов недвижимости

Состояние рынка недвижимости является одним из индикаторов уровня социально-экономического развития территорий. Гибкое реагирование на глобальные изменения характеризует его параметры надежными и устойчивыми к вызовам и угрозам. В истории страны зафиксировано четыре основных периода, которые стали переломными для рынка недвижимости и внесли существенные изменения в его темпы развития и, как следствие, нормативно-правовое регулирование. В статье проведен анализ влияния финансово-экономических кризисов 1998 г., 2008–2010 гг., 2014–2015 гг., 2022 г. на состояние рынка недвижимости. Раскрыты особенности его функционирования в каждом из периодов и установлены причинно-следственные связи между ними. В исследовании особое значение уделяется 2014 и 2022 гг., для них составлена сравнительная характеристика, выявлены

закономерности развития и проанализирована эффективность предпринятых мер поддержки со стороны государства. Внимание уделено санкциям 2022 г., которые усилили экономическое давление на российский рынок, привели к замораживанию многих строительных проектов и росту числа незавершенных объектов. Рассмотрены последние года, которые также ознаменованы важными событиями для рынка недвижимости и ипотеки. Ужесточение условий для приобретения квартир спровоцировало рост цен на аренду жилья и увеличило его доходность сдачи. Проведенная работа позволила разработать направления поддержки рынка, которые могут стать стимулом для его восстановления. Анализ экономических ожиданий позволяет сформировать вектор развития на краткосрочный и среднесрочный период, а также эффективные способы восстановления просевших сегментов. В статье подчеркивается важность государственной поддержки и разработки мер для стабилизации ситуации в условиях продолжающихся кризисов и высокой неопределенности.

Ключевые слова: *территориальное развитие, транзакционные издержки, эффективность логистики, пространственное развитие, управление земельными ресурсами, цифровизация кадастра, инвестиционный цикл*

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Об авторах: **Романенко Мария Игоревна** — доцент, кандидат экономических наук, доцент кафедры «Экономика, организация и управление производством»; **Пензенский государственный университет архитектуры и строительства**; 440028, г. Пенза, ул. Германа Титова, д. 28; AuthorID: 757101, Scopus AuthorID: 57214679876, WoS ResearcherID: AAZ-9685-2021, ORCID: 0000-0003-3243-9205, SPIN-код: 6563-8022; romanenko.masha@yandex.ru;

Болдырев Егор Сергеевич — магистрант группы кафедры «Строительные конструкции»; **Пензенский государственный университет архитектуры и строительства**; 440028, г. Пенза, ул. Германа Титова, д. 28; ORCID: 0009-0000-7562-5636; egr-b@yandex.ru.

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Borozdina S.M.
Koveshnikov V.V.

Supply and Demand Analysis by Stages of the Residential Real Estate Market Life Cycle

The Russian residential real estate market has undergone substantial volatility since 2022, driven by geopolitical shocks, restrictive monetary policy, and rapid growth in housing prices. These factors have reduced housing affordability and altered the structure of effective demand in the primary market.
Low-interest mortgage programmes introduced in 2020 supported demand for new housing but also contributed to price growth and widened the gap between the primary and secondary markets. As market-based mortgage rates increased, buyers became more sensitive to apartment size, finishing, parking availability, layout functionality, and total purchase cost.
This study examines how consumer demand changes across the stages of the residential real estate market cycle. Using Rosstat statistics, Bank of Russia and MOEX indicators, Yandex Wordstat data, and published marketing studies, the article segments demand by market phase and compares pre-crisis and post-crisis consumer preferences.
The results show that expansion and overproduction phases are associated with stronger demand for housing with enhanced consumer characteristics, including larger apartments, higher-class projects, finishing, and parking. During contraction and recovery phases, demand shifts toward smaller, more affordable, and more functional units, while mortgage conditions become a key determinant of purchasing decisions.
The proposed segmentation can help developers adjust product concepts to the current market phase, increase the perceived value of apartments, and improve sales rates. The findings also provide a basis for subsequent regression-based forecasting of demand for the next three to five years.
Keywords: *residential real estate, primary housing market, demand analysis, market cycles, Kitchin cycle, housing affordability, mortgage lending, developer competitiveness*



Borozdina Svetlana Mikhailovna,
Candidate of Economic Sciences, Associate Professor, Department of Economics and Management in Construction; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; ID RSCI: 654497, Scopus AuthorID: 57194450904, WoS ResearcherID: AAM-6451-2020, ORCID: 0000-0002-7198-4655, SPIN-code: 7176-5790; BorozdinaSM@mgsu.ru



Koveshnikov Vladislav Vladimirovich,
Postgraduate student, Department of Economics and Management in Construction; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; v.koveshn1kov@yandex.ru

INTRODUCTION

The development of the real estate sector is closely linked to macroeconomic conditions, demographic trends, labour-market dynamics, and capital-market processes. The strength of this relationship depends on the structure of a particular real estate market, the configuration of relationships among market participants, the transformation of market systems, and the factors that ultimately change market dynamics.

Industry-specific characteristics of any commodity market shape the relationships between sellers and consumers, the degree of state involvement, the mechanisms and instruments used, industry structure, producer concentration, and entry conditions. A key feature of the real estate market is its reliance on a continuous flow of income-generating capital, which fundamentally distinguishes it from traditional, consumable commodity markets. Real estate transactions involve financial relationships and a wide range of professional intermediaries and institutions, including lenders, brokers, appraisers, and public authorities. Capital invested in real estate may also support production processes. Consequently, a well-functioning real estate market contributes to the real sector of the economy. In residential real estate, market conditions directly affect household formation, quality of life, and the willingness of investors and households to save and invest. Real estate cycles are commonly explained by supply lags, durability of housing stock, demand shocks, and credit conditions [1].

MATERIALS AND METHODS

As for the primary housing market, the gradual decline in demand, caused in part by increases in the key rate of the Central Bank of the Russian Federation and by a reduction in purchasing power, creates new challenges for investors and developers. Against this background, improving project competitiveness becomes a key task for development companies.

The study first considers the characteristics of cyclical development of the real estate market, including the duration of stages and the processes occurring within them, as described by G.M. Sternik [2] (Table 1).

Sternik's classification of market phases is sufficiently detailed. However, its application is limited by the scale of analysis. Distinctions between development and active-growth stages are difficult to identify empirically for 5- to 10-year periods.

Therefore, this study uses J. Kitchin's short-term cycle framework, which distinguishes expansion, overproduction, contraction, and recovery phases (Fig. 1) [3].

The cyclical nature of the Russian real estate market was analyzed using data on housing stock flow, as shown in Fig. 2.[1]

The dynamics of housing development are shown in Fig. 2. The graph shows recession periods in 2008–2010, 2016–2019, and from 2023 onward, as well as recovery periods in 2010–2015 and

[1] Federal state Statistics Service (ROSSTAT) : Official Website. URL: ttps://rosstat.gov.ru (accessed: 25.06.2026).

Table 1. Characteristics of cyclical development of the real estate market

Stage	Description
Accumulation	In the long term, real estate prices and household incomes are steadily rising, but the growth rate of real estate prices does not exceed the growth rate of incomes
Development	In the long run, prices and incomes are rising, while the rate of price growth is higher than the rate of income growth
Intensive growth	There is an increase in prices and incomes; in the medium term, the rate of price growth exceeds the rate of income growth
Overheating	The market is growing significantly, so the rate of price growth is several times higher than the rate of income growth. There are high risks of aspeculative bubble forming and market failure over a short period of time
Stability	The market is entering a stabilization stage following the stage of rapid price growth. There are signs of proximity to a developed market; price and income growth rates are close to zero
The market bubble	The pace of real estate prices exceed that of revenues, which is close to zero. Excessive lending artificially provokes an increase in effective demand
Collapse	The growth rates of prices and incomes are negative, while real estate prices decrease faster than incomes in the medium term. Construction volumes and supply are decreasing in the market
Depression	In the long term, the planned slide of the market continues, real estate prices are sagging, revenues are not growing
A new start	Despite the low performance and falling real revenues, real estate prices are starting to rise, although at a slow pace
Rise	There are a sufficient number of solvent buyers on the market who generate demand and stimulate a sharp increase in prices to a level corresponding to well-developed segments of the real estate market

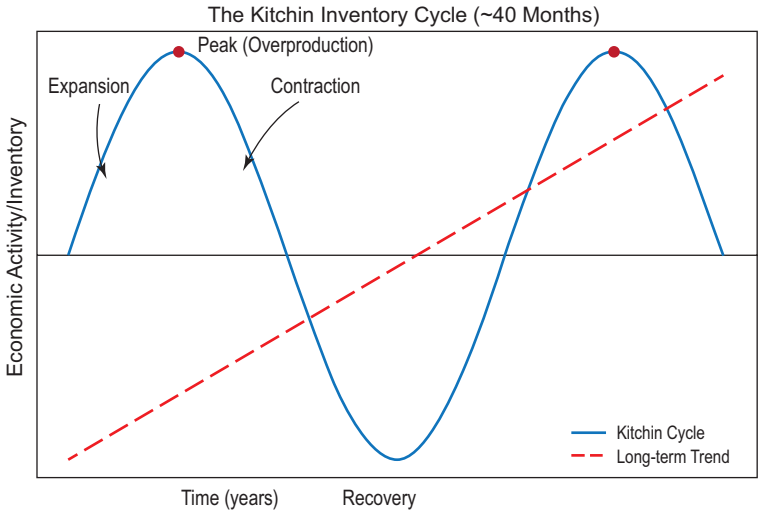


Fig. 1. Market cycles according to J. Kitchin

2015–2022. After the collapse of the Soviet Union, the construction industry faced low effective demand and underfinancing for developers. A temporary solution was to attract financing from purchasers. This approach offered benefits because square-meter prices were lower at early construction stages, but it also generated major risks for stakeholders. The strategy revived the market and contributed to a construction boom. However, it also helped form a large price bubble that burst in 2009 [1].

In recent years, state policy aimed at increasing housing affordability, particularly through low-interest mortgage programmes to accelerate the development of the housing industry. The mortgage rate of 6.5 % during the period when the key rate was 6 % increased demand for housing in apartment buildings and contributed to price growth. Hence, the programme designed to improve affordability ultimately reduced it. In Moscow, the ratio of the square-meter price in the primary market to average income decreased from 0.59 in the third quarter of 2021 to 0.48 in the third quarter of 2024, a decline of 22 %.

The low-interest mortgage programme also affected the price gap between the primary and secondary markets. According to the Central Bank of the Russian Federation, this gap began to widen in 2017 and continued to increase annually: it was 1 % in 2016 and reached 44 % by 2023.

At the same time, the introduction of escrow accounts in 2019 improved the security of mortgage and shared-construction transactions.

Using the Kitchin-cycle framework, the main features of an overheated primary real estate market can be identified as a decrease in the average number of rooms, a reduction in demand, and a shift toward functionality and economic efficiency. The high correlation between the secondary and primary markets suggests that the secondary market may enter a phase of stabilization followed by gradual decline.

The market currently has many participants, including sellers, buyers, and intermediaries. Their interests and needs are taken into account when development companies develop pricing policies.

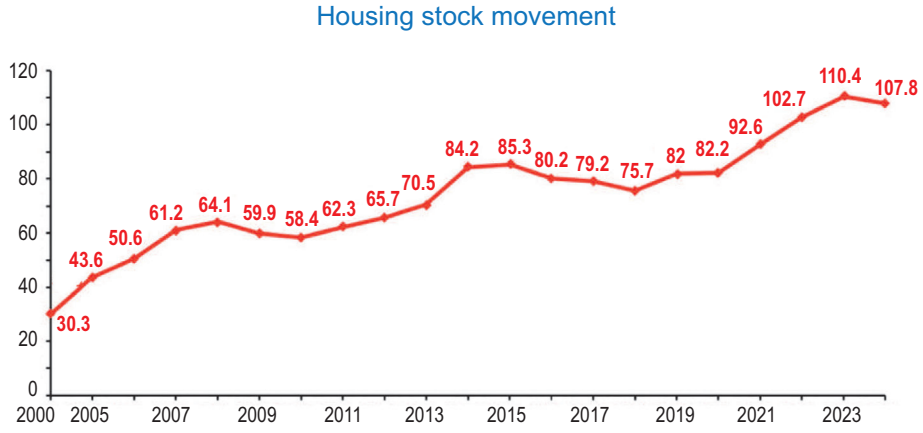


Fig. 2. Housing stock flow based on data from the Federal State Statistics Service (Rosstat)

Table 2. Distribution of market cycles in the primary real estate market by year

Cycle	Years			
Expansion	2000–2006	2010–2012	2018–2020	2023–2024
Overproduction	2006–2008	2012–2014	2020–2022	2025–2026
Contraction	2008–2009	2014–2015	2022	–
Recovery	2009–2010	2015–2018	2022–2023	–

An overheated primary market is characterized by a high concentration of sellers and higher competition among development companies. This competition may improve construction product quality, diversify marketing programmes, and encourage new tools to rise project profitability. However, such practices are not evenly distributed across local markets. In some markets, construction activity is monopolized, which reduces competition and investment attractiveness; these markets are often regulated by administrative and non-market mechanisms and remain cyclical [4].

During contraction, the primary market experiences a decline in supply and an increasing role of non-market regulatory mechanisms. Recovery is characterized by the entry of new players and growth in demand. At this stage, the market begins to develop features of monopolistic competition.

The data allow market cycles to be segmented by year and by stage of market development (Table 2).

The article analyzes the main directions and trends in the primary residential real estate market from the perspective of consumer demand. The data sources include Rosstat statistics, Yandex LLC data obtained through the Yandex Wordstat service, MOEX indicators, and published marketing studies for the period under review.

RESULTS

Rosstat data demonstrate clear patterns in the dynamics of demand for apartments of different sizes and room numbers (Fig. 3). Before each crisis, demand rose and so did the quality and area of purchased housing. For example, in 2008, three-room apartments accounted for approximately 28 % of all purchases; by the end of 2009, their share had fallen by four percent to 25 %. A similar increase in demand for two-room apartments was observed from 2013 to 2014.[2]

Further analysis of Fig. 3 shows a subsequent decline in demand for apartments with a larger number of rooms and a sharp increase in demand for one- and two-room apartments. The decline in purchasing power in the post-crisis period indicates a change in the vector of consumer demand.

[2] Yandex Wordstat : Online Service. URL: yandex.ru (accessed: 25.06.2026).

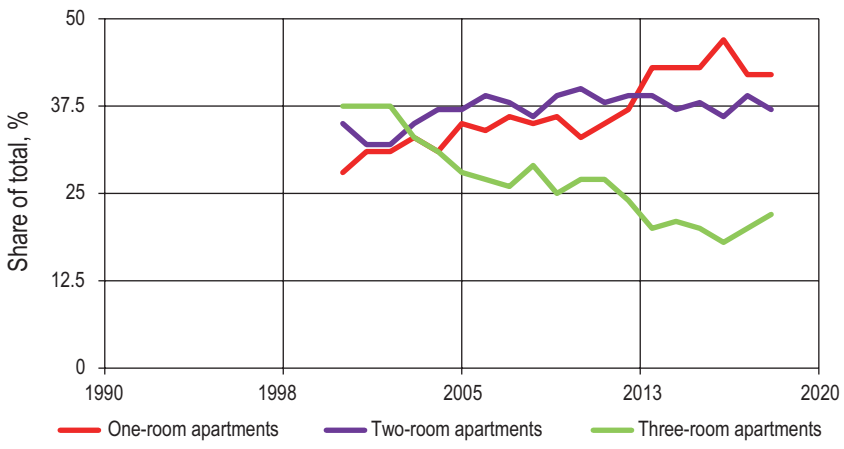


Fig. 3. Dynamics of apartment sales by the number of rooms, 2000–2018

Table 3. Housing-demand characteristics during and after the crises [5]

Before the 2008 crisis	*Before the 2014 crisis*
The growing popularity of luxury housing	Real estate investments
Finished apartments and finishes	Large apartments
Investing	Luxury housing
Increasing the housing area	Finished apartments with finishing
After the 2008 crisis	*After the 2014 crisis*
Caution in buying	Caution and conservatism
Simplification and minimalism	Simplified and affordable options
Higher requirements for functionality	Functional layouts
A variety of mortgage programs	Less interest in investments
Interest in new buildings in the suburbs	Popularity of new buildings outside the center
Predominance of ready-to-move-in facilities	–

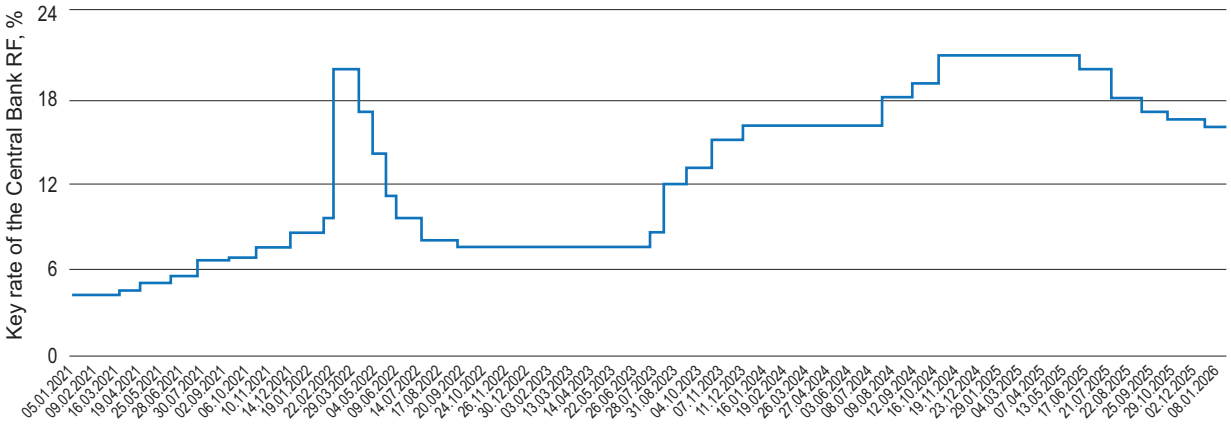


Fig. 4. Dynamics of the key rate of the Central Bank of the Russian Federation

Although marketing research data on changes in consumer demand are not fully accessible, the available sources are sufficient to compare pre-crisis and post-crisis demand characteristics (Table 3).

The pre-crisis state and the overproduction stage are characterized by demand for better consumer characteristics. An analysis of consumer demand made using Yandex Wordstat shows that demand for higher-quality apartments reduces as the economic situation deteriorates. For example, demand for apartments with parking and finishing increased after 2019, but began to decline after the key rate rise (Fig. 4).

In addition to GDP and housing commissioning values, the Moscow Real Estate DomClick Index (MOEX MREDC) was analyzed using the relative strength index (RSI), which helps assess the trend direction and strength (Fig. 5).

The previous peak of the index, 303,283.07 rubles per square meter, was recorded in July 2024 and surpassed in March 2025. The square-meter price in the Moscow primary housing market reached 309,858.43 rubles, the highest value in the observed period.

The MREDC index was analyzed using the RSI (relative strength index) developed by *W.* Wilder in 1978.

Positive (*U*) and negative (*D*) price changes are used to calculate RSI. A day is classified as upward if today's closing price is higher than the previous day's closing price:

$$U = close_{today} - close_{yesterday};$$
$$D = 0.$$

A day is classified as downward if today's closing price is lower than the previous day's closing price.

If today's and the previous day's closing prices are equal, then *U* and *D* are both equal to zero. The *U* and *D* values are then smoothed using a modified exponential moving average (EMA) with period *N*; relative strength (RS) is calculated first, and RSI is then derived from RS.

The RSI formula is presented below (Fig. 6) [6].

An RSI value above 72 points shows overbought market conditions, whereas a value below 30 points shows oversold conditions. Values in the range of 55–67 points indicate a relatively balanced market situation and a potentially favorable period for purchasing housing.

The price dynamics in the Moscow residential real estate market in the first quarter of 2026 conveys the continuing influence of state regulation of mortgage-subsidy programmes. As of 1 January 2026, government subsidies for low-interest mortgages were reduced by 0.5 percentage points.

Additional restrictions were introduced as of 1 February 2026, including a limit of one mortgage per family, a ban on donor mortgages, and mandatory involvement of spouses as co-borrowers.

The mortgage market in 2026 is expected to enter a transition period involving a redistribution of demand and supply. According to Sberbank estimates, the number of low-interest loans may decline by 20–25 %.

The reduction in low-interest lending programmes may be accompanied by a temporary price surge; however, in the long term, state regulation is expected to have a stabilizing effect on residential real estate values.



Fig. 5. MOEX MREDC (Moscow Real Estate DomClick Index) as of March 2025

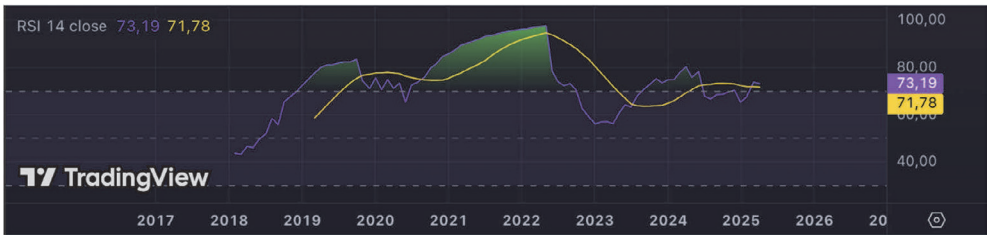


Fig. 6. RSI 14 for the MOEX MREDC index



Fig. 7. MOEX MREDC index as of January 2026

According to MOEX data, from March 2025 to January 2026 (Fig. 7), the average square-meter price in the Moscow real estate market increased by 6.58 %, from 310,470.89 to 330,894.85 rubles per square meter. The RSI 14 index reached 78.81 points, indicating overbought market conditions and the possibility of a subsequent correction.

Demand for housing across different classes has also changed significantly (Fig. 8). Since the end of 2022, demand for business-class housing has increased. As noted above, this shift is typical of a pre-crisis period, when housing is perceived as an investment instrument and a means of preserving capital amid continuous price growth. The dynamics of demand by housing class are shown in Fig. 9.

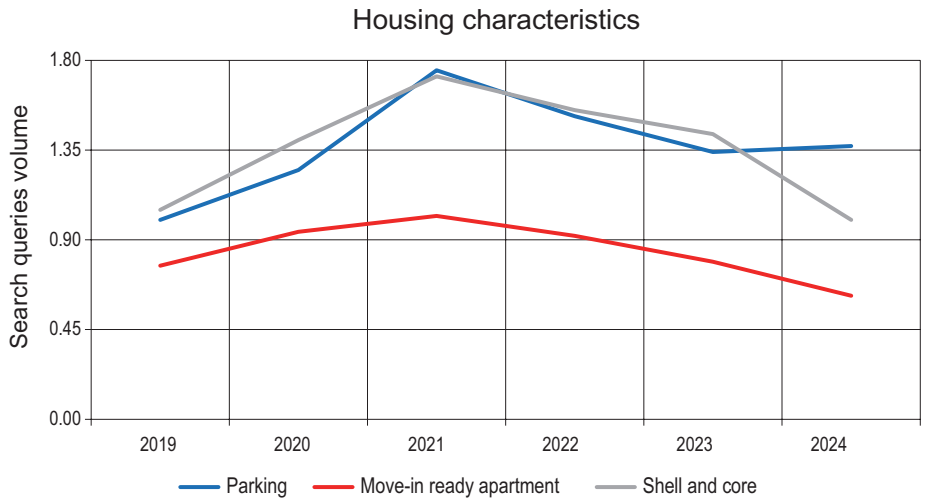


Fig. 8. Housing characteristics, 2019–2024[2]

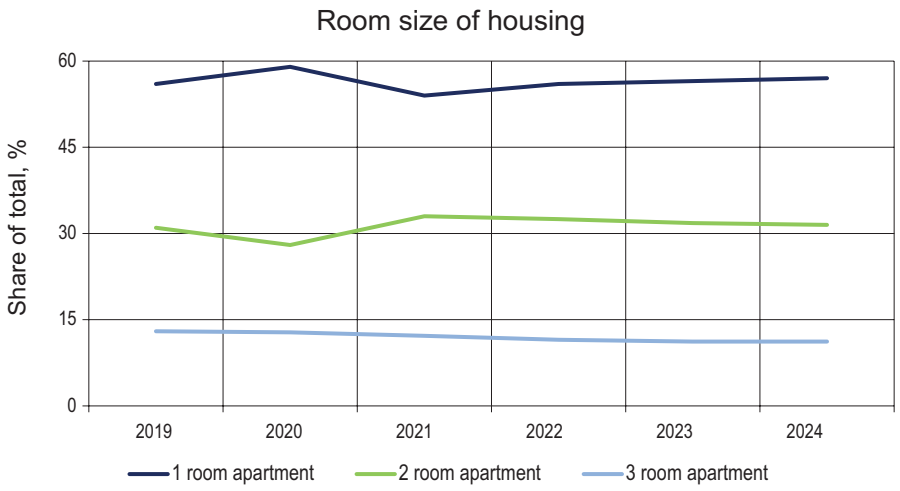


Fig. 9. Dynamics of demand for business-, comfort-, and economy-class housing[2]

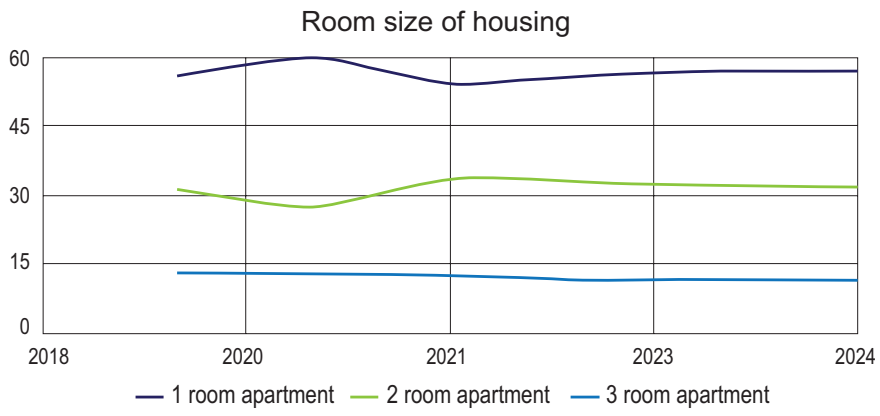


Fig. 10. Dynamics of demand by apartment room count, 2020–2024[2]

With respect to the number of rooms, the primary market shows a long-term trend toward a decrease in the average room count. Since 2000, the total share of three-room apartments in the primary market has decreased from 37 to 14 %, while the share of one-room apartments has increased from 28 to 67 %. Consistent with the earlier figures, demand for apartments with more rooms increased from 2020 to 2021 (Fig. 10).

DISCUSSION

The analysis shows that the recovery and expansion stages are characterized by demand for residential real estate with the following consumer characteristics:

- large apartments: buyers show high interest in spacious apartments with several rooms, particularly for family households;

• higher-class housing: demand increases for apartments in premium and business-class projects, especially in metropolitan and large cities;

• ready-to-move-in units: buyers prefer apartments with full or partial turnkey finishing to reduce renovation costs and time;

• location: prestigious districts with developed infrastructure and proximity to the city center receive priority.

The post-crisis period is characterized by the following demand factors:

• simplified and affordable options: buyers shift toward lower-cost apartments and economy-class or comfort-class projects, often choosing smaller units;

• functional layouts: interest increases in efficient space use, flexible planning solutions, open layouts, and studio apartments;

• mortgage demand: during crisis periods, mortgage lending and state-backed subsidy programmes become increasingly important for purchasing decisions.

CONCLUSIONS

The research supports the conclusion that demand in the housing market is cyclical and depends on the current market stage. Expansion and overproduction phases are associated with increased demand for products with enhanced consumer characteristics, such as underground parking, larger apartment size, finishing, and higher-class project positioning. These phases also show a stronger tendency toward investment-oriented purchases.

Contraction and recovery phases are characterized by lower consumer activity, a shift toward smaller apartments, and higher sensitivity to the efficiency of invested funds. This is conveyed in reduced demand for finished apartments and a stronger focus on economy- and comfort-class housing.

This article represents one stage of a broader study of demand dynamics in the residential real estate market. Further research should apply regression models to analyze market trends and produce a 3- to 5-year forecast. Such forecasting can help identify future demand factors for each market phase and improve developers' competitiveness by aligning apartment characteristics with the current stage of the market cycle.

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Анализ спроса и предложения по стадиям жизненного цикла рынка жилой недвижимости

Российский рынок жилой недвижимости переживает крайне тяжелые и нестабильные времена. Внешнеэкономические и внешнеполитические изменения привели к повышению ключевой ставки ЦБ до рекордных значений, а стоимость недвижимости с 2022 по 2026 г. растет с невероятной скоростью. Текущая ситуация на рынке значительно снизила потребительские возможности мажоритарного количества граждан РФ.
Введенная в апреле 2020 г. для повышения покупательской способности граждан программа льготной ипотеки способствовала росту спроса на жилье, и, как следствие, увеличению его стоимости, привела к ускорению инфляции, особенно в сегменте массового рынка. Из-за высокой ключевой ставки и стоимости недвижимости позволить себе квартиру по указанной программе способна лишь малая часть граждан с достатком выше среднего по стране.
Текущая ситуация на рынке заставляет застройщиков пересматривать свои стратегии и оптимизировать процессы строительства, что, в свою очередь, может отразиться на запуске новых жилых объектов. Пониженные темпы распроданности введенных объектов негативно сказываются на конкурентоспособности девелоперских компаний (далее — ДК). Распроданность объектов и, как следствие, конкурентоспособность ДК возможно повысить за счет увеличения ценности конечного продукта. Ценность конечного продукта (квартир), в свою очередь, по мнению авторов исследования, возможно увеличить основываясь на потребностях рынка.

В статье рассматривается динамика изменения спроса потребителей недвижимости или целевой аудитории (далее — ЦА) в привязке к рыночным циклам. Целью данной статьи является сегментация и разложение спроса по рыночным фазам для последующей разработки методических рекомендаций для застройщиков в части разработки новых конкурентоспособных объектов.

Анализ рынка и спроса не позволяет заглянуть дальше сегодняшнего дня, мы можем исследовать, что необходимо рынку сейчас, но не знаем, как изменятся запросы в перспективе нескольких лет. Прогнозирование спроса ЦА позволит увеличить конкурентоспособность ДК путем увеличения темпов возврата инвестиций за счет увеличения ценности конечного продукта (квартир), и, как следствие, увеличения темпов их распроданности.

Ключевые слова: *анализ рынка недвижимости, анализ спроса, рынок недвижимости*

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Об авторах: **Бороздина Светлана Михайловна** — кандидат экономических наук, доцент кафедры экономики и управления в строительстве; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; ID RSCI: 654497, Scopus AuthorID: 57194450904, WoS ResearcherID: AAM-6451-2020, ORCID: 0000-0002-7198-4655, SPIN-код: 7176-5790; BorozdinaSM@mgsu.ru;

Ковешников Владислав Владимирович — аспирант кафедры экономики и управления в строительстве; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; v.koveshn1kov@yandex.ru.

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UDC 332.62:332.6:332.2:69.05

Belyakov M.V.
Kostryukova A.S.

Theoretical and methodological foundations for determining cadastral and market value

The paper provides a comparative analysis of the essential characteristics of cadastral and market value of land plots as key categories of appraisal activities in the Russian Federation. Methodological approaches to determining each type of value are examined, and their fundamental differences are identified in terms of the purpo es of establishment, calculation methods, frequency of revision, and the degree of influence of market factors. It is substantiated that the cadastral value, being derived from the market value, often demonstrates significant deviations from real market indicators due to the mass nature of the assessment and the limited availability of initial data. The problematic issues of ensuring the reliability of the state cadastral assessment are analyzed, including the shortcomings of the methodology, the unreliability of the initial data of the USSRE and the personnel problems of budgetary institutions. Promising directions for improving the accuracy of SCV in connection with the transition to the use of a single digital platform "National Spatial Data System" from 2026 are considered. The conclusion is made about the need for an integrated approach to solving the problem, combining the improvement of the regulatory and methodological framework, improving the quality of information support and the introduction of a single software for conducting SCV. Practical recommendations for improving the accuracy of cadastral valuation based on modern digital solutions are proposed. The research results can be used to improve the methodological support for state cadastral valuation and in the educational process when training specialists in the field of land management and cadastres.

Keywords: *cadastral value, market value, state cadastral valuation, land plot, Unified Digital Platform, National Spatial Data System, assessment reliability, land management, cadastres*



Belyakov Michail Vladymyrovich,
Master's student of Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; mr.bmv2015@mail.ru



Kostryukova Anna Sergeevna,
Master's student of Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; kosssstrr@gmail.com

INTRODUCTION

The modern system of land resource management and real estate taxation in the Russian Federation is based on two fundamental valuation categories — the cadastral and market value of land plots. Despite their apparent similarity, these concepts have fundamental differences in terms of their application purposes, determination methods, and degree of reliability. The cadastral value, serving as the basis for calculating land tax and rental fees, has a direct impact on the economic interests of millions of landowners and users [1]. The market value, in turn, reflects the real worth of an object in a free market and is used in civil law transactions [2, 3].

The problem of the discrepancy between these two types of land value becomes particularly relevant in the context of the reform of the state cadastral valuation (SCV) system, which began with the adoption of Federal Law No. 269-FZ in 2020, and entered a new stage on January 1, 2026, with the introduction of Federal Law No. 243-FZ dated July 23, 2025, and the transition to the use of the National Spatial Data System (NSDS) [4, 5]. The aim of this study is to identify the essential differences between the cadastral and market value of land plots and to determine ways to improve the accuracy of the cadastral valuation based on an analysis of current trends in the development of appraisal activities.

APPROACHES TO DETERMINING CADASTRAL AND MARKET VALUE

The concept of cadastral value of a real estate object includes the result of the valuation of the real estate object obtained as of a specific date, determined based on price-forming factors and methodological guidelines for cadastral valuation. The cadastral value is determined for taxation purposes based on market information and other information related to the economic characteristics of the use of the real estate object. State cadastral valuation is a set of procedures aimed at determining the cadastral value of real estate objects, which is carried out simultaneously for all objects registered in the Unified State Register of Real Estate (USRRE) within the territory of a constituent entity of the Russian Federation [5].

In turn, market value, in accordance with the Federal Valuation Standard, is the most probable price at which the subject of valuation can be disposed of on the open market, subject to a number of conditions: the transaction is carried out between well-informed parties acting in their own interests and not under duress [6]. The fundamental difference between market value and cadastral value lies in the individual nature of its determination, whereas cadastral value is mass-based and is calculated for all objects simultaneously. However, upon closer examination, there are many more differences.

For clarity, the differences between cadastral and market value are systematized in Table.

Based on the data presented, it can be concluded that the cadastral value is derived from the market value, and due to the mass nature of the valuation and the limited nature of the initial data, it often shows significant deviations from real market indicators, which has a negative impact on the process of conducting the cadastral valuation [9].

Manukhina L.A.
Geraskin Yu.M.

PROBLEMATIC ISSUES RELATED TO ENSURING THE RELIABILITY OF STATE CADASTRAL VALUATION

An analysis of the practice of conducting SCV allowed us to identify several groups of problematic issues that negatively affect the accuracy of determining the cadastral value of land plots.

Problems related to organization and staffing

In the constituent entities of the Russian Federation, state budgetary institutions vested with the authority to conduct state-controlled appraisals face problems related to insufficient staffing, the lack of clear requirements for employees' qualifications, and insufficient funding. These factors objectively reduce the quality of appraisal work and increase the likelihood of errors.

Methodological problems

The lack of a unified methodology and methodology for conducting SCV in the past led to the fact that different regions used different approaches and methods, which created inconsistencies in the evaluation results. A number of contradictions and gaps have been identified in the Methodological Guidelines on SCV, in particular: the procedure for solving the problem of the discrepancy between the type of permitted use of the land plot according to the document and its actual use has not been regulated; a contradiction has been revealed between the Methodological Guidelines and the Federal Law "State Cadastral Valuation" regarding the lack of authority from Rosreestr to provide the SBI with the necessary information on transactions with real estate [5, 8].

Inaccuracy of the source data

The use of unreliable source data when conducting SCV, which are taken from the USSRE, is one of the most serious problems. Errors in information about the characteristics of land plots — area, location, type of permitted use — directly affect the assessment result. There is a lack of market information, especially in municipalities with an underdeveloped real estate market, a lack of information on the engineering support of facilities and contradictory information from the Unified State Register of Legal Entities [10].

Technological problems

Until 2026, there was no unified software package for conducting the SCV that would take into account all the requirements of the Methodological Instructions [8]. Different state budgetary institutions used different software products, which led to data fragmentation and lack of transparency in the algorithms for calculating the cadastral value.

Problems of interdepartmental cooperation and information exchange

A significant problem remains the lack of effectiveness of interagency cooperation in the implementation of SCV. To determine the cadastral value, information is needed from various sources: USSRE data, information on real estate transactions from

Comparative characteristics of cadastral and market value of land plots

Comparison criterion	Cadastral value	Market value
Purpose of the assessment	Taxation, rent, redemption price	Purchase and sale transactions, collateral, insurance, investment projects
Assessment method	Mass assessment methods	Methods of individual assessment (comparative, income-based, cost-based) [7]
Review frequency	No more than once every 4 years (in federal cities — once every 2 years) [5]	Determined as of the valuation date for a specific transaction.
Nature of the assessment	Mass-scale, applicable to all regions simultaneously	Individual, for a specific object
Accounting for market factors	Limited, based on generalized indicators	Complete, taking into account all individual characteristics
Subject of the assessment	The authorized body of the constituent entity of the Russian Federation [5]	Appraiser (an individual entrepreneur or a legal entity)
Legal regulation	Federal Law No. 237-FZ, Methodological Guidelines [5, 8]	Federal Law No. 135-FZ, FSO I–VI, No. 5, 7 [6, 7]



Manukhina Lyubov Andreevna,
Candidate of Economic Sciences, Associate Professor at the Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; AuthorID: 676588, SPIN-code: 7435-9741, Scopus AuthorID: 57194450337, ORCID: 0000-0003-4300-7002; ManuhinaLA@mgsu.ru



Geraskin Yuri Mikhailovich,
Candidate of Technical Sciences, Associate Professor at the Department of Construction Organization and Real Estate management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; ID RSCI: 296774, Scopus AuthorID: 57197806961, WoS ResearcherID: AAE-8696-2022, ORCID: 0000-0001-8343-9040; y.geraskin@gmail.com

Rosreestr, information on engineering infrastructure from municipal authorities, data on urban planning regulations and restrictions. The lack of a unified system for exchanging these data leads to their irrelevance, inconsistency and, as a result, to a decrease in the accuracy of the assessment. It is not uncommon for the USSRE to lack up-to-date information about the type of permitted use of a land plot or its area, and requesting information from related departments takes a long time and requires additional administrative procedures. This problem is particularly acute in relation to objects that have not been inventoried or surveyed. The solution to this issue is seen in the creation of a single digital platform that accumulates all the necessary data in real time, which is implemented within the framework of the NSDS.

A UNIFIED DIGITAL PLATFORM AS THE FOUNDATION FOR IMPROVING THE ACCURACY OF STATE CADASTRAL VALUATION

In response to the identified problems, Federal Law No. 243-FZ was adopted in 2025, significantly reforming the cadastral valuation system [5]. Starting from January 1, 2026, cadastral valuation is carried out in all constituent entities of the Russian Federation using the advanced federal state geographical information system "National Spatial Data System" (NSDS) [8]. The transition to the NSDS platform has ensured a unified calculation algorithm across the entire country, increased its transparency, and improved the accuracy of cadastral valuation results. This unified digital platform contains spatial data that serve as price-determining factors. In addition, this innovative methodology actively employs modern Earth remote sensing technologies, using high-resolution satellite images, as well as precise ground geodetic measurements.

The NSDS digital platform is not just a tool for calculating cadastral value, but a full-fledged ecosystem that unites all key information resources in the field of land and property relations [11]. Within this platform, spatial data are collected and processed, serving as the basis for determining price-determining factors when conducting cadastral valuation. A key element of the platform is the cartographic component, which provides external information systems with access to official cartographic layers and spatial analysis tools.

As of the end of 2025, 64 regions participated in the NSDS project; another 11 joined in 2026, including the federal city of Sevastopol. More than 120 information systems — data providers — are integrated with the platform, and the NSDS cartographic component is already built into 15 federal and regional information systems. The NSDS includes 16 subsystems and 26 digital services [12]. The necessary decisions have been taken to ensure the mandatory use of NSDS data in the provision of state and municipal services; this work is planned to be completed by the end of 2028 [12].

The platform's attendance is showing steady growth: by the end of 2025, more than 50 million visits were recorded, and 6–7 million hits are observed monthly, taking into account the use of the cartographic component [12]. Specialized services are in particularly high demand: "Land for Construction" saw a 10-fold increase (from 26,000 to 260,000 visits), "Land Simple" saw an increase from 160,000 to 1.8 million visits, and the "FGIS ECP NSDS Map" service received 59 million visits in 2025, compared to 1.5 million in 2024 [12].

The regulatory framework is also developing actively: as part of the implementation of Federal Law No. 317-FZ, 10 entities in the first wave of implementation have completed 97 % of the activities related to making changes to administrative regulations; in total, changes have been made to 1,892 regulations in 317 government bodies [12]. In 2026, another 15 entities of the Russian Federation will be additionally included in this work [12].

The NSDS is integrated into the work of federal agencies. The Russian Ministry of Agriculture uses the "Land for a Farmer" service, which has registered more than 6,800 plots with an area of over 558,000 hectares in 53 regions [12]. By the end of December 2025, 35 constituent entities of the Russian Federation had gained access to the service [12]. The Ministry of Economic Development, using the maps component of the NSDS in the Federal State Information System "Territorial Planning", carries out automatic spatial analysis, which has significantly accelerated the process of approving general plans [12]. The Ministry of Digital Development has integrated the map component of the NSDS into the Public Services Portal, and the "Smart Cadastre" service is used to identify unregistered capital construction objects [12].

It is important to note that the implementation of the NSDS yields a significant economic effect that goes far beyond the scope of the cadastral valuation itself. Thus, according to Rosreestr, the digital transformation of land data and the optimization of cadastral registration and registration of rights based on the NSDS have already reduced the investment and construction cycle by 87 days — from 1,021 to 934 days, that is, by about 9 % [13]. This is achieved by improving the quality and accessibility of spatial data, which reduces the time required to conduct engineering surveys, prepare design documentation, and obtain permits.

The new system enables the prompt acquisition of the necessary information and the timely updating of the value of real estate objects, provides a clear picture of the cadastral value level in different locations, and allows for a comparative analysis of cadastral value indicators in neighboring or comparable territories. The task of the FSIS ECP NSDS is to collect all significant spatial data in one place: information about land, capital construction objects, boundaries, zones with special usage conditions, etc. [14]. The data will come from multiple federal and regional systems, and a unified electronic cartographic framework will serve as a map for their visual representation [14]. As a result, an interactive environment will be created, where, in a single window, you can see the boundaries of the plot, information about rights, data on protected, nature conservation, or other zones, and urban planning restrictions [14].

How the FGIS NSDS is useful to ordinary people:

- free verification of the boundaries, value, and encumbrances of the plot when buying or selling real estate;
- searching for permitted zones and checking utilities during construction planning;
- selection of available land based on specified parameters when looking for land for business, tourism, or farming.

Online registration of a lease, easement, and urban planning plan without unnecessary bureaucracy [14].

The transition to a common digital platform for all participants in the process — from independent appraisers to regional authorities — will ensure the use of uniform calculation methods and maximum transparency of the procedure [15]. To ensure a smooth transition and prevent errors, a two-year adaptation period is provided: in 2026–2027, the use of the previous systems is still permitted [15]. Feedback mechanisms will enable citizens to participate more actively in the assessment process, and the cadastral value itself will be determined more objectively [15].

PRACTICAL RECOMMENDATIONS FOR IMPROVING THE ACCURACY OF CADASTRAL VALUATION

However, despite the introduction of the new system, other problems related to ensuring the reliability of SCV remain relevant. Based on the analysis conducted, the following practical recommendations for addressing them have been formulated:

1. Improving the information base. A systematic inventory of the USSRE information on land plots is needed, and contradictions and inaccuracies should be eliminated. As noted in the research, inventory is an important tool for improving the quality of cadastral valuation.

2. Development of methodological support. Further elaboration of methodological guidelines on SCV is required, along with the elimination of identified contradictions, particularly in terms of accounting for the actual use of land plots and interaction with other government bodies.

3. Strengthening human resources. It is necessary to establish clear qualification requirements for SBI employees involved in the implementation of the SCV, and to ensure their regular professional development. In addition, it is advisable to introduce a system of independent assessment of the quality of appraisers' work, which will improve the professional level of specialists and reduce the risks of errors during the SCV.

4. Use of modern technologies. Active use of remote sensing technologies, geoinformation systems, and spatial analysis methods to take into account priceforming factors.

5. Ensuring transparency and feedback. Creating effective mechanisms for submitting and reviewing comments on the results of the SCV by right holders.

CONCLUSION

The comparative analysis of cadastral and market values of land plots allows us to conclude that these categories, while closely related, have fundamental differences in terms of their application purposes, determination methods, and degree of reliability. The cadastral value, due to the mass nature of the assessment, the limited availability of initial data, and methodological shortcomings, often does not correspond to market realities, which creates social tension and reduces the efficiency of taxation.

The introduction of the Unified Digital Platform "National Spatial Data System" starting in 2026 is a crucial step towards improving the accuracy and transparency of state cadastral valuation. A unified calculation algorithm, centralized storage of spatial data, the use of remote sensing technologies, and the involvement of property rights holders in the valuation process create the necessary conditions for establishing a fair and economically justified cadastral value of land plots.

Further improvement of the cadastral valuation system requires a comprehensive approach that combines the development of the regulatory framework, improving the quality of information support, strengthening the human resources of budgetary institutions, and actively using modern digital technologies.

Implementing all these areas will significantly reduce the gap between cadastral and market value, increase citizens' and businesses' trust in the cadastral valuation system, and ensure fair taxation of real estate.

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Теоретико-методологические основы определения кадастровой и рыночной стоимости

В статье проведен сравнительный анализ сущностных характеристик кадастровой и рыночной стоимости земельных участков как ключевых категорий оценочной деятельности в Российской Федерации. Рассмотрены методологические подходы к определению каждого вида стоимости, выявлены их принципиальные различия по целям установления, методам расчета, периодичности пересмотра и степени влияния рыночных факторов. Обосновано, что кадастровая стоимость, являясь производной от рыночной, в силу массового характера оценки и ограниченности исходных данных часто демонстрирует существенные отклонения от реальных рыночных показателей. Проанализированы проблемные вопросы обеспечения достоверности государственной кадастровой оценки, включая недостатки методологии, недостоверность исходных данных ЕГРН и кадровые проблемы бюджетных учреждений. Рассмотрены перспективные направления повышения точности ГКО в связи с переходом на использование Единой цифровой платформы «Национальная система пространственных данных» с 2026 года. Сделан вывод о необходимости комплексного подхода к решению проблемы, сочетающего совершенствование нормативно-методической базы, повышение качества информационного обеспечения и внедрение единого программного обеспечения для проведения ГКО. Предложены практические рекомендации по повышению точности кадастровой оценки на основе современных цифровых решений. Результаты исследования могут быть использованы при совершенствовании методического обеспечения государственной кадастровой оценки и в учебном процессе при подготовке специалистов в области землеустройства и кадастров.

Ключевые слова: *кадастровая стоимость, рыночная стоимость, государственная кадастровая оценка, земельный участок, Единая цифровая платформа, Национальная система пространственных данных, достоверность оценки, землеустройство, кадастры*

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Об авторах: **Беляков Михаил Владимирович** — магистрант кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; mr.bmv2015@mail.ru;

Кострюкова Анна Сергеевна — магистрант кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; kosssstrr@gmail.com;

Манухина Любовь Андреевна — кандидат экономических наук, доцент кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; AuthorID: 676588, SPIN-код: 7435-9741, Scopus AuthorID: 57194450337, ORCID: 0000-0003-4300-7002; ManuhinaLA@mgsu.ru;

Гераськин Юрий Михайлович — кандидат технических наук, доцент кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; РИНЦ ID: 296774, Scopus AuthorID: 57197806961, WoS ResearcherID: AAE-8696-2022, ORCID: 0000-0001-8343-9040; y.geraskin@gmail.com.

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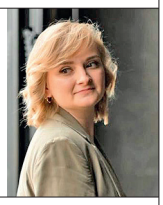
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Dekhtyar E.V.
Kapustkina A.V.

Impact of urban development mechanisms and processes on the preservation of agricultural land and natural areas

This paper examines the comprehensive impact of urban development processes on the preservation and rational use of agricultural lands and natural areas. The study analyzes current urbanization trends in the Russian Federation, which lead to a reduction in the area of productive agricultural land, its degradation, and unjustified transfer to other land categories. Key challenges and contradictions in peri-urban areas are investigated, where the interests of the agricultural sector, developers, and the state intersect. Particular attention is paid to legal mechanisms for protecting agricultural lands, including the tightening of rules for the transfer of agricultural land to the category of settlement lands and measures to bring unused lands into circulation. Approaches to the development of general plans ensuring balanced territorial development are examined. Based on the analysis, a set of measures is proposed aimed at reducing anthropogenic pressure on valuable lands and ensuring sustainable development of peri-urban zones.

Keywords: *urban development, urbanization, agricultural lands, natural areas, land use, general plan, food security, sustainable development*



Dekhtyar Ekaterina Vladislavovna,
Candidate of Technical Sciences, Associate Professor at the Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; ID RSCI: 921719, Scopus AuthorID: 57216582395, ORCID: 0000-0001-9650-4083; DekhtyarEV@mgsu.ru



Kapustkina Anna Vyacheslavovna,
Candidate of Economic Sciences, Associate Professor at the Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; ID RSCI: 800331, Scopus AuthorID: 57192660191, ORCID: 0000-0001-6920-312X; KapustkinaAV@mgsu.ru

INTRODUCTION

Urbanization processes, as an integral part of socioeconomic development, exert a multifaceted influence on the environment and land resources. The expansion of cities, infrastructure development, and housing construction inevitably entail the transformation of adjacent areas, often affecting valuable agricultural lands and natural landscapes. This problem is particularly acute for the Russian Federation, which possesses a significant land fund but faces challenges in the rational use and preservation of productive lands amid active urban development.

The relevance of the topic is determined by the need to strike a balance between the demands of urban development, ensuring the country's food security, and preserving the natural potential of areas. As V.I. Denisov and I.M. Potravny rightly note, lands near cities are subject to active demand from various economic entities, including residential developers, recreational facilities, and agricultural producers, which generates intense competition for their use. This poses a complex challenge for the state and society to develop effective land resource management mechanisms capable of preventing irrational use and degradation.

The purpose of this work is to conduct a comprehensive analysis of the impact of urban development on the preservation of agricultural lands and natural areas, identifying the main threats and contradictions, as well as determining promising directions for improving territorial planning and land policy in the Russian Federation.

CHAPTER 1. CURRENT TRENDS AND CHALLENGES OF URBAN DEVELOPMENT FOR AGRICULTURAL LANDS

1.1. Scale and Dynamics of Agricultural Land Reduction

An analysis of the structure of the land fund of the Russian Federation indicates a steady trend toward a reduction in the area of agricultural lands. According to the State Report on the State and Protection of the Environment, over the period from 2010 to 2018, their share decreased from 23 to 22.4 %, concurrently with an increase in lands of settlements and industry [1, p. 33]. In absolute terms, the area of settlement lands increased by 0.9 million hectares, or 4.6 % [1, p. 33].

The most intensive transformation processes occur in peri-urban zones of large cities. Research by Denisov and Potravny demonstrates that in the Central and Northwestern Federal Districts (Table), over

Share (%) of land categories in the total utilized area by administrative districts of the non-chernozem zone of the European part of the Russian Federation (1995 and 2019)

Land Users	Central Federal District		Northwestern Federal District	
Land Category	1995	2019	1995	2019
Agricultural enterprises	53.8	38.4	64.6	48.0
Dacha plots, homesteads	11.7	36.7	7.4	29.5
Industrial facilities	7.6	5.1	8.3	7.9
Sports and recreational complexes	5.8	10.8	5.0	8.3
Other categories	21.1	9.1	14.7	—

Samsonova O.Yu.
Akhmetyanova A.R.

the period from 1995 to 2019, the share of agricultural enterprise lands decreased from 53.8 to 38.4 % and from 64.6 to 48.0 %, respectively. Simultaneously, the share of dacha plots and homesteads increased nearly threefold — from 11.7 to 36.7 % in the Central District [1, p. 34]. This indicates significant pressure on the agricultural sector from residential and recreational land use.

More alarming dynamics are observed over the long-term horizon: compared with 1995, the area of agricultural lands decreased by 42 %, and from 2010 to 2020 — by 4.6 % [2]. For comparison, according to FAO data, from 1990 to 2020, the global agricultural land area decreased by only 2.1 % [2]. Thus, the rate of reduction in Russia significantly exceeds the global average.

Studies also confirm a direct correlation between the level of urbanization and the loss of agricultural land. In low- and medium-urbanized groups, the reduction amounted to 0.3 % (relative to the 1999 level), in highly urbanized groups — 0.5 %, and in agglomerations — 1.9 %. More than 60 % of total losses (535.5 thousand hectares) occur precisely in highly urbanized regions and agglomerations [3].

1.2. Main Factors and Reasons for Unjustified Land Transfer

The reduction of agricultural lands near cities is driven by a complex of economic, legal, and social factors.

From an economic perspective, peri-urban lands possess high value due to differential rent based on location. Proximity to markets, transport infrastructure, and utilities make them attractive for development. Agricultural enterprises, as the least competitive, cannot compete with developers for ownership of plots, leading to their displacement from the most advantageous areas [1, p. 32].

Legal issues are associated with the absence of clear boundaries for agricultural lands in the Unified State Register of Real Estate (USRRE). Currently, this information is contained only in the Unified Federal Information System on Agricultural Lands (UFISAL), which makes land information legally "fluid" and vulnerable to unjustified redistribution [4]. It is precisely the absence of boundaries in the USRRE that allows agricultural lands to be transferred to other categories, threatening their loss as an agricultural resource [4].

A significant problem is also the non-use of lands for their designated purpose. According to the Ministry of Agriculture of Russia, as of January 1, 2022, the area of unused agricultural lands was estimated at 44.94 million hectares, including 18.65 million hectares of arable land. The area of unclaimed land shares amounts to 11.32 million hectares [5]. Actual arable land losses are even higher: whereas in 1990 the sown area was 131.02 million hectares, in 2021 it was only 91.70 million hectares [5].

The social aspect is related to the growing demand for suburban real estate, facilitated by the development of transport accessibility, remote work, and the desire to live in a better ecological environment. This leads to the active development of peri-urban areas for individual housing construction, fragmentation of agricultural landscapes, and reduction of arable land [6].

CHAPTER 2. LEGAL AND INSTITUTIONAL MECHANISMS FOR THE PROTECTION OF AGRICULTURAL LANDS

2.1. Reform of Legislation in the Sphere of Agricultural Land Turnover

In recent years, the state has consistently tightened the rules for transferring agricultural lands to other categories. A key change was the introduction, effective March 1, 2026, of a new procedure for the transfer of agricultural land to settlement lands based on Federal Law No. 52-FZ of April 1, 2025 [1]. Transfer is now permitted only in exceptional cases, clear prohibitions and restrictions have been introduced, and the transfer of particularly valuable productive lands is not permitted [1].

The principle of "two keys" has been introduced: decisions by regional government bodies are made only in coordination with the Ministry of Agriculture and upon the conclusion of the governor [7]. This limits the ability of local authorities to unilaterally transfer valuable lands for development. The law also prohibits the withdrawal of agricultural lands for the extraction of common minerals [2].

Of significant importance is the work on entering agricultural land boundaries into the USRRE. Draft Law No. 943257-8 proposes a mechanism for fixing boundaries with graphic descriptions and coordinates. The law is expected to come into force on July 1, 2026, by which time the development of a digital map-scheme and integration of registry systems must be completed [4]. This will lay the foundation for the legal protection of agricultural areas.

Changes have also affected the involvement of unused lands. Federal Law No. 101-FZ (as amended on December 29, 2022) facilitates the transfer of lands formed from unclaimed shares to municipal ownership. Local self-government bodies have received the right to participate in meetings of shareholders and transfer such plots for lease [5]. Since 2016, the Land Code has established a prohibition



Samsonova Olga Yuryevna,
Master's student at the Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; ssonov7877@yandex.ru



Akhmetyanova Anita Radikovna,
Master's student at the Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; anitaahmetyanova@yandex.ru

on the use of lands adjacent to rural settlements for purposes not related to agriculture [2].

2.2. Improvement of Territorial Planning Instruments

An important role is played by the general plans of municipalities, which determine the directions of territorial development, zoning, and requirements for the preservation of natural objects [8]. ITP "Grad" at the "Agro Management 2026" forum presented approaches linking territorial development with the preservation of agricultural lands, prioritizing human interests and the quality of the living environment [9].

When developing general plans, a calculation of territorial needs is conducted. If existing lands are insufficient, the need arises to expand boundaries at the expense of agricultural lands [9]. However, this is a strategic decision that requires consideration of the planning structure, infrastructure, and environmental constraints [9]. It is important that the inclusion of a plot within the boundaries of a settlement does not complete the change of category but only creates a legal possibility, followed by the procedure provided by law [10].

General plans designate zones of various functional purposes, including agricultural use zones and particularly valuable lands [6]. Territorial planning scheme projects are checked for compliance with agricultural development goals [1]. At the same time, for more effective protection of lands, it is necessary to conduct ecological and economic zoning as part of land management projects, which will allow for more complete consideration of local characteristics.

CHAPTER 3. SOCIOECONOMIC AND ENVIRONMENTAL CONSEQUENCES OF URBANIZATION IN PERI-URBAN AREAS

3.1. Economic Contradictions and Ways to Resolve Them

At the heart of the conflict between development and the preservation of agricultural lands lie profound economic contradictions. Land near cities is a limited resource with high capital value. Among users, three groups can be distinguished: agricultural enterprises, non-agricultural developers, and recreational facilities [1, p. 36]. The competitiveness of developers is higher, as their profitability from land use significantly exceeds that of agriculture. This leads to the most fertile lands being the most vulnerable to development [1, p. 37].

A striking example is the Leningrad Oblast. The construction of the Ring Road led to the loss of 1,020 hectares of arable land belonging to the "Ruchi" stud farm [9; 11]. In the Vsevolozhsk District, urbanization led to the emergence of new cities (Bugry, Kudrovo, Murino) and significant loss of arable land by agricultural enterprises [9].

To resolve contradictions, a set of measures is needed: economic incentives for agricultural producers (subsidies, compensation, preferential lending) and administrative restrictions for developers (strengthening control over intended use, prohibition of construction on valuable lands) [1, p. 38]. It is important to remember that urbanization carries not only negative aspects: the development of processing of local raw materials in cities creates linkages between urban and rural economies, contributing to the growth of well-being on both sides [5].

3.2. Environmental Consequences of Urban Development

Urbanization has a significant negative impact on nature. Rural areas suffer from industrial waste, loss of water resources, and pollution. Fertile lands are built over, leading to reduced production. Changes in the production structure toward intensification increase the use of chemicals and worsen the ecological situation [10]. Land degradation reduces their fertility [10].

Special attention should be paid to biodiversity. The growth of cities and landscape changes lead to the loss of traditional farming methods and the reduction of farm plant varieties adapted to local conditions [4]. Fragmentation of lands reduces genetic exchange between populations, leading to isolation and impoverishment of genetic diversity [4].

CHAPTER 4. SOLUTIONS TO THE PROBLEM AND RECOMMENDATIONS FOR SUSTAINABLE DEVELOPMENT OF PERI-URBAN AREAS

4.1. Forecasting and Planning of Land Use as a Tool for Agricultural Land Preservation

Solving the problem requires a transition to strategic planning and integrated land resource management. An important tool is forecasting. Using the Belgorod Oblast as an example, an approach to statistical modeling of arable land areas has been developed [6, 8]. According to the forecast, regional programs for the preservation of meadow lands will lead to a reduction in arable land by 3.07 % (83.2 thousand hectares). In one district with high rates of urbanization, the transformation of about 6.2 thousand hectares of arable land into residential development lands is forecast, with 2/3 of the area within 6 km of Belgorod [6, 8]. This approach is relevant for all agricultural regions.

It is necessary to form a balanced system ensuring equilibrium between the preservation of agricultural lands, food security, and housing development [9]. An example is the general plan of the Sysert Urban District, where the goals of nature conservation and agricultural development are considered complementary rather than conflicting [12, 13].

4.2. Stimulating the Efficient Use of Agricultural Lands and Development of Institutions

Alongside restrictions, measures are needed to stimulate efficient use. State support for agricultural enterprises should be expanded, particularly in land acquisition and technology adoption [1, p. 38]. A key mechanism is bringing unused plots into circulation (in Russia, up to 30 % of such lands exist). In 2024, 2.4 million hectares were returned, and by 2030 it is planned to bring up to 13 million hectares into circulation [4, 14, 15].

The role of land management is also important: work is needed on the formation of plots, surveying, cadastral registration, and rights registration [2]. Simplification of these procedures for unclaimed shares will accelerate the return of lands.

The development of peri-urban agriculture to supply cities with fresh produce is promising, as is the application of innovative technologies (hydroponics, aeroponics) that allow crops to be grown in urban conditions without occupying agricultural lands [10].

CONCLUSION

The conducted analysis shows that urban development creates a complex of threats to agricultural lands. The expansion of cities and infrastructure leads to the unjustified reduction of productive lands, their degradation and fragmentation, creating a threat to food security. The problem manifests itself most acutely in peri-urban zones.

The state is taking active steps: new rules for land transfer are being introduced (coordination with the Ministry of Agriculture and

the governor, prohibition on the transfer of particularly valuable lands), mechanisms for the seizure of unused lands and the entry of boundaries into the USRRE are being improved, and strategic planning is being developed. However, the problem requires a comprehensive solution, including economic incentives, support for the agricultural sector, and the development of peri-urban farming.

Promising areas of research include the development of methodologies for ecological and economic zoning, analysis of the effectiveness of new legislative mechanisms, and investigation of the socioeconomic effects of sustainable land use. The implementation of such an integrated approach will make it possible to ensure a balance between urban development and the preservation of the strategic resource of agricultural lands for future generations.

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Влияние градостроительного развития на сохранение сельскохозяйственных земель и природных территорий

В статье рассматривается комплексное влияние процессов градостроительного развития на сохранение и рациональное использование земель сельскохозяйственного назначения и природных территорий. Анализируются современные тенденции урбанизации в Российской Федерации, приводящие к сокращению площади продуктивных сельхозугодий, их деградации и необоснованному переводу в иные категории. Исследуются ключевые вызовы и противоречия на пригородных территориях, где сталкиваются интересы аграрного сектора, девелоперов и государства. Особое внимание уделяется правовым механизмам защиты сельхозземель, включая ужесточение правил перевода угодий в категорию земель населенных пунктов и меры по вовлечению неиспользуемых земель в оборот. Рассматриваются подходы к разработке генеральных планов, обеспечивающие сбалансированное территориальное развитие. На основе анализа предложен комплекс мер, направленных на снижение антропогенной нагрузки на ценные земли и обеспечение устойчивого развития пригородных зон.

Ключевые слова: *градостроительное развитие, урбанизация, сельскохозяйственные земли, природные территории, землепользование, генеральный план, продовольственная безопасность, устойчивое развитие*

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Об авторах: **Дехтярь Екатерина Владиславовна** — кандидат технических наук, доцент кафедры Организации строительства и управления недвижимостью; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; РИНЦ ID: 921719, Scopus AuthorID: 57216582395, ORCID: 0000-0001-9650-4083; DekhtyarEV@mgsu.ru;

Капусткина Анна Вячеславовна — кандидат экономических наук, доцент кафедры Организации строительства и управления недвижимостью; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; РИНЦ ID: 800331, Scopus AuthorID: 57192660191, ORCID: 0000-0001-6920-312X; KapustkinaAV@mgsu.ru;

Самсонова Ольга Юрьевна — магистрант кафедры Организации строительства и управления недвижимостью; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; ssonov7877@yandex.ru;

Ахметьянова Анита Радиковна — магистрант кафедры Организации строительства и управления недвижимостью; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; anitaahmetyanova@yandex.ru.

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Kozlov I.S.
Beliakov S.I.

Management of technological solutions in industrial construction investment projects

An industrial capital project is aimed at creating a production system in which buildings and structures, utility systems, process equipment, automation, and personnel ensure the required output of industrial products under specified operating conditions. The article examines how the mechanisms used to select process engineering solutions affect design decisions, cost parameters, procurement procedures, specialized installation activities, process control and automation systems, and commissioning.
The study analyzes the management-specific characteristics of capital projects and the procedure for end-to-end verification of process engineering solutions from the design brief through the startup of an industrial facility. The research is based on an analysis of regulatory documents, industry standards, and scientific publications on front-end project planning, work organization, cost estimating, management of approvals, and industrial facility commissioning and startup.
The ability of the facility to perform its intended production function is adopted as the criterion for successful project delivery. A process engineering solution is proposed as a single object of control across the design brief, design documentation and cost estimates, procurement, construction and installation, process control and automation documentation, and commissioning. The results may be used by the owner, the owner's technical representative, the design consultant, and the contractor when developing input data, approving alternative equipment, preparing the budget, and organizing facility startup.
Keywords: *industrial capital project, process engineering solutions, design brief, design documentation and cost estimates, cost management, process equipment, construction and installation, procurement, process control and automation, commissioning, change management*



Kozlov Ilya Sergeevich,
Master's student, Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; kozlov.i.s@tsenastroyki.ru



Beliakov Sergei Igorevich,
Doctor of Economic Sciences, Associate Professor, Professor of Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; ID RSCI: 587836, Scopus AuthorID: 39763951700, ORCID: 0000-0001-5179-737X; BelyakovSI@mgsu.ru

INTRODUCTION

Management of a capital and construction project includes management of schedule, cost, quality, procurement, risks, and changes [1]. For an industrial facility, however, the project outcome cannot be assessed solely against these dimensions. Completion of an industrial project means that the equipment has been installed and connected, utility systems provide the required parameters, automation is operational, all necessary tests have been completed, and the operations personnel have received the full set of operation and maintenance (O&M) documentation.

The manufacturing process establishes the initial requirements for the facility's structural and engineering design. Process equipment parameters determine loads, layout, and installation conditions, while process characteristics define requirements for utility systems, power supply, automation, and safety. Consequently, a process engineering solution simultaneously affects the spatial, technical, cost, procurement, and organizational parameters of the project.

This interdependence is most evident when process equipment is changed. Substitution of a single equipment item may require revisions to structural and engineering design, power supply and automation systems, scope of work, cost estimates, delivery schedule, and test program. In a standard procurement review, such a substitution is often assessed in terms of price and lead time. That assessment alone, however, cannot confirm compatibility with the adopted facility configuration.

The research problem is that the parameters of a single process engineering solution are successively transformed into design, cost, procurement, installation, and operational decisions, while in practice they are controlled by different participants and in different documents. As a result, a change approved at one stage may not be reflected in the design documentation, cost estimates, project schedule, or other documentation required for construction and installation.

The aim of the study is to identify the management-specific features of process engineering solutions in industrial capital projects and to determine the parameters that should be verified from the design brief through commissioning. The object of the study is industrial capital projects. The subject of the study is the organizational and management processes for approving and changing process engineering solutions during design, cost estimating, procurement, construction and installation, automation, and commissioning.

In this study, a process engineering solution is defined as a set of equipment parameters, process characteristics, and operating conditions that determine requirements for the facility's structural design, utility systems and automation systems, scope of work, and conditions for putting the facility into operation. These parameters should be reflected consistently in the design brief, design documentation and cost estimates, cost model, procurement documentation, construction and installation activities, and commissioning. Thus, the process engineering solution is treated as a single object of management throughout all stages of an industrial capital project delivery.

PROCESS ENGINEERING DRIVERS OF INDUSTRIAL CAPITAL PROJECT DECISIONS

Design decisions in industrial projects depend on the manufacturing process to be implemented. In civil construction, requirements are primarily determined by the building's intended use and operating conditions. For an industrial facility, the manufacturing process is an additional and often decisive factor: equipment parameters, process media, and operating modes affect the structures, utility systems, and facility layout. If equipment loads on the building, connection points to process and utility systems, requirements for air cleanliness, temperature, pressure, drainage, or maintenance access are not taken into account, the facility may be unable to perform its intended production function.

This dependency is particularly pronounced in projects involving unique, oversized, or dynamically loaded equipment. Floor and foundation load-bearing capacity, elevations, installation openings, transport routes, maintenance clearances, and dismantling conditions must be defined in advance. In chemical, pharmaceutical, and food-processing facilities, the manufacturing process also affects ventilation, dust extraction, dedicated process piping, drainage, room classifications, and material requirements. Late revisions to process data therefore trigger changes across multiple design disciplines and the scope of construction and installation works.

The close coupling between building parameters and equipment explains why a process change cannot be treated as an isolated revision. An increase in machine weight changes the foundation and floor calculations. New temperature, pressure, or cleanliness requirements affect ventilation, piping, drainage, and power supply. Replacement of equipment with a different input/output (I/O) list requires revisions to cable routes, control panels, and control algorithms. The later a change enters the design, the more completed or contracted work must be reconsidered.

The design brief for an industrial facility is usually refined as equipment is selected. At an early stage, the production program is known; later, suppliers provide weight, dimensions, connection sizes, utility consumption, maintenance requirements, and automation requirements. For each unconfirmed parameter, it is advisable to record the source of information, the responsible party, and the list of decisions developed on the basis of the relevant assumption.

A further characteristic of industrial projects is the difference between the facility delivery cycle and the technology renewal cycle. The design brief records the current production configuration, but the owner may change the product range, capacity, or equipment configuration before construction is complete. The design should include only those allowances for loads, utility capacity, dimensions, and maintenance clearances that are supported by the production program and the project's economic justification. Excessive allowances increase cost, while their absence can make future modification disproportionately expensive.

During the reconstruction of an operating facility, archived documentation often differs from the actual arrangement of utilities and equipment. Production operations may impose specific work windows, outage durations, permissible noise and dust levels, and access restrictions. Therefore, before detailed design solutions are issued, project participants should verify actual dimensions, the location of existing utilities, available spare capacity in utility systems, and the outage sequence. These data are required by the design consultant to issue documentation, by the contractor to prepare and organize the work, and by operations personnel to coordinate outages.

At an operating facility, a process engineering solution must also be assessed in terms of its impact on production output. Even a technically correct change may be unacceptable if it requires an extended production shutdown, no suitable work window is available, or existing utility systems cannot be isolated safely. The design documentation, project schedule, and production plan should therefore be based on the same set of constraints. If they are not aligned, the contractor may be technically ready to start work while the facility cannot make the required workface available. Key questions for evaluating such changes are shown in Fig. 1.

The parameters of a process engineering solution originate from different sources and are confirmed through different procedures. Equipment characteristics are generally refined by the supplier; requirements for the installation of process equipment and process piping are defined by the design solutions and applicable codes and standards [2, 3]. For hazardous production facilities, the design scope of solutions is additionally governed by industrial



Source: compiled by the author.

Fig. 1. Key questions when selecting and changing process engineering solutions

safety requirements [4]. Automation systems require a separate set of design and O&M documentation during their development and commissioning stages [5]. Accordingly, changes to a process engineering solution cannot be approved solely between the owner and the supplier; they should be reviewed with participation from the process engineer, design consultant, cost estimator, automation engineer, contractor, and representative of the facility operator.

Thus, in industrial projects, the manufacturing process provides input data for structural, engineering, cost, and organizational decisions. A change to equipment or the process should be approved only after its implications for design decisions, procurement procedures, construction and installation, testing, and the startup schedule have been assessed. This is the key distinction between a process-related change and an isolated revision to an individual section of the documentation.

END-TO-END VERIFICATION OF A PROCESS ENGINEERING SOLUTION

End-to-end verification of a process engineering solution begins with the requirements of future operation: the manufacturing process defines the input data and content of the design brief, after which the adopted parameters should be reflected consistently in design documentation and cost estimates, procurement, construction and installation, process control and automation documentation, and the commissioning program. The Project Definition Rating Index, Advanced Work Packaging/WorkFace Planning, and interface management, discussed below, are applied at different points in this sequence and help control the level of definition and consistency of the process engineering solution.

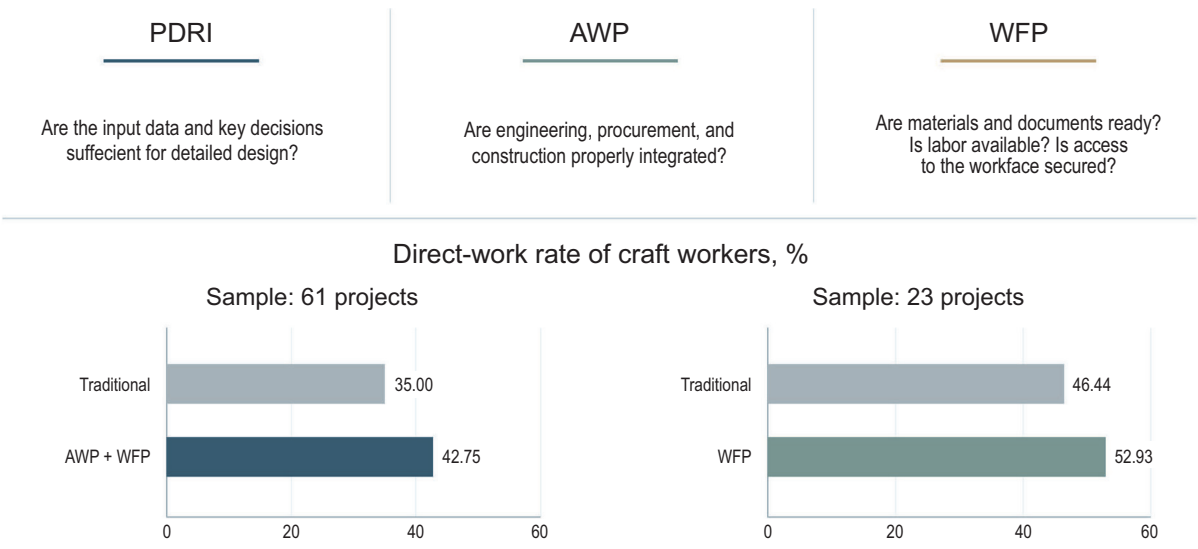
In international practice, PDRI-Industrial (Project Definition Rating Index) is used to assess front-end planning for major industrial projects. It is a structured checklist for evaluating project definition: 70 elements are grouped into three sections — Basis of Project Decision, Basis of Design, and Execution Approach. The project team uses it to assess the definition of the production program, process technology, process flow diagrams, site characteristics, piping and instrumentation diagrams (P&IDs), and the project delivery approach. According to the Construction Industry Institute, projects with high Front End Engineering Design (FEED) maturity and a high PDRI accuracy achieved 24 % greater project certainty and 12 % better change performance than projects with low FEED maturity and low PDRI accuracy [6].

Advanced Work Packaging (AWP) is an approach to organizing industrial projects around work packages. Under AWP, engineering, procurement, and construction are aligned with the installation sequence: before field work begins, drawings and materials should be available, access to the workface secured, the required tools and equipment provided, and safe working conditions established. WorkFace Planning (WFP) is short-range planning at the workface used to verify this readiness before a specific task starts [7].

A 2025 study compared two independent samples: 61 projects from a productivity consulting firm and 23 projects from a large engineering, procurement, and construction (EPC) firm. Direct-work rate is defined as the share of craft labor time spent directly installing, assembling, or connecting equipment; waiting for materials and drawings, obtaining access to the workface, and other delays are excluded. In the first sample, the direct-work rate was 42.75 % with AWP and WFP versus 35.00 % in traditional projects. In the second sample, it was 52.93 % with WFP versus 46.44 %. These results indicate that ensuring the readiness of documentation, materials, and the workface in advance can help reduce waiting time and delays associated with an insufficiently developed process engineering solution [8].

Fig. 2 summarizes the functions of PDRI, AWP, and WFP within the end-to-end verification of a process engineering solution. These tools are treated as complementary: PDRI is used to assess the completeness of input data and the level of design-brief definition, while AWP and WFP align design, procurement, and readiness for construction and installation. This allows process engineering parameters and the required readiness conditions to be verified before work is transferred to the next project stage.

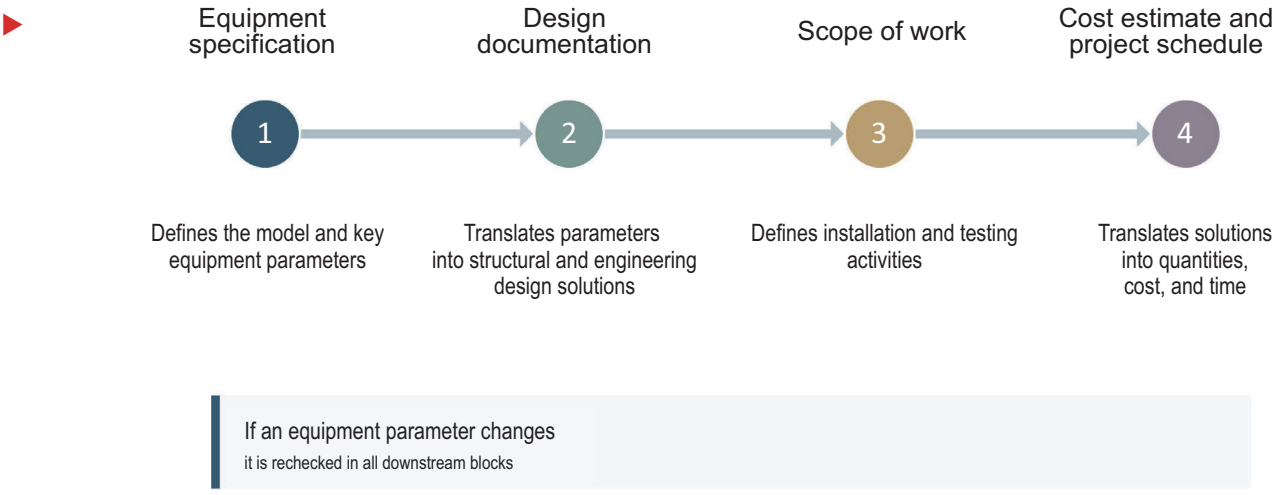
The central management task in an industrial project is to maintain the consistency of process engineering parameters as they are transferred between project stages. In the design brief, the process engineering solution is expressed through requirements for capacity,



Two independent samples; the size of each sample is shown above the corresponding chart

Source: compiled by the author based on [6–8].

Fig. 2. Functions of PDRI, AWP, and WFP in end-to-end verification of a process engineering solution



Source: compiled by the author based on [9, 10].

Fig. 3. Relationship of a process engineering solution to the scope of work, cost estimate, and project schedule

process media, operating mode, and maintenance conditions; in the design documentation, these requirements are translated into layout and engineering design solutions; and in the cost estimates, they are converted into the scope of work, resources, and costs. Procurement documentation fixes the selected equipment item, delivery dates, service and maintenance requirements, and the spare-parts package. During construction, installation, and commissioning, compliance with the process engineering solution is verified against the actual readiness of equipment and systems for startup.

End-to-end verification is performed against a list of key process engineering parameters. For equipment, these include capacity, dimensions, weight, loads, process media, connection points to process and engineering systems, power-supply parameters, the process control and automation signal list, maintenance conditions, and delivery lead time. For process piping and engineering systems, the material, diameter, pressure, temperature, test method, and required as-built documentation are recorded. When the project moves to the next stage, the responsible participant should confirm that the relevant parameters are reflected in the documents and work under that participant's responsibility.

The design brief defines the functional purpose of the equipment and its operating conditions: capacity, operating mode, process media, product-quality requirements, maintenance, and safety. At an early stage, the specific equipment model may not yet be selected. In that case, unresolved parameters are included in an open-items register with the data source, responsible participant, and confirmation deadline. The register is used during design development, preparation of design documentation and cost estimates, and requests for quotation.

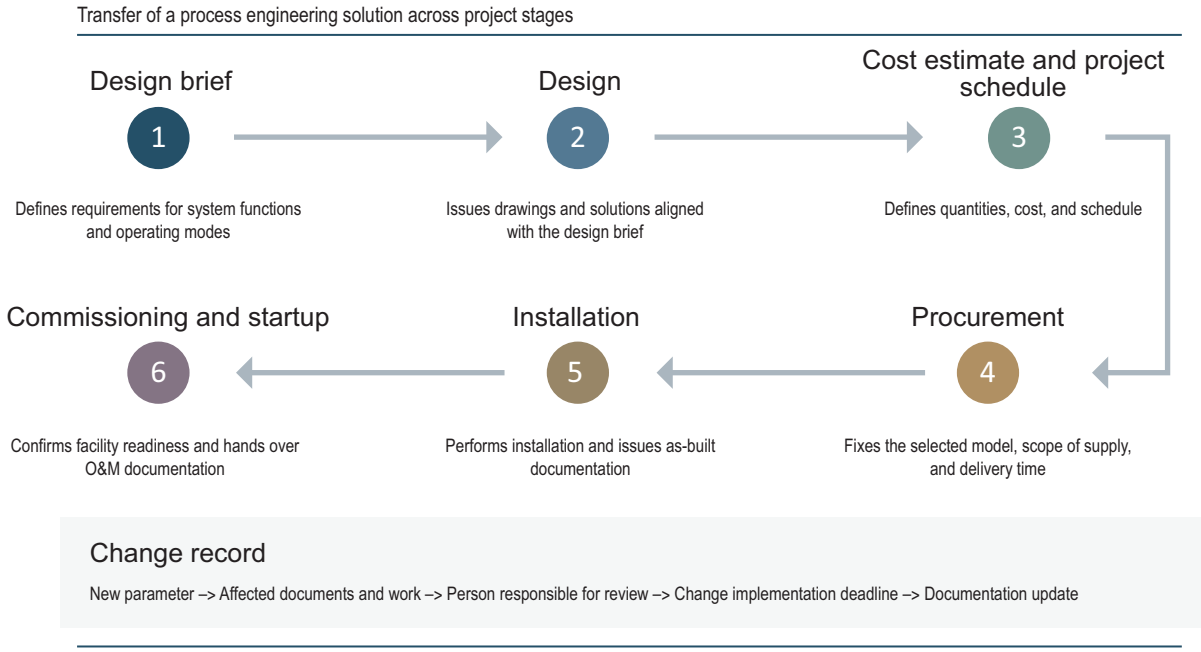
The minimum set of input data depends on the type of production process; however, for most facilities it is necessary to define equipment capacity and operating mode, requirements for process media, dimensions and weight, connection points to process and utility systems, maintenance clearances, safety requirements, and installation conditions. Reconstruction projects also require survey results, available spare capacity in utility systems, permissible outages, and constraints associated with ongoing operations. Where the design brief is incomplete, adopted assumptions should be recorded in a separate project document.

The U.S. Government Accountability Office (GAO) is an oversight agency of the U.S. Congress. Its guide describes approaches to developing and auditing cost estimates for government capital projects, including construction projects. This article uses the guide's principle that a cost estimate should be based on the project's technical baseline, work breakdown structure, and explicitly documented assumptions [9]. Design documentation and cost estimates define the scope and cost of work, while the project schedule defines the timing. Comparing these documents with the technical baseline makes it possible to verify that the work and resources required to implement the adopted process engineering solution have been included.

AACE International classifies estimates for process-industry projects according to the maturity of project definition deliverables. Class 5 is used at the conceptual stage at a level of project definition of 0–2 %; the typical accuracy range is –50 to +100 %. Class 3, used for budget authorization or control, corresponds to 10–40 % project definition, with a typical accuracy range of –20 to +30 %. Class 1 is applied at 65–100 % project definition for check estimates or bid/tender estimates, with a typical range of –10 to +15 % [10]. The level of project definition is an indicator rather than a standalone criterion: assignment to a class depends on the maturity of specific project definition deliverables, not merely on the percentage of design documentation issued.

For process industries, such deliverables include process flow diagrams, piping and instrumentation diagrams (P&IDs), and single-line diagrams (SLDs). For example, if only the capacity and type of a pump unit are defined at an early stage, the cost estimate may include the equipment and a high-level scope for its connection. After a specific model has been selected and the relevant drawings issued, the foundation, piping connections, valves, and cable routes are refined. At the same time, I/O lists for instrumentation and control (I&C) systems and the scope of installation and testing work are developed in greater detail. Replacing the unit after this stage therefore requires verification of the entire set of associated work rather than only its purchase price. The relationship between these decisions, the cost estimate, and the project schedule is shown in Fig. 3.

The pump-unit example illustrates this relationship across the entire sequence. The equipment specification defines capacity, weight, connection dimensions, and power consumption. The design documentation provides for the foundation, piping connections, valves, cable route, I/O lists for I&C and process-control systems, and



Source: compiled by the author based on [6, 7, 9–13].

Fig. 4. End-to-end verification of a process engineering solution from the design brief to facility commissioning and handover

the required maintenance clearances. The cost estimate and project schedule should include equipment installation, connection, and testing, as well as the duration of commissioning. If any item is missing, the scope of supply should be clarified or the relevant documentation revised.

The completeness of the cost estimate is checked by comparing the design brief, equipment specification, design schedules, and project schedule. This review identifies the specific work and resources required to put each item of equipment into operation. If a particular activity has no specific design basis, it should be justified by the input data and the scope of supply.

When equipment is substituted, the parameters of the original and proposed items are compared: capacity, loads, dimensions, connection points to process and utility systems, utility consumption, control-system requirements, and installation conditions. The design drawing sheets, estimate line items, schedule milestones, and contractual documents requiring update are then identified. The supply decision is made on the basis of this review, taking both equipment cost and manufacturing lead time into account.

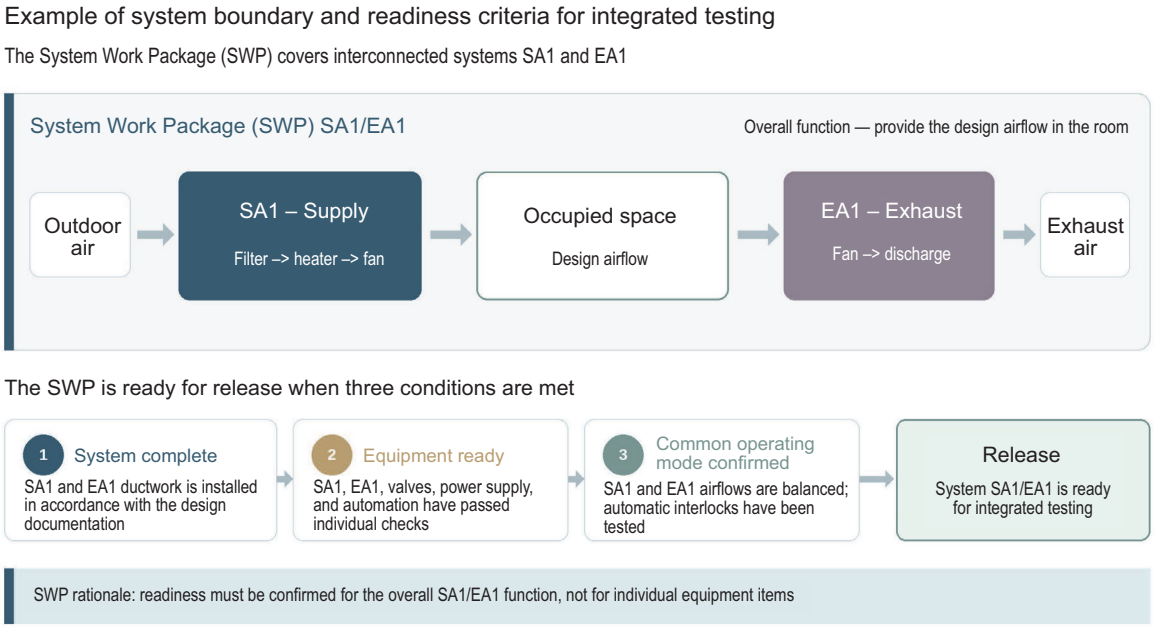
Information obtained during procurement should be reflected promptly in the design documentation and cost estimates. The supplier confirms the actual equipment dimensions and connection sizes, electrical characteristics, manufacturing lead time, service and maintenance requirements, and scope of supply. These parameters may differ from those assumed in the original specification. If the changes are not reviewed by the process engineer, design consultant, cost estimator, and automation engineer, equipment may arrive on site in a configuration that does not comply with the approved design. The overall end-to-end verification sequence is shown in Fig. 4.

Specialized installation of process equipment, process piping, I&C, and control systems requires an assessment of the specialist contractor. Before appointment, the contractor's experience on comparable facilities, qualifications of key personnel, proposed construction and installation methods and work organization, availability of the required tools and equipment, quality-control system, and scope of as-built documentation should be evaluated. This information should be aligned with the equipment delivery schedule, site readiness, and test program [2, 14].

Readiness of the installed system is confirmed before testing begins. The actual equipment positions and routing, quality of completed connections, consistency of as-built drawings with the actual installation, maintenance access, and results of prescribed checks are verified. Based on these data, a decision is made to proceed to individual testing and subsequent integrated system testing [15].

Commissioning should be incorporated into the overall project plan at an early stage and organized by system. A System Work Package (SWP) links a specific facility system to the documents and verification results required for release to integrated testing. The SWP records the system boundaries, startup sequence, existing constraints, participant roles, and readiness criteria [11]. The SWP is developed in parallel with design, procurement, and installation, allowing design, installation, and organizational readiness to be confirmed before testing begins [5, 11, 15]. The logic of the System Work Package (SWP) for supply and exhaust ventilation system SA1/EA1 is shown in Fig. 5.

O'Connor and Mock developed three models for organizing industrial facility commissioning and startup, a map of 124 activities, and a RACI (Responsible, Accountable, Consulted, and Informed) matrix covering 60 functions [13]. These results illustrate the scale of organizational tasks involved in the transition from construction completion to facility operations. Within a project, each system's readiness for commissioning is determined by equipment condition, availability of power and the required process media, readiness of control loops, completeness of test documentation, and assignment of responsible participants. The project schedule should include individual tests, rectification of identified deficiencies, integrated testing, personnel training, and handover of O&M documentation. An example of responsibility allocation among project participants is shown in Fig. 6.



Source: compiled by the author based on [11].

Fig. 5. Logic of the System Work Package (SWP) for supply and exhaust ventilation system SA1/EA1: system boundary, readiness confirmation, and release to integrated testing

Activity	Owner	Design organization	Installation contractor	Commissioning organization	Operatining organization
Preparation of the design brief	A/R	I/R	I	I	C
Design	C	A/R	I	I	I
Installation	A	C	R	I	I
Development of process control algorithms	A	R	I	C	C
Commissioning	A	I	C	R	I
Handover of as-built and operating documentation	A	C	R	R	C

R Performs A Approves and is accountable C Consulted I Informed

Role allocation is refined to reflect the contractual structure of the specific project

Source: compiled by the author based on [13].

Fig. 6. Illustrative RACI fragment for commissioning preparation and execution

Role allocation among participants should be complemented by a defined change communication procedure. If a supplier or process engineer changes an input parameter, the project team should record which documents and work packages require additional review, who is responsible for that review, and the deadline for completion.

Shokri et al. define systematic interface management as the management of communications, relationships, and deliverables transferred between project participants. Their study was based on structured interviews covering 46 projects. Systematic interface management was more frequently applied on large industrial projects with many participants; for this group, both the average cost growth and the variation in cost growth were lower [12]. In the context of this study, participant interaction when a pump unit is substituted can be illustrated as follows.

For example, a supplier proposes an alternative to a previously selected pump unit. The corresponding change-log entry links the supplier, process engineer, design consultant, cost estimator, procurement specialist, and contractor. It records the new unit parameters, design drawing sheets and estimate line items to be reviewed, the response deadline, and the final decision. This creates a change workflow from the supplier's proposal through its

incorporation into detailed design documents, procurement procedures, and construction and installation.

The change log includes revisions that affect the configuration of the process engineering solution, cost, schedule, installation method, control systems, or facility startup conditions. For each entry, the team should confirm that the design documentation, cost estimates, procurement documentation, project schedule, and the document set required for execution have been updated. A change record may be closed once it is confirmed that all participants have received the current information.

Taken together, the approaches considered provide a framework for managing a process engineering solution from future operating requirements through the development of input data and across the entire industrial project life cycle. The manufacturing process defines requirements for the design brief and design decisions. PDRI supports assessment of input-data completeness; AWP and WFP align design, procurement, and installation; and System Work Packages (SWPs), interface management, and the change log support facility preparation for commissioning and the communication of change information between participants. The object of end-to-end control is the process engineering solution and the consistency of its parameters across all project stages.

CONCLUSIONS

The analysis shows that the management framework for industrial capital construction projects should account for the process-specific characteristics of the facility's intended production function. The parameters and process requirements of future operation should be fully reflected in the input data and design brief and then controlled consistently during the development and approval of design documentation and cost estimates, procurement, construction and installation, process control and automation, and commissioning. The applied scientific contribution of the study is the systematization of this end-to-end verification around a single object of control — the process engineering solution.

1. The manufacturing process creates interrelated requirements for building structures, utility systems, equipment, cost estimates, procurement procedures, construction and installation, and preparation of the facility for startup. Therefore, equipment substitution or a change in the process cannot be treated as an isolated revision to a single design discipline.

2. End-to-end verification should link each key parameter of the process engineering solution to its source input data, affected documents, responsible participant, and confirmation deadline. Comparison of the design brief, design documentation and cost estimates, and the project schedule makes it possible to identify missing work and resources before construction, installation, and commissioning begin.

3. PDRI, AWP/WFP, System Work Packages (SWPs), and interface management perform complementary functions: they support assessment of input-data completeness, control of workface readiness, and transfer of changes among project participants. The change log records these operations for a specific process engineering solution.

4. Design documentation and cost estimates, on the one hand, and commissioning readiness, on the other, form two control points in the end-to-end verification process. The first confirms that the selected configuration of the process engineering solution is supported by the required budget and reflected in the project schedule; the second confirms that equipment, process media, control systems, documentation, and responsible participants are ready for testing and facility startup.

The proposed systematization is analytical and applied in nature. Further validation requires anonymized project case studies to determine which control questions most effectively identify inconsistencies in a process engineering solution before construction and installation or commissioning begins.

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Особенности управления технологическими решениями в инвестиционных проектах промышленного строительства

Инвестиционный проект промышленного строительства (ИППС) направлен на создание производственной системы, в которой строительные объекты, инженерные сети, технологическое оборудование, автоматизация и персонал обеспечивают выпуск промышленной продукции в заданном режиме. В статье рассмотрено, как механизмы выбора технологических решений влияют на проектные решения, стоимостные параметры, процедуры закупок, процессы специализированного монтажа, АСУ ТП и пусконаладочные работы.

Проанализированы управленческие особенности ИППС и порядок сквозной проверки технологических решений от технического задания на проектирование до запуска эксплуатации промышленного объекта. Исследование основано на анализе нормативных документов, отраслевых стандартов и научных публикаций по ранней проработке проектов, организации работ, оценке стоимости, управлению согласованиями и пуску промышленных объектов.

В качестве критерия достижения результата ИППС принята способность объекта выполнять предусмотренную производственную функцию. Технологическое решение предложено рассматривать как единый предмет контроля в рамках ТЗ, ПСД, закупок, СМР, документации АСУ ТП и при выполнении ПНР. Результаты могут использоваться заказчиком, техническим заказчиком, проектировщиком и подрядчиком при формировании исходных данных, согласовании аналогов оборудования, подготовке бюджета и организации запуска объекта.

Ключевые слова: *инвестиционный проект промышленного строительства, технологические решения, техническое задание, проектная и сметная документация (ПСД), управление стоимостью, технологическое оборудование, строительно-монтажные работы (СМР), закупки, АСУ ТП, пусконаладочные работы, управление изменениями*

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Об авторах: **Козлов Илья Сергеевич** — магистрант кафедры организации строительства и управления недвижимостью; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; kozlov.i.s@tsenastroyki.ru;

Беляков Сергей Игоревич — доктор экономических наук, профессор, доцент; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; РИНЦ ID: 587836, Scopus AuthorID: 39763951700, ORCID: 0000-0001-5179-737X; BelyakovSI@mgsu.ru.

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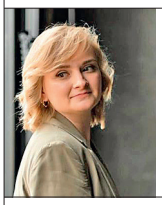
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Dekhtyar E.V.
Pushkova E.A.

Forecasting and Optimization of Technological Process Parameters for the Construction of Monolithic Residential Buildings Considering Organizational and Technological Reliability Requirements

This paper examines forecasting and optimization of technological-process parameters in the construction of monolithic residential buildings, considering the requirements of organizational and technological reliability. The relevance of the study is determined by the significant dependence of construction duration and production stability on the alignment of scheduling, technological, and resource-related decisions.
Achieving the required outcomes in monolithic residential construction directly depends on the quality of work organization. Effective work organization depends on workflow continuity, the availability and timely delivery of materials, the appropriate allocation of work crews, and the consistent performance of operations in designated work areas. The purpose of this study is to identify the factors that have the greatest impact on organizational and technological reliability and to forecast and optimize the parameters of technological processes.
The paper presents the results of an expert assessment involving the ranking of technological, organizational, resource-related, personnel, and external factors. The assessment was conducted among seven construction industry specialists, followed by the calculation of mean rank values and Kendall's coefficient of concordance, which indicates the degree of agreement among expert opinions.
The findings showed that the alignment of the construction schedule with resource provision, consistency of the technological sequence, workers' qualifications, resource availability, and their timely delivery to the construction site are key factors in ensuring organizational and technological reliability. The combined weight of these factors was 64.09 %, while Kendall's coefficient of concordance was $W = 0.87$, confirming a high level of agreement among the experts. The analysis of the expert assessment results confirms that organizational and technological parameters should be forecast with due regard for the specific conditions of the construction site. The practical significance of the proposed approach lies in its applicability to the development of construction schedules and construction work execution plans.
Keywords: *monolithic residential construction, organizational and technological reliability, construction scheduling, technological process, expert ranking, optimization, resource provision, forecasting*



Dekhtyar Ekaterina Vladislavovna,
Senior lecturer, Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; ID RSCI: 921719, Scopus AuthorID: 57216582395, ORCID: 0000-0001-9650-4083; dekhtyarev@mgsu.ru



Pushkova Eseniya Aleksandrovna,
2nd year student, groups 2m-9 of The Institute of Economics, Management and Communications in Construction and Real Estate; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; ID RSCI: 7044-2528; PushkovaEA@mgsu.ru

Monolithic (cast-in-situ) housing construction occupies a stable position in the structure of modern residential development, since it combines structural versatility, wide architectural and space-planning possibilities, and technological adaptability to urban development conditions [1]. At the same time, the processes involved in erecting monolithic residential buildings are among the most complex from the standpoint of production organization, as they include repeatedly recurring cycles that are rigidly linked in terms of time, work fronts, composition of performers, and provision of material and technical resources [2]. Under these conditions, the quality of technological process design directly affects not only the construction duration, but also the feasibility of implementing the adopted decisions in a real production environment [3].

Construction practice shows that schedule deviations in the erection of monolithic facilities are in many cases caused not only by external influences, but also by insufficient accuracy in determining the parameters of organizational and technological solutions at the construction preparation stage [4]. Overestimated work intensity, inconsistency of cycles, irrational division of the facility into work zones, a shortage of formwork sets, disruptions in material delivery schedules, and inadequate coordination of labour resources with the construction schedule lead to idle time, shifts in the sequence of operations, and the accumulation of delays across floors and sections. Consequently, meeting the required construction deadlines is impossible without preliminary forecasting of the key parameters of the technological process and their subsequent selection based on criteria of organizational and technological reliability [5].

In contemporary sources, organizational and technological reliability is regarded as a characteristic of construction production that reflects the ability of the adopted system of work organization and technology to ensure the achievement of the planned result within given time, resource, and production constraints [6].

This approach is fundamental in monolithic housing construction, since the efficiency of work execution here depends not only on individual operations, but also on the quality of their coordination within the overall workflow.

Organizational and technological reliability implies not only compliance with regulatory requirements, but also verification of the feasibility of the selected scheme in practice with reference to the specific conditions of the construction site.

Organizational and technological reliability is ensured by a combination of factors, the key ones being those related to resource provision, the organization

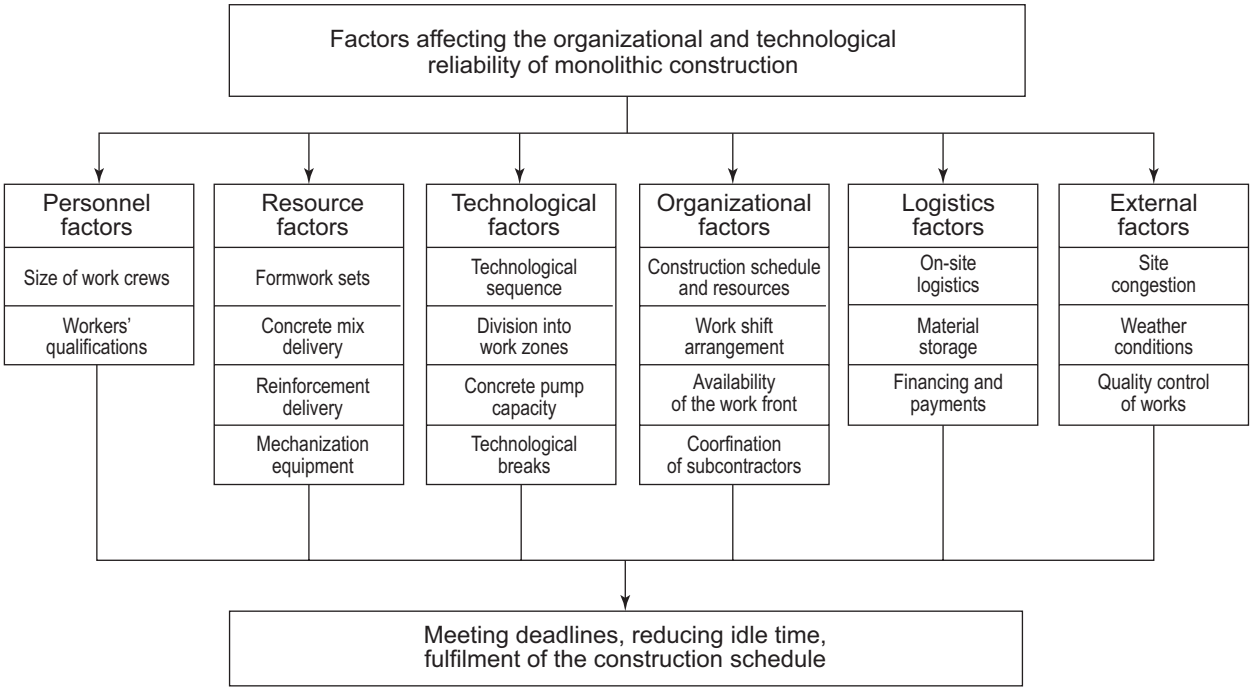


Fig. 1. Factors affecting organizational and technological reliability in the construction of monolithic residential buildings

of the construction flow, and the soundness of construction scheduling [7]. A distinctive feature of monolithic works is the dependence of each subsequent work cycle on the completion of the preceding one. For this reason, any deviation in the duration of individual operations may cause a shift in the entire work execution schedule [8]. Consequently, organizational and technological reliability must be considered as a basic criterion for substantiating the parameters of work organization [9].

The set of principal groups of factors that determine the organizational and technological reliability of monolithic construction and affect the fulfilment of the construction schedule is presented in Fig. 1.

In order to identify the factors exerting the most significant influence on the organizational and technological reliability of erecting monolithic residential buildings, an expert ranking of twenty organizational, technological, resource-related, personnel, and external

Table 1. Results of the expert ranking

Number	Factor	E_1	E_2	E_3	E_4	E_5	E_6	E_7	R_i	Mean rank	Rank	w, %
1	Availability of formwork sets	4	1	6	2	4	7	2	26	3.71	4	9.60
2	Alignment of the construction schedule with resource provision	1	3	4	1	2	3	6	20	2.86	1	12.48
3	Consistency of the technological sequence	3	2	3	7	1	2	4	22	3.14	2	11.35
4	Timely delivery of the concrete mix	2	5	1	3	9	1	1	22	3.14	3	11.35
5	Timely delivery of reinforcement	7	4	8	4	3	4	3	33	4.71	5	7.57
6	Size of work crews	5	7	2	5	5	6	7	37	5.29	6	6.75
7	Workers' qualifications	9	9	5	6	11	5	5	50	7.14	7	4.99
8	Rational division of the facility into work zones	6	10	9	8	8	11	9	61	8.71	9	4.09
9	Concrete pump capacity	11	6	7	9	6	8	12	59	8.43	8	4.23
10	Serviceability of mechanization equipment	8	8	13	10	10	10	8	67	9.57	10	3.73
11	Work shift arrangement	12	11	15	12	7	9	11	77	11.00	11	3.24
12	Duration of technological breaks	14	15	17	16	13	15	10	100	14.29	14	2.50
13	On-site logistics	13	12	10	11	14	14	13	87	12.43	12	2.87
14	Material storage conditions	10	14	19	13	12	13	14	95	13.57	13	2.63
15	Construction site congestion	15	17	14	17	19	12	15	109	15.57	15	2.29
16	Weather conditions	19	18	12	18	15	18	17	117	16.71	17	2.13
17	Availability of the work front	17	16	18	15	18	16	16	116	16.57	16	2.15
18	Coordination of subcontractors	16	20	11	19	17	20	18	121	17.29	18	2.06
19	Quality control of works	20	19	20	14	16	17	20	126	18.00	20	1.98
20	Financing and payment discipline	18	13	16	20	20	19	19	125	17.86	19	2.00

factors was carried out. The assessment was performed on a rank scale from 1 to 20, where a lower rank corresponds to a greater degree of influence of the factor on the completion of monolithic works within the planned time (Table 1).

Based on the processing of the expert estimates, the seven most significant factors were found to be: the soundness of construction scheduling, consistency of the technological sequence, timely delivery of the concrete mix, availability of formwork sets, timely delivery of reinforcement, and the size and qualifications of work crews. The combined weight of these factors amounted to 64.09 %, which allows them to be treated as priorities in the development and adjustment of organizational and technological solutions.

Consistency of the expert estimates was verified using Kendall's coefficient of concordance. The value $W = 0.870$ indicates a high degree of agreement among the expert opinions. The result obtained confirms the appropriateness of using the identified factors as a basis for forecasting and optimizing the parameters of technological processes for erecting monolithic residential buildings.

The assessment covers 20 factors affecting the organizational and technological reliability of monolithic construction. The expert group nominally consists of 7 specialists: work superintendents, construction site managers, engineers of the production and technical department, and construction scheduling specialists.

Each expert assigns ranks from 1 to 20:

1 — the factor with the greatest influence;

20 — the factor with the least influence.

Overall significance is determined by the sum of ranks R_i: the smaller it is, the higher the priority of the factor.

The reciprocal of the mean rank was used to calculate the relative weight:

$$q_i = \frac{1}{\overline{r}_i},$$

where q_i is the calculated significance of the i-th factor;

$\overline{r}_i$ is the mean rank of the factor.

The relative weight was determined by the formula:

$$w_i = \frac{q_i}{\sum_{i=1}^{20} q_i} \cdot 100\ \%.$$

The calculations identified the 7 most significant factors (Table 2).

Table 2. Most significant factors

Rank	Priority factor	w, %
1	Alignment of the construction schedule with resource provision	12.48
2	Consistency of the technological sequence	11.35
2	Timely delivery of the concrete mix	11.35
4	Availability of formwork sets	9.60
5	Timely delivery of reinforcement	7.57
6	Size of work crews	6.75
7	Workers' qualifications	4.99

Combined weight of the seven factors:

$$\sum w_i = 12.48 + 11.35 + 11.35 + 9.60 + 7.57 + 6.75 + 4.99 = 64.09\ \%.$$

Thus, the seven priority factors account for 64.09 % of the calculated aggregate significance of the conditions under consideration.

The mean sum of ranks is determined by the expression:

$$\overline{R} = \frac{m(n+1)}{2},$$

where $m = 7$ is the number of experts;

$n = 20$ is the number of factors.

$$\overline{R} = \frac{7(20+1)}{2} = 73.5.$$

Sum of squared deviations of the rank sums:

$$S = \sum_{i=1}^{n} (R_i - \overline{R})^2 = 28{,}339.$$

Kendall's coefficient of concordance:

$$W = \frac{12S}{m^2\left(n^3 - n\right)};$$

$$W = \frac{12 \cdot 28{,}339}{7^2(20^3 - 20)} = 0.870.$$

The value obtained, $W = 0.870$, indicates a high consistency of the ranking: the opinions of the expert group largely coincide.

In addition, the criterion of statistical significance is calculated by the expression:

$$\chi^2 = m(n-1)W;$$

$$\chi^2 = 7 \cdot 19 \cdot 0.870 = 115.67.$$

With the number of degrees of freedom $f = n - 1 = 19$, the calculated value considerably exceeds the critical values for common significance levels. Therefore, the hypothesis that the coincidence of ranks is random is rejected; the consistency of the estimates can be recognized as statistically significant.

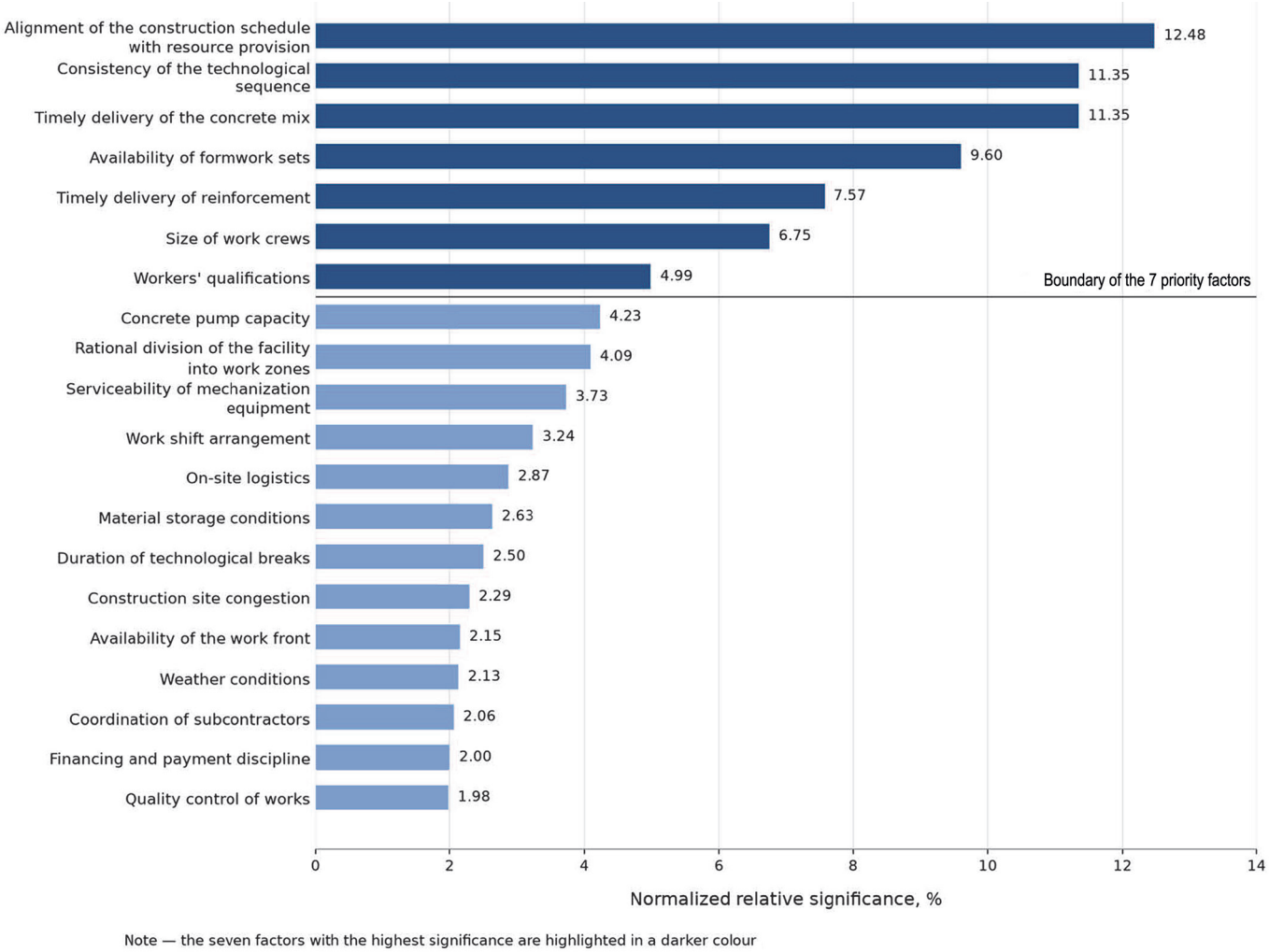
To present the results of the expert ranking in a visual form, a graphical distribution of the factors according to their normalized relative significance was produced. The diagram makes it possible to compare the contribution of each of the twenty factors considered to ensuring the organizational and technological reliability of erecting monolithic residential buildings, and to distinguish the group of priority factors that require primary consideration when developing scheduling and resource-related solutions.

The results of ranking the factors by the value of their normalized relative significance are presented in Fig. 2. The darker colour highlights the seven factors whose combined significance amounts to 64.09 % and which are recommended for consideration as the main parameters in forecasting and optimizing the technological processes of monolithic construction.

When developing organizational and technological solutions for a residential building, the forecasting of technological process parameters is of primary importance; its main task is to determine such values of duration, intensity, and resource provision as most closely reflect the actual situation of work execution on the construction site [10].

The forecast parameters should include those of cyclicity, resource provision, and mechanization of works, since these parameters are fundamental in forming the construction schedule and create the conditions for preventing deviations in work completion dates. The scheme for forming and optimizing technological processes on the construction site is presented in Fig. 3.

The forecasting of parameters should not be based solely on the data of regulatory documents; the experience of already



Note — the seven factors with the highest significance are highlighted in a darker colour

Fig. 2. Ranking of the factors affecting the organizational and technological reliability of erecting monolithic residential buildings

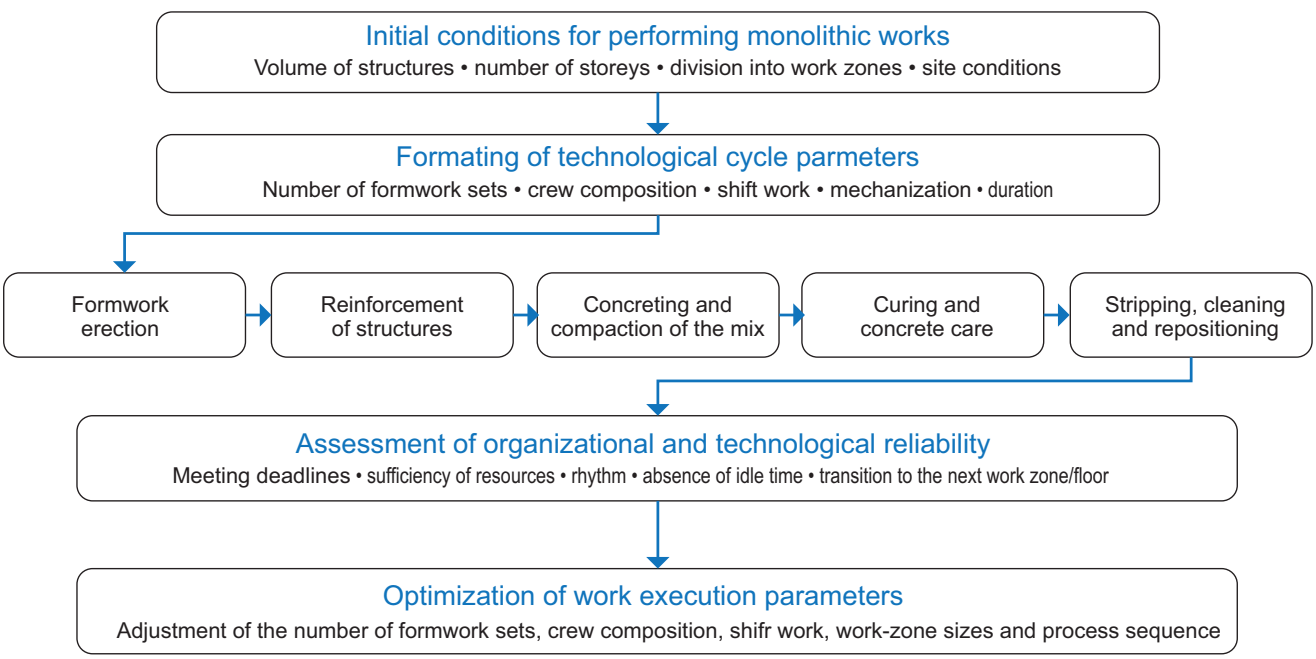


Fig. 3. Scheme for forming and optimizing technological processes on the construction site

completed analogous facilities and the specific features of organizational and production conditions should also be taken into account. Such an approach makes it possible to avoid the direct transfer of regulatory values to a particular facility and strengthens the evidence base of the decisions taken. This approach is especially relevant for monolithic construction, since the actual duration of processes depends on the volumetric and space-planning solution of the facility, the degree of site congestion, the rationality of the material and technical supply scheme, the contractor's work regime, and the adopted scheme of interaction between individual construction flows. It follows that the effectiveness of forecasting is based not only on the completeness of the initial data, but also on the rational coordination of technological parameters with the organizational conditions under which the project is implemented [11].

The further elaboration of organizational and technological solutions is directly linked to the optimization of technological process parameters. In practice, optimization should be regarded as the selection of a scheme for performing monolithic works that achieves the most rational balance between the duration of work execution and the use of resources, while complying with the requirements of organizational and technological reliability. This implies that reducing the construction duration should not become the ultimate goal of achieving it requires excessive compression of the schedule, which would lead to the overloading of work crews and to other consequences that reduce the feasibility and efficiency of the adopted organizational solution [12]. On the contrary, preference should be given to organizational and technological schemes in which the works are performed within the established time limits, at a coordinated production rate and with rational use of resources [13].

The parameters and number of work zones, the sequence of works by sections and floors, the number of formwork system sets, the labour organization regime, the composition of work crews, and the distribution of duration among the key production cycles are the most significant parameters subject to optimization. Changes in these parameters determine the rhythm of the construction process, the rational use of labour and technical resources, the duration of critical works, and the continuity of subsequent operations [14]. It follows from the above that the choice of a work organization scheme should be based on a comparative analysis of schemes differing in the structure of the construction flow and in resource provision. The most appropriate option is one in which the established scope of work is completed on time, without disrupting the sequence of technological processes [15, 16].

At the stage of organizational and technological planning, it is necessary to formulate a baseline work organization option that reflects the structure of the construction flows and specifies the work zones, the sequence of works, the composition of work crews, and the structure of provision with material and technical resources. At subsequent stages, the calculated parameters are determined and then adjusted in accordance with the conditions of the particular site, the level of resource provision, and the established construction duration. A comparative analysis of work organization options makes it possible to substantiate the choice of the optimal solution that most fully meets the requirements of organizational and technological reliability and the actual conditions of work execution.

This approach is particularly relevant in the erection of monolithic residential buildings, since they are characterized by the repeatability of work cycles, and therefore any organizational error may affect the duration of work execution. An example is the incorrect determination of the throughput capacity of individual flows. The deviations that occur may be reproduced on subsequent floors and accumulate towards completion. It follows that, in practice, the forecasting and optimization of technological process parameters make it possible to reduce the likelihood of such deviations and to increase the effectiveness of the use of the contractor's production resources.

On the basis of the above, the forecasting and optimization of technological process parameters in construction act as interrelated elements of the system of organizational and technological design.

Their combined application makes it possible to move from the formal assignment of regulatory parameters to a more substantiated choice of production solutions that takes into account the specific features of the facility, the structure of the construction flow, and the actual conditions of the construction site. In this context, organizational and technological reliability serves as the key criterion for assessing the quality of such solutions, since it reflects the possibility of their practical implementation within the given time limits and resources. Taking this requirement into account when developing organizational and technological documentation contributes to increasing the reliability of schedule calculations, reducing organizational losses, and improving the practice of erecting monolithic residential buildings.

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Прогнозирование и оптимизация параметров технологических процессов возведения монолитных жилых зданий с учетом требований организационно-технологической надежности

В статье рассматривается задача прогнозирования и оптимизации параметров технологических процессов при возведении монолитных жилых зданий с учетом требований организационно-технологической надежности. Актуальность исследования обусловлена высокой зависимостью сроков и устойчивости строительного производства от согласованности календарных, технологических и ресурсных решений.

Достижение требуемого результата в процессе выполнения работ в монолитном жилищном строительстве напрямую зависит от качественной организации работ, которая характеризуется такими факторами, как ритмичность потока, обеспеченность материалами и их своевременное предоставление, рациональное распределение рабочих звеньев, а также последовательное выполнение операций на захватках. Выявление факторов, оказывающих наибольшее влияние на организационно-технологическую надежность, прогнозирование и оптимизация параметров технологических процессов являются целью данного исследования.

В статье представлены результаты экспертной оценки, которая представляет собой ранжирование технологических, организационных, ресурсных, кадровых и внешних факторов. Экспертная оценка была проведена среди семи специалистов строительной отрасли с последующим расчетом среднего значения рангов и коэффициента конкордации Кендалла, означающим согласованность мнений экспертов.

Итоги исследования выявили, что согласованность календарного плана с ресурсным обеспечением, согласованность технологической последовательности, квалификация рабочих, обеспеченность ресурсами и их своевременная поставка на площадку являются ключевыми факторами обеспечения организационно-технологической надежности. Совокупный вес факторов составил 64,09 %, коэффициент конкордации $W = 0,87$, что подтверждает высокую согласованность экспертных оценок. Анализ результатов экспертной оценки подтверждает, что прогнозирование организационно-технологических параметров должно осуществляться с учетом конкретных условий строительной площадки. Возможность применения данного подхода представляет собой практическую значимость при разработке календарных планов, проектов производства работ.

Ключевые слова: *монолитное жилищное строительство, организационно-технологическая надежность, календарное планирование, технологический процесс, экспертное ранжирование, оптимизация, ресурсное обеспечение, прогнозирование*

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Об авторах: **Дехтярь Екатерина Владиславовна** — старший преподаватель кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; РИНЦ ID: 921719, Scopus AuthorID: 57216582395, ORCID: 0000-0001-9650-4083; dekhtyarev@mgsu.ru;

Пушкова Есения Александровна — студентка 2 курса, институт ЭУКСН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; РИНЦ ID: 7044-2528; PushkovaEA@mgsu.ru.

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Orymbayev D.N.
Prykina L.V.

Development of a methodology for reducing the duration of life cycle stages of housing construction projects

The national project “Infrastructure for Life” sets a target investment-construction cycle duration for multi-apartment residential buildings (MRB) at no more than 1,000 days by 2030; the actual figure fell from 2,181 days in 2021 to 1,253 days in 2025. The heterogeneity of delivery — from zero delay to one-third overrun — reveals a methodological gap: no unified calculation tool links the compression of life cycle stages with the integral economic effect and with the quality of handover of the information model to operation. The paper develops such a methodology for industrial MRB. The apparatus combines a seven-stage decomposition of the investment-construction phase; an additive-multiplicative convolution of three tool groups (BIM, Lean Construction, organizational-technological modelling) through coupling coefficients; and a penalty function for as-built degradation capitalized over a 50-year operational horizon. Trial calculation for a 17-storey, 18,000 m² MRB yields a 22–28 % ICC reduction potential combined with a 3.5–7.5 % NPV uplift over the life cycle — conditional on maintaining digital twin maturity at no lower than L2 by Deng – Menassa – Kamat. The novelty is a two-contour control of “T + NPV” through coupling coefficients and a critical threshold that compensates OPEX loss by construction-phase time gains. The methodology is applicable to developers operating under Federal Law 214-FZ and in integrated territorial development projects.

Keywords: *building life cycle, multi-apartment residential building, investment-construction cycle, life cycle cost, building information modelling, digital twin, net present value, lean construction, organizational-technological modelling, integrated territorial development*



Orymbayev Daken Nurlanovich,
Postgraduate student, Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation;
ORCID: 0009-0007-4318-6967;
daken29.12.98@gmail.com



Prykina Larisa Viktorovna,
Doctor of Economics, Professor of the Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation;
ID RSCI: 416224,
Scopus AuthorID: 6505996610,
ORCID: 0000-0003-3666-3140;
daken29.12.98@gmail.com

INTRODUCTION

The target duration of the investment and construction cycle for an apartment building (AB), as established by the national project “Infrastructure for Life” with a start date of January 1, 2025, is 1,000 days. For comparison: in 2021, the average duration was 2,181 days; in 2024, it was about 1,500 days; and in 2025, it dropped to 1,253 days. The dynamics are noticeable. However, behind the aggregated figures, there is a significant variation between developers and property types.

According to the ERZ.RF[1], in 2025, 724 out of 1,430 developers handed over new buildings with a delay. The weighted average construction period for one house is 827 days (≈27.2 months), and from the date of the construction permit to commissioning is 43 months and 15 days. This indicator is significantly lower for the leaders of the rating: 621 days for “Unistroy”, 682 for FGC, 789 for PIK. The gap between the industry benchmark and typical practice reaches 30–40 %, and this gap is manageable.

At the same time, the scientific literature summarizing the effects of three groups of tools — TIM, Lean Construction and organizational and technological modelling (OTM) — is developing separately. The MGSU school leads the line of an organizational and technological platform and a deterministic model of construction production [1, 2]. St. Petersburg authors formalize calendar and network planning on 4D models [3]. Foreign studies outline the boundaries of fast-tracking and nonlinear trade-off time-cost [4].

To date, no single calculation model has been proposed that links the reduction in the duration of the MRB life cycle to the contribution of each tool and, more importantly, to the quality of transferring the as-built model into operation.

In our view, it is precisely this latter circumstance that makes the task non-trivial. Accelerating the investment and construction phase without concurrent management of the operational stage turns time savings into hidden operational losses: over a 50-year horizon, CAPEX covers only 15–25 % of the total cost of owning an apartment building, while operations account for 70–80 % [5]. Shortening the schedule in a way that creates “gaps” in the information model or engineering solutions ultimately results in OPEX that is several times higher, thereby negating the benefits achieved.

The goal of the work is to develop a methodology that links the duration of the stages of the life cycle of an apartment building not only to the integral reduction indicator but also to the net present value (NPV) of the total cost of ownership over a 50-year horizon. Objectives: to carry out a decomposition of the investment and construction phase of the MRB life cycle; to systematize empirical estimates of reduction for each tool; to build a “stage × tool” applicability matrix with coupling coefficients; to formulate a calculation model for integral reduction; to link it to a penalty function reflecting the degradation of the quality of transferring the as-built project into operation; to conduct testing on a hypothetical project.

The scientific novelty of this study lies in the two-loop description of management: the first loop (ΔT) expresses the reduction of duration

[1] ERZ.RF. URL: https://erzrf.ru/top-zastroyshchikov/rf?topType=1&date=2025&regionKey=0

through an additive-multiplicative convolution of tools; the second (ΔNPV) imposes a quality constraint that does not allow acceleration at the cost of capitalized operating losses. Both loops are closed via the level of maturity of the digital twin, which is interpreted as a technical parameter of the methodology.

LITERATURE REVIEW

Relevant works are divided into four blocks: digital modelling and BIM; lean construction; organizational and technological modelling; life cycle economics and digital twins of the operational phase.

BIM and digital modelling. E.A. Gusakova formulated the concept of modelling the life cycle using information flows, within the framework of which reducing data losses between stages directly accelerates the transfer of work [6]. A.R. Kulakov and V.A. Akristiniy described the mechanisms for applying BIM at certain stages of the life cycle of a development project in the Vestnik "Real Estate: Economics, Management" [7]. V.V. Galishnikova and M.E. Bocharov traced the evolution of information models and substantiated the requirement for their continuity throughout the entire life cycle [8]. Empirical assessments — a 25–50 % reduction in the number of requests for information (RFI), a 60 % reduction in the number of design changes, a 30–80 % reduction in design errors, a 20 % reduction in schedule duration, and a 15 % reduction in estimated costs — are compiled in a summary study in Discover Materials [9]; N. Moazzen, T. Ashrafian and M.E. Karagüler achieved a 55 % reduction in primary energy and a 45 % reduction in LC CO_2 for a five-story residential building in Turkey using the nZEB package [10].

Lean construction. The Last Planner System (LPS), developed by G. Bollard, increases the percentage of PPC (percentage plan complete) from the typical 50 % to 70–85 % and the associated performance by 15–25 %. For the housing segment, the key reference point is the work of Yu. Lehtovaary and O. Seppyanena: the introduction of tact planning in multi-apartment construction reduces the finishing phase already on the first project [11]. The Russian adaptation of Lean is reflected in the works of T.S. Meshcheryakova and V.V. Kuzuzov [12], K.Yu. Kulakov, A.K. Orlov and V.S. Kankhva [13].

OTM. The school of A.A. Lapidus develops the concept of an organizational and technological platform for construction, which integrates a deterministic organizational model with digital resources [1]. M.V. Zhdanova and A.A. Lapidus presented a three-stage life cycle model with three types of relationships — sequential, overlapping, and iterative — and identified "reduction points" [2]. S.V. Bovteev and co-authors formalized calendar-network planning using 4D models, in which control of spatio-temporal conflicts increases organizational and technological reliability [3]. The key foreign limitation was set by P. Ballesteros-Pйrez: the realistic limit for schedule reduction due to fast-tracking is ≈ 25 % of the original duration, and concurrent design without adequate information support increases the probability of project failure by four times [4].

Life cycle economics and digital twins. E.P. Gorbaneva, I.A. Kosovtseva, T.V. Kstenin substantiated the NPV criterion when selecting energy-saving measures in the full life cycle of a facility [14]. I.V. Kushchenko and E.A. Bocharova developed an LCC modelling algorithm taking into account the risks of technical and economic security [15]. R.V. Volkov applied the Verhulst model to manage the life cycle of real estate [16]. L.A. Adamcevich demonstrated the necessity of continuity in the "design – construction – operation" stages in RCD projects [17]. The work by P. Ylmén, J. Berlin, K. Mjörnell, J. Arfvidsson (Buildings, MDPI) provides quantitative sensitivity of LCC to the discount rate: a reduction in r from 7 to 3 % increases LCC by 18 % over a 50-year horizon [5]. M. Deng, C.C. Menassa, V.R. Kamat proposed a five-level maturity ladder L1–L5 for applying BIM/DT in the design–operation cycle; most of the claimed "doubles" in the AEC sector correspond to L2–L3 [18]. H.H. Hosamo and co-authors achieved predictive diagnostic accuracy of ~95 % and a 20 % extension of component service life in two AHU systems in Norwegian public buildings [19].

The review reveals a persistent gap. The quantitative effects for each instrument have been verified, but an integral calculation framework linking them to the stages of the life cycle of a specific type of building — namely, MRB — and to the quality of handing over the as-built project into operation is not available in the open literature. This gap is what we are trying to close.

MATERIALS AND METHODS

The methodology consists of three blocks, connected parametrically.

LIFE CYCLE DECOMPOSITION

The investment and construction phase of the life cycle of an apartment building is divided into seven stages:

- pre-project preparation and urban planning approvals;
- engineering surveys;
- design;
- examination of project documentation;
- preparatory period and mobilization;
- construction and installation works;
- commissioning and putting into operation (7).

The operational phase is accounted for separately — through a quality penalty function, rather than as a stage with an internal duration; the basis is SP 333.1325800.2020[2], which treats operation as a continuous information process.

For each stage, the standard duration T_j^{norm} is determined (according to SNIP 1.04.03–85*[3] with extension factors and SP 48.13330.2019[4] as amended in 2025) and the empirical duration T_j^{emp} (based on data from EPZ.RF[1], Main State Expertise, and analytics from DOM.RF[5]). The difference forms the absolute reserve for the stage.

APPLICABILITY MATRIX AND CALCULATION MODEL FOR REDUCTION (BLOCK A)

A matrix k_{ij} has been constructed, where $i \in$ {TIM, Lean, OTM} is a tool, and $j \in \{1...7\}$ is a stage of the life cycle. The coefficient $k_{ij} \in [0; 1]$ reflects the proportion of the stage duration to which the tool's effect applies.

The integral reduction in the duration of the ISC is expressed by an additive-multiplicative convolution:

$$\Delta T_{ЖЦ} = \Sigma_j[w_j \cdot T_j^{norm} \cdot (1 - \Pi_i(1 - k_{ij} \cdot \varepsilon_i \cdot c_{ij}))], \quad (1)$$

where w_j is the weight of the stage in the total duration ($\Sigma w_j = 1$); T_j^{norm} is the standard duration of the j-th stage; ε_i is the verified

[2] SP 333.1325800.2020. URL: https://expert.tmbreg.ru/files/Gosudarstvenn/sp_333.pdf

[3] SNIP 1.04.03–85*. URL: https://kmdrus.ru/uploads/snip/5.СНиП_1.04.03-85.pdf

[4] SP 48.13330.2019. URL: https://www.all-sro.ru/Resources/Files/СП%2048.13330.2019.%20Свод%20правил.%20Организация%20строительства..pdf

[5] DOM.RF. URL: https://domrfbank.ru/for-developers/project-finance/

empirical reduction coefficient for the i-th tool; c_{ij} is the coupling coefficient, reflecting the mutual reinforcement or conflicting overlap of tools at the stage. The multiplicative form $(1 - \prod(1 - \ldots))$ eliminates the arithmetic addition of effects, which leads to overestimated values, and treats the simultaneous use of several tools as the probability of processing the duration by at least one of them. The arithmetic sum is methodologically incorrect here: if two tools each yield 20 %, their "sum" of 40 % assumes that they independently cut the same duration twice, whereas in reality they compete for the same resource.

The initial values are taken from the lower bounds of the empirical intervals to avoid overestimation: $\varepsilon_{TIM} = 0.20$ [9, 10]; $\varepsilon_{Lean} = 0.20$ [11]; $\varepsilon_{OTM} = 0.15$ [4] — adjusted for the limitation of fast-tracking. Conservatism is a fundamental choice: the upper bounds of the empirical intervals refer to foreign cases and are not directly transferred to the Russian institutional environment.

PENALTY FUNCTION OF QUALITY AND THE RELATIONSHIP $\Delta T \leftrightarrow \Delta$NPV (BLOCK B)

The reduction in the investment and construction phase is assessed not only in terms of time but also in monetary terms. The increase in NPV resulting from the reduction in ΔT consists of three components:

$$\Delta\text{NPV} = \Delta CF_{escrow} + \Delta C_{fin} + \Delta C_{overhead} - \Delta\text{OPEX}_{pv}, \quad (2)$$

where ΔCF_{escrow} is the effect of accelerating the disclosure of escrow accounts under 214–FZ, discounted at the project financing rate;

ΔC_{fin} is the saving of interest costs on the project loan (the rate decreases as the escrow is filled to a minimum level with full coverage according to the tariffs of DOM Bank. RF[5]);

$\Delta C_{overhead}$ — the release of semi-fixed overhead costs (the benchmark is 15 % of the project cost × $\Delta T/T_{total}$, based on industry practice);

ΔOPEX_{pv} — a penalty for the degradation of as-built quality, capitalized over a 50-year horizon.

The penalty is set based on the digital twin maturity level according to Deng et al. [18]. L1 (static as-built IFC in the CDE of the customer-operator according to SP 333.1325800.2020[2]) is accepted as basic; L2 (connection of BMS/IoT circuits, one-way telemetry flow) is accepted as a threshold value at which the penalty ΔOPEX_{pv} is zero; L3 (predictive maintenance analytical layer) gives a premium of ≈ 10 % OPEX; L4 (two–way control loop) — up to 20–25 % [18, 19]. Below L2, a positive penalty arises: an incomplete or contradictory as-built model increases operating costs, and even a 6-month gain during the construction phase may be offset by capitalizing 3–8 % of OPEX over a 50-year horizon.

LCC MODEL (BLOCK B)

The total life cycle cost is calculated as the sum of cash flows discounted to the initial point:

$$\text{LCC} = C_{CAPEX} + \Sigma_{t=1,\ldots T}[(C_{OPEX,t} + C_{MAINT,t} - R_t)/(1+r)^t] + C_{EoL}/(1+r)^T, \quad (3)$$

where C_{CAPEX} is the investment costs;

T is the horizon (50 years, median according to [5]);

$C_{OPEX,t}$ is the annual operating expenses;

$C_{MAINT,t}$ is the maintenance and capital repairs;

R_t is the revenues (rental income, capitalization effects);

r is the real discount rate;

C_{EoL} is the decommissioning.

The structural shares are taken as an average [5]: CAPEX ≈ 20 %, OPEX + MAINT ≈ 75 %, EoL ≈ 5 % at r = 7 %. Sensitivity is checked in the range $r \in [3; 10]$ %; for Russian conditions, the baseline scenario r = 7 % reflects a long-term inflation rate of 4 % and a risk premium for the developer project.

The empirical basis of the methodology includes 25 peer-reviewed publications from Scopus/WoS for the period 2018–2026, as well as industry reports from DOM.RF[5] and EPZ.RF[1], the Ministry of Construction of Russia, Glavgosekspertiza, and NOSTROY, as well as regulatory documents (SNiP 1.04.03–85*[3], SP 48.13330.2019[4], SP 333.1325800.2020[2], Decree of the Government of the Russian Federation No. 614[6], 214-FZ[7]).

RESULTS: DECOMPOSITION AND STANDARD DURATION OF STAGES

For an industrial multi-apartment building of increased height (16–17 storeys, with a total area of 15–20 thousand m²), the standard structure of the stages is presented in Table 1. The standard

[6] Decree of the Government of the Russian Federation No. 614. URL: https://www.kontur-extern.ru/info/normativ/document/1/471103-postanovlenie-pravitelstva-rf-ot-17-05-2024-n-614

[7] Federal Law No. 214-FZ. URL: https://www.kontur-extern.ru/info/normativ/document/1/471103-postanovlenie-pravitelstva-rf-ot-17-05-2024-n-614

Table 1. Standard duration and weight structure of the life cycle stages of a hypothetical apartment building (18,000 m², 17 floors)

Number	Stage	No. T_j^{norms}, months	Weight w_j	Source of rationing
1	Pre-project and grade coordination	4.0	0.12	GrK RF[8]; data DOM.RF[5]
2	Engineering surveys	1.5	0.05	SP 47.13330.2016[9]
3	Design	6.0	0.18	PP No. 87[10]; industry practice
4	PD examination	1.0	0.03	PP No. 145[11] (20 working days + possible extension)
5	Preparatory period	1.5	0.05	SP 48.13330.2019[4]
6	Construction and installation works	18.0	0.53	SNiP 1.04.03–85*[3] (with coef.)
7	Start up and commissioning	1.0	0.04	SP 48.13330.2019[4]
8	Total for	33.0	ISC 33,0 1,00	–

Source: compiled by the author on the basis of SNiP 1.04.03–85*[3], SP 48.13330.2019[4], PP No. 87[10], PP No. 145[11]; calibration w_j — according to ERZ.RF[1] (2025).

[8] GrK RF. URL: https://www.consultant.ru/document/cons_doc_LAW_51040/

[9] SP 47.13330.2016. URL: https://nav.tn.ru/cloud/iblock/661/66119e6532fdd298a14c43d2847888fc/SP-47.13330.2016-Inzhenernye-izyskaniya-dlya-stroitelstva.-Osnovnye-polozheniya.pdf

[10] PP No. 87. URL: https://rpn.gov.ru/upload/iblock/1a5/5hz74l2d6a8jd0w2fhlawld9mo91l19b/Postanovlenie-Pravitelstva-RF-ot-16.02.2008-N-87-_red.-ot-28.12.2024_-O-sostave-razdelov-proektnoy-dokumentatsii-i-trebovaniyakh-k-ikh-soderzhaniyu.pdf

[11] PP No. 145. URL: https://www.kontur-extern.ru/info/normativ/document/1/505956-postanovlenie-pravitelstva-rf-ot-05-03-2007-n-145

duration of construction and installation work for a 16-storey monolithic residential building with an area of 6,000 m², according to SNiP 1.04.03–85*[3], is 12 months; for an area of 18,000 m², taking into account the scaling factor for labour intensity, it is 18 months. The weighted average empirical period for ERZ.RF[1] for 2025 is 827 days (≈27.2 months), which reflects the accumulated losses relative to the standard.

TOOL APPLICABILITY MATRIX AND COUPLING COEFFICIENTS

The k_{ij} matrix is formed expertly on the basis of generalization [7–10, 13–23, 28–31] and reflects the depth of tool penetration into the stage (Table 2).

Table 2. Matrix $k_{ij}k_{ij}$ of tool applicability to MRB LC stages

Stage/Tool	TIM	Lean	OTM
1. Pre	0.40	0.30	0.60
2. Research	0.60	0.20	0.30
3. Design	0.90	0.40	0.50
4. Expertise	0.70	0.10	0.20
5. Preparation	0.50	0.70	0.80
6. SMR	0.60	0.90	0.90
7. Commissioning	0.80	0.40	0.50

Source: compiled by the author on generalization [1–4, 6–13, 18, 19].

The pattern of accents is obvious. The team works as best as possible at the project and expert stages — this is where the main effect of implementing the information model is achieved (reducing the number of RFI, speeding up documentation verification). Lean focuses on the preparation period and QMS-where clock planning and LPS provide measurable compression. OTM makes the greatest contribution to training and QMS through on-line organization and fast-tracking. This distribution is consistent with the data of [9] (efficiency increase at the junctions of stages) and [4] (fast-tracking limit ≈25 %).

Interaction coefficients c_{ij} are assumed according to the following logic. BIM acts as a data carrier for design and expertise, Lean organizes the flow of designers — $c_{TIM,j} \cdot c_{Lean,j}$ = 1.10 (mutual reinforcement). During the CIW, the combination of OTM (in-line organization, fast-tracking) and Lean (clock planning, LPS) works synergistically at c = 1.15. Applying fast-tracking at the design stage without BIM support increases the risk of alterations and is penalized with a lowering c = 0.85 [4]. No explicit conjugation — c = 1.00.

ESTIMATED REDUCTION ESTIMATE (BLOCK A)

Substituting the parameters in formula (1) gives: at the lower bounds of ε_i and c_{ij} = 1.00, the integral reduction of DT_JC = = 7.6 months (23 %); when positive conjugates are included, it is 9.2 months (28 %). The sensitivity to ε_{TIM} is low (±2 % over the entire empirical interval), while the variation of ε_{Lean} and c parameters at the CIW stage shifts the result in the range of 5–10 %. The reason is structural: more than half of the standard duration of the ICC falls on the CIW (w_6 = 0.53), so any tools that work on the construction site give the maximum absolute gain.

ΔNPV ESTIMATION AND COMPENSATION THRESHOLD (BLOCK B)

For a 17-storey MRB with an area of 18,000 m² (216 apartments), the following parameters are accepted: specific CAPEX of 160 thousand rubles m² (data from DOM. RF[5]/ERZ.RF[1], 2025), specific OPEX of 1,100 rubles/m²/year, capital repairs of 15 % CAPEX every 25 years, EoL of 3 % CAPEX. Discount rate r = 7 %, tariff escalation 4 %. The results of the LCC calculation for the basic and optimized scenarios are presented in Table 3.

Multidirectional result. The optimized scenario requires an additional RUB 57 million in CAPEX to equip the building IoTwith L2-level IoT/BMS circuits. These costs are already repelled by the effect of opening escrow (–90 million rubles) and releasing invoices (–72 million rubles), but the main gain is 400 million rubles. reduction of the reduced OPEX over 50 years-is formed in the operational phase due to predictive maintenance of HVAC, timely response to deviations and extension of the service life of engineering systems by 20 % [19]. The final reduction in the NPV of the LC is 8.6 %.

However, the result is reversible. If the reduction of the construction phase by 6 months is accompanied by a decrease in the as-built transmission level below L2, OPEX increases. With moderate degradation (+3 % OPEX from the base), the threshold for compensation of losses by temporary gain is $\Delta T \approx 4.5$ months, with significant (+8 %) – $\Delta t > 9$ months, which exceeds the realistic limit of fast-tracking. In other words: you can accelerate, but only if you maintain the maturity of the digital twin. Below this threshold, the acceleration of construction becomes economically harmful on the housing and utilities horizon.

TESTING: TWO SCENARIOS ON A CONDITIONAL OBJECT

Basic scenario: the developer applies TIM only at the design and expert stages (mandatory minimum for PP No. 614), uses the classic flow-based organization of the CIW without clock

Table 3. LCC-calculation of the model MRB of 18,000 m²: basic and optimized scenarios (billion rubles, given at the beginning of the LC)

NPV	Basic component (CIW 36 months, L1)	Optimized (CIW 30 months, L2+)	Δ
CAPEX (design + CIW)	2,880	2,937 (+2 % on IoT/BMS)	+0.057
Escrow Disclosure acceleration effect (6 months)	–	0.090	–0.090
Semi-fixed overhead costs	0.432	0.360 (–17 %)	–0.072
OPEX pv over 50 years (r = 7 %)	2,670	2,270 (–15 % due to DT)	–0.400
Major repairs pv	0.380	0.340	–0.040
EoL pv	0.003	0.003	0.000
Total LCC (NPV)	6,365	5,820	–0.545 (– 8.6 %)

Source: author's calculation by the method of Blocks A, B, C; calibration-DOM. RF[5] (2025), Hosamo et al. [19], Deng et al. [18].

planning, passes as-built at the L1 level. The estimated reduction of the ICC is 4.9 months, with an increase in NPV of about 1.2 %.

Advanced Scenario: TIM at all seven stages with continuous CDE; LPS and clock scheduling on the CIW with a clock cycle of 5 working days; fast-tracking with positive coupling c = 1.15; transfer of as-built to L2 with a transition to L3 in 18 months after input. The reduction of the ICC is 9.2 months, the increase in the NPV of the LC is 7.5 %. The estimated cycle duration falls to 23.8 months (~720 days) and fits into the target corridor of the national project "Infrastructure for Life" (1,000 days by 2030) with a margin.

The reachability of the extended scenario is limited by three conditions: the current shared data environment at the level of the customer-developer (requirement of PP No. 614); adoption of the LPS regulations no later than the 5th stage; resource availability of teams for clock cycles. If at least one of the conditions is violated, the realistic estimate falls to 5–6 months of reduction– a level comparable to the indicators of the leaders of the ERZ.RF[1].

DISCUSSION

The resulting 22–28 % integral reduction coincides with the boundaries of independent empirical benchmarks: 20 % in time on an average BIM case [9] and ≈ 25 % as a realistic limit of fast-tracking [4]. This means that there is no "miracle" beyond the physical limitations of the industry — the methodology does not promise anything beyond what the cumulative empirical base provides. In our opinion, this is rather a virtue: a conservative convolution protects better from disappointment than an optimistic one.

Correlation with Russian schools. The works of A.A. Lapidus operate with the integral potential of organizational and technological solutions without direct translation into days [1]; our potential is reduced to the coupling coefficients c_{ij}, which makes the model measurable in terms of time and money at the same time. The concept of three types of inter-stage relationships between Zhdanova and Lapidus [2] is reflected in the matrix structure: the overlapping relationship is manifested in an increased k_{ij} for stages where TIM and OTM work simultaneously (design — preparation). Works in the journal "Real Estate: Economics, Management" [7, 8, 14–17] form the methodological base to which we add the quantitative contour of trade-off assessment "speed – quality".

Limitations of the method. First, the model does not take into account the probabilistic nature of external barriers — delays in connecting to engineering networks and passing state expertise beyond the standard time limits, which play a significant role in the actual duration of the ICC. Secondly, the personnel deficit of the industry (according to industry estimates, NOSTROY — about 750 thousand people) is not directly included in the formula and is taken into account only by lowering ε_{Lean} for facilities with a proven shortage of teams. Third, testing is performed on a conditional object; verification on a real specimen requires data from developers' corporate ERP systems, which are still closed to researchers. Fourth, the choice of additive-multiplicative convolution is not unique — alternatives based on Bayesian network theory model causality more accurately, but require training specimens that are not publicly available.

Conditions of applicability. The method is adequate for industrial MRB with a typical number of floors of 9–25 fl. with an area of 10–30 thousand m², built using monolithic or prefabricated monolithic technology, if the developer has a full-fledged CDE and an up-to-date as-built model in IFC format. Unique items, high-rise buildings over 75 m, and spot buildings require recalibration of k_{ij} and c_{ij} — their applicability coefficients differ systematically (for more information, see a separate paper).

What is left out of the box. The effect of TIM at the operational stage is manifested through a reduction in operating costs, but not directly through the duration of the stage. The method takes this effect into account indirectly-through the penalty function $\Delta OPEX_{pv}$, and not as an independent term of DT_JC. This choice is realized: it is methodically unsafe to mix time and cost reductions in the same denominator.

CONCLUSION

The proposed methodology reduces three independently developed areas-TIM, Lean Construction and OTM-to a single calculation formula for reducing the duration of the investment and construction phase of the MRB housing and utilities complex. The estimated reduction for a conventional 17-storey building with an area of 18,000 m² is 22–28 % with lower limits of empirical coefficients and correct coupling of tools. This translates the standard facility from the current mode of 33–43 months to 24–26 months and is consistent with the target of 1,000 days of the national project "Infrastructure for Life".

The main methodological result is dual-circuit control "$\Delta T + \Delta NPV$". The first contour describes a reduction in duration, while the second one imposes a quality restriction that prohibits saving time at the cost of capitalized OPEX losses. The connection of the contours is closed through the maturity level of the digital twin: L2 according to Deng et al. [18] — the threshold value at which the increase in the NPV of LC reaches 3.5–7.5 % when the construction phase is reduced by 6 months. Below L2, the acceleration is reset to zero or becomes negative.

The practical significance of the work lies in the fact that the methodology is suitable for use by developers under Federal Law No. 214-FZ[7] at the stage of forming a schedule for the project of integrated development of territories and at the same time serves as a diagnostic tool for assessing the gap between the regulatory and actual terms. The k_{ij} matrix k_{ij} allows you to evaluate at which stages and which tools the reduction reserve is most fully used, and the penalty function $\Delta OPEX_{pv}$ allows you to cut off false savings scenarios.

Areas of development. First, empirical calibration of the c_{ij} coefficients c_{ij} on a specimen of at least 30 implemented MRB with the participation of enterprise ERP systems of industry leaders. Secondly, integration of the probabilistic block of external barriers — state expertise, connection to engineering networks, and personnel availability. Third, extending the model to the operational phase through the cost indicators of LC with calibration of penalty degradation coefficients as-built according to HEAD OF STATE EXPERTISE[12] and GIS EGRZ[13].

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Разработка методики сокращения продолжительности этапов жизненного цикла объектов жилищного строительства

Национальный проект «Инфраструктура для жизни» задает целевую длительность инвестиционно-строительного цикла (ИСЦ) многоквартирного жилого дома — не более 1000 суток к 2030 г., тогда как фактический показатель снизился с 2181 дня в 2021 г. до 1253 дней в 2025 г. Наблюдаемый разрыв между нормативом и практикой неоднороден: у одних застройщиков перенос ввода нулевой, у других достигает трети срока. Сохраняется методический пробел — нет единого расчетного аппарата, который связывал бы сокращение этапов жизненного цикла (ЖЦ) с интегральным экономическим эффектом и с качеством передачи информационной модели в эксплуатацию. Цель — разработать такую методику для индустриальных МКД. Инструментарий опирается на декомпозицию инвестиционно-строительной фазы на семь этапов; аддитивно-мультипликативную свертку эффектов трех групп мероприятий (технологии информационного моделирования, бережливое строительство, организационно-технологическое моделирование) через коэффициенты сопряжения; штрафную функцию деградации as-built модели, капитализируемую в операционной фазе на 50-летнем горизонте. Апробация на условном 17-этажном МКД площадью 18 000 м^2 дает потенциал сокращения ИСЦ на 22–28 % при одновременном приросте чистой приведенной стоимости жизненного цикла в диапазоне 3,5–7,5 %, но лишь при удержании зрелости цифрового двойника на уровне не ниже L2 по таксономии Deng – Menassa – Kamat. Новизна — двухконтурное управление «*T* + NPV» через коэффициенты сопряжения и критический порог компенсации потерь OPEX. Методика применима застройщиками по 214-ФЗ и в проектах комплексного развития территорий.

Ключевые слова: *жизненный цикл здания, многоквартирный жилой дом, инвестиционно-строительный цикл, стоимость жизненного цикла, информационное моделирование, цифровой двойник, чистая приведенная стоимость, бережливое строительство, организационно-технологическое моделирование, комплексное развитие территорий*

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Об авторах: **Орымбаев Дакен Нурланович** — аспирант кафедры организации строительства и управления недвижимостью; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; ORCID: 0009-0007-4318-6967; daken29.12.98@gmail.com;

Прыкина Лариса Викторовна — доктор экономических наук, профессор кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; РИНЦ ID: 416224, Scopus AuthorID: 6505996610, ORCID: 0000-0003-3666-3140; daken29.12.98@gmail.com.

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Москва. Театральная площадь

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Akristiniy V.A.
Rumiantsev D.S.

Reconstruction of linear communication networks in confined conditions as part of comprehensive territorial development

The paper examines the specifics of reorganizing telephone duct networks within densely built urban areas of Moscow during implementation of comprehensive territorial development and renovation projects. The focus is on four cable duct construction technologies: open-cut construction (installation of pipelines in trenches), aerial construction (installation of pipelines on overhead supports or laying cables in dedicated trays), horizontal directional drilling (HDD), and horizontal jacking. A comparative analysis is presented of their technical capabilities, limitations, application conditions, and impacts on schedule, cost, and construction organization. The study demonstrates that the open-cut method is the simplest, most transparent, and economically accessible solution; however, its applicability is constrained by the high density of underground utilities, the need for subsequent site restoration, and its unsuitability for sections with intensive traffic. Horizontal directional drilling enables installation without disrupting the road surface and is particularly effective for crossing railways, highways, and other obstacles, but requires specialized equipment and is associated with higher costs. Horizontal jacking is considered a related technology that allows work in confined conditions but is limited by pipeline diameter and imposes elevated strength requirements on the pipes. The aerial method is characterized as the most expedient and temporary solution when rapid clearance of a construction site is required, yet it is inferior to other methods in terms of reliability and is sensitive to certain weather conditions. Based on practical case studies, an algorithm is proposed for selecting the optimal cable duct construction method, taking into account the engineering environment, work schedules, and economic feasibility. The recommendations obtained can be used in the design and reorganization of communication networks in large metropolitan areas.

Keywords: *communication network reconstruction, Moscow renovation, horizontal directional drilling, HDD, horizontal jacking, open-cut laying, dense urban development, telecommunication network constraints*



Akristiniy Vera Aleksandrovna,
Ph.D., Associate Professor of the Department of Construction Engineering; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation;
ID RSCI: 689002,
Scopus AuthorID: 57194451445,
WoS ResearcherID: AAE8964-2022,
ORCID: 0000-0002-6488-420X;
akristiniyva@mgsu.ru



Rumiantsev Danil Sergeevich,
Postgraduate student of the Department of OSUN; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation;
rumyancevdanilka@mail.ru

Comprehensive territorial development is an extremely complex organizational and technical process that requires a balanced integration of urban-planning, infrastructure, and social objectives [1]. Under Moscow's federal housing-renovation program for 2017–2032, 5,175 buildings are scheduled for demolition and more than one million residents are to be relocated.

In the digital era, the functioning of modern society is impossible without high-speed internet, which enables data transmission via Ethernet and GPON protocols using fibre-optic or copper cables laid in telephone ducts [2]. Traffic volume in Moscow's communication networks increased by 50 % in 2025, which makes the modernization of more than 150,000 km of cable lines necessary. In this context, the relocation and reconstruction of communication networks is an important factor in the territorial-renovation process.

In megacities such as Moscow, dense development and limited space impose strict constraints on the flexibility of reconstructed duct networks. Confined conditions caused by roads, green spaces, and a large number of underground utilities in redevelopment areas present a serious challenge to engineers involved in communication-network reconstruction [3].

When reconstructing communication networks, a construction organization faces a number of difficulties and constraints[1]:

1. The minimum permissible distance from existing utilities: no less than 0.5 m, as well as the need to reinforce the pipeline with casings in certain cases.
2. Minimum burial depth of the pipeline in soil: 0.6 m under roadways and 0.4 m in other areas. It is also recommended to place the pipeline below the frost depth for greater structural reliability.
3. Maximum distance between inspection structures: 150 m, and the installation of cable-duct manholes at route bends.
4. Required pipeline slope: at least 3–4 mm from the centre of the span toward the manholes for water drainage.

These conditions often lead to downtime, the impossibility of using mechanized labour for trench excavation, an increased share of manual labour, and, consequently, longer construction times and more complicated installation.

The novelty of the study lies in the systematization of four methods of cable-duct reconstruction and the development of a technology-selection algorithm based on a comprehensive analysis of technical constraints, economic parameters, and practical case studies.

Within this study, the authors attempted to develop methodological recommendations for selecting the optimal method of telephone-duct reconstruction in dense urban development based on a comparative analysis of technologies and practical verification.

Analysis of methods

There are four main methods for installing telephone duct networks.

[1] SP 519.1325800.2023. Communication networks. Design rules. Introduction. 2023-04-18. Moscow, Ministry of Construction of Russia, 2023.

1. Open-cut reconstruction of a telephone duct is a traditional method involving trench excavation and pipeline installation within the trench [4]. This method is the most widely used in Moscow.

Advantages:

- simplicity of the process;
- no need for complex technological equipment;
- low cost;
- process transparency: trench excavation makes it possible to identify existing utilities crossing the constructed pipeline, thereby allowing route adjustment [5].

Disadvantages:

- the method requires subsequent site restoration;
- when laid beneath roadways, it may disrupt public transport routes, making it necessary to create a replacement route and causing additional financial costs;
- when crossing railways, it may require traffic stoppage, which is unacceptable on heavily trafficked railway lines;
- in areas with a high density of underground infrastructure, this method may be impossible because it is physically impossible to maintain the required distances between utilities.

2. Horizontal directional drilling (HDD) is a technologically more complex method involving drilling a borehole of the required diameter and pulling pipes into it [6].

Advantages:

- simpler from a design standpoint, since the pipeline can be placed at a depth that avoids contact with existing utilities;
- there is no need to close or reconstruct railways; only rail protection mats are required to minimize settlement risks, so post-construction restoration costs are much lower than with the open-cut method.

Disadvantages:

- high cost;
- the need for complex equipment.

3. Horizontal jacking is a method similar to HDD, but its distinguishing feature is that the pipes are jacked directly into the ground at the bore location [7].

The advantages of this technology are similar to those of HDD, and additionally, the soil is strengthened in the jacking zone.

Disadvantages:

- higher strength requirements for the pipes;
- pipe diameter limitations: from 0.8 to 1.7 m.

4. Aerial reconstruction of communication networks is the simplest of the methods presented [8]. It consists of suspending ducts on supporting structures and running cables along them[2].

Advantages:

- no earthworks;
- simplicity;
- low cost.

Disadvantages:

- structural unreliability;
- difficult operation under unfavorable weather conditions, including subzero temperatures, excessive precipitation, and wind loads.

Analyzing all methods, a comparative table of the advantages and disadvantages of different communication-network installation methods can be compiled, as shown in Table.

The study also included a detailed comparison of the costs of communication-network reconstruction methods based on cost-estimate analysis using the TSN-2001 collections[3]. The results showed that open-cut and aerial installation remain the most economical options, at approximately 1.2 and 1.0 arbitrary units (a.u.), respectively. Horizontal jacking shows an intermediate cost level of about 2.0 a.u., whereas HDD is the most expensive method, at 3.8 a.u.

The difference between the cheapest and the most expensive methods is significant: HDD is approximately 3.8 times more expensive than the aerial method. This is explained by the high cost of specialized machinery, drilling fluids, preparatory operations, and the drilling technology itself.

From the standpoint of economic efficiency, the aerial installation method is the best solution because it requires minimal costs. However, the final choice should be made not only on the basis of cost, but also on the basis of working conditions, the presence of existing utilities, requirements for preserving the pavement, construction deadlines, and restrictions on open excavation.

PRACTICAL CASES

1. Open-cut reconstruction

In December 2025, communication networks were being reconstructed at the site: “Demolition of residential buildings at 6, 8, 10, and 12 Rodnikovaya Street, Solntsevo District, Moscow, and engineering preparation of the area for residential construction with relocation of engineering utilities” (Fig. 1).

Based on the existing underground utilities at this site, the open-cut method was chosen as the most appropriate method for constructing the cable duct, since the low density of underground utilities made it possible to maintain the required spacing between networks. Open-cut construction was considered economically optimal and technically satisfactory.

[2] Konosov D.V. Utility Model Patent RU 129310 U1. Aerial cable conduit system and cable routing distribution device. Published June 20, 2013. URL: https://rusneb.ru/catalog/000224_000128_0000129310_20130620_U1_RU (rus.).

[3] TSN 2001-01. Laying engineering communications in an open manner in the cramped conditions of Moscow. Moscow, Moskomarkhitektura, 2001; 25.

Comparative characteristics of telephone-duct installation methods

Method	Advantages	Disadvantages	Application
Open-cut	Simple equipment, simple operation, no pipeline diameter restrictions	Difficult to implement in areas with dense utilities; site restoration required after construction	Optimal where underground utility density is low
Method	Advantages	Disadvantages	Application
HDD	Can be used in areas with dense underground utilities; minimal restoration required after construction	Process is difficult to monitor; minimum length is 60 m	Suitable for installation under railways within right-of-way boundaries and in areas with very dense existing utilities
Horizontal jacking	Can be used in areas with dense underground utilities; minimal restoration required after construction	Higher pipe strength requirements; process is difficult to monitor; maximum length is 60 m	Suitable for installation under roadways when closing the road is economically unjustified, and in areas with very dense existing utilities
Aerial	Simple network installation; no earthworks required	Structural unreliability; unsuitable at low temperatures	Temporary solution

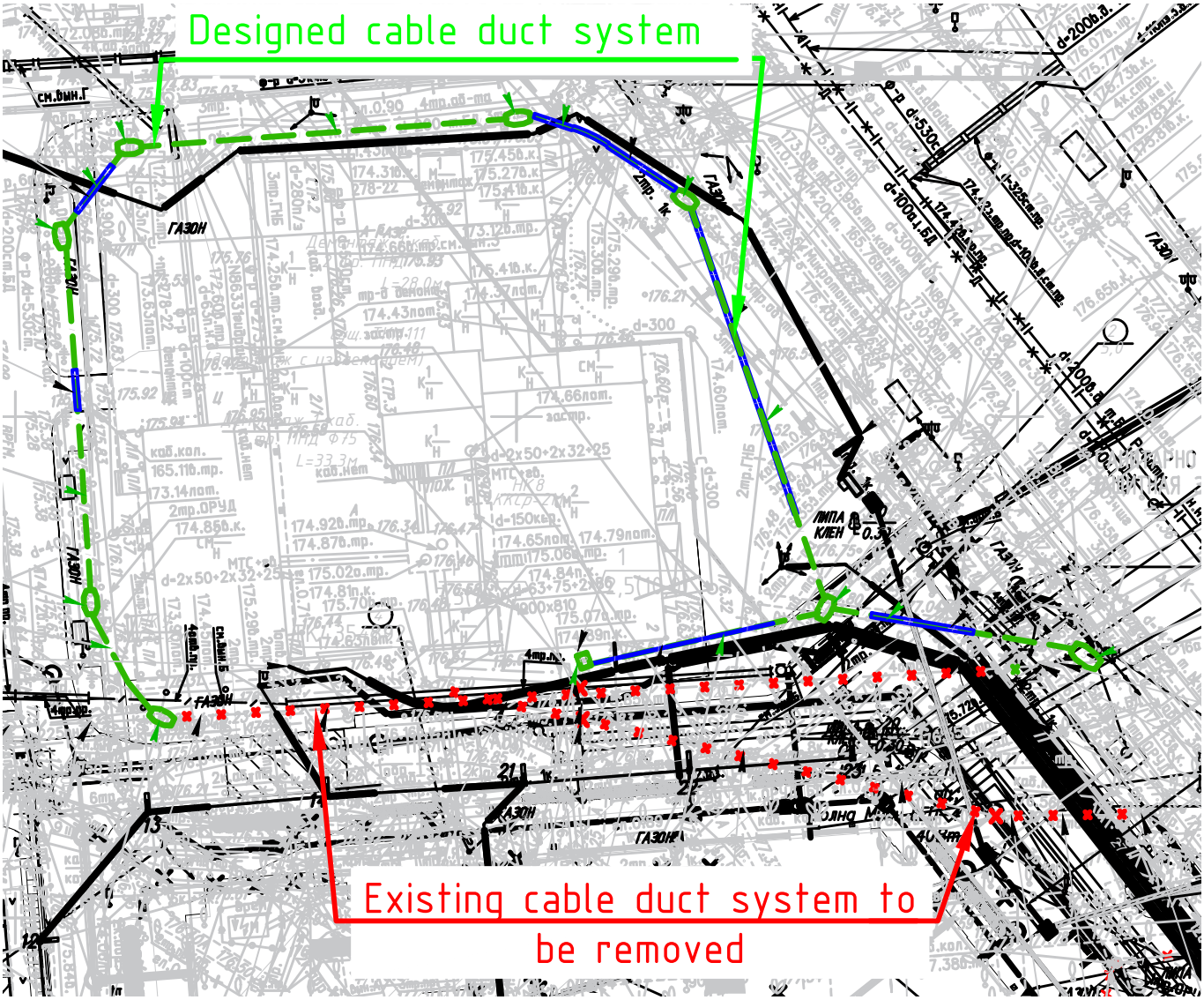


Fig. 1. Reconstruction of communication networks by the open-cut method

2. HDD construction

In 2025, telephone-duct reconstruction (reconstruction of PJSC MTS communication networks) was carried out at the site: "Pedestrian crossing over the MCD in the Lokomotivny Proezd area. Construction of the street-and-road network" (Fig. 2). At this site, it was necessary to reconstruct a telephone duct passing under railway tracks. The section has very intensive train traffic, about 100 pairs of passenger and freight trains per day, and because of the short duration of available technological windows, open-cut construction should be considered impossible.

At the same time, aerial construction was also impossible at this site because the redevelopment area is within the protected zone of operating Russian Railways (RZD) overhead power lines, including the contact network and a 10 kV overhead line[4].

Based on these facts, the possible installation methods were HDD and horizontal jacking [9]. Considering the length of the duct to be reconstructed, 70 m, HDD was the preferred method [10].

[4] SP 32.13330.2012. Sewerage. External networks and structures. Updated version of SNiP 2.04.03–85.

3. Aerial construction

In April 2024, construction was carried out at the site: "Residential building with adaptation of an underground parking facility into a civil defense shelter («shelter»), with engineering networks and landscaping of the territory (including demolition of residential buildings at 2A Okruzhnaya Street and 1 Svetlogorsky Proezd) at land plot 2A, Okruzhnaya Street, South Tushino District, Moscow (North-West Administrative Okrug)" (Fig. 3, 4).

Because the construction site had to be cleared of communication networks in a short time, it was decided to carry out the works in two stages: first, part of the span was built using the aerial method, and then it was reconstructed by the open-cut method.

The use of the aerial method was driven by the tight construction schedule, since the other methods would have required much more time. However, this method is limited by ambient temperature conditions: construction cannot be performed in winter, when the air temperature is below the permissible threshold, because laying communication cables under such conditions is prohibited due to their brittleness [11].

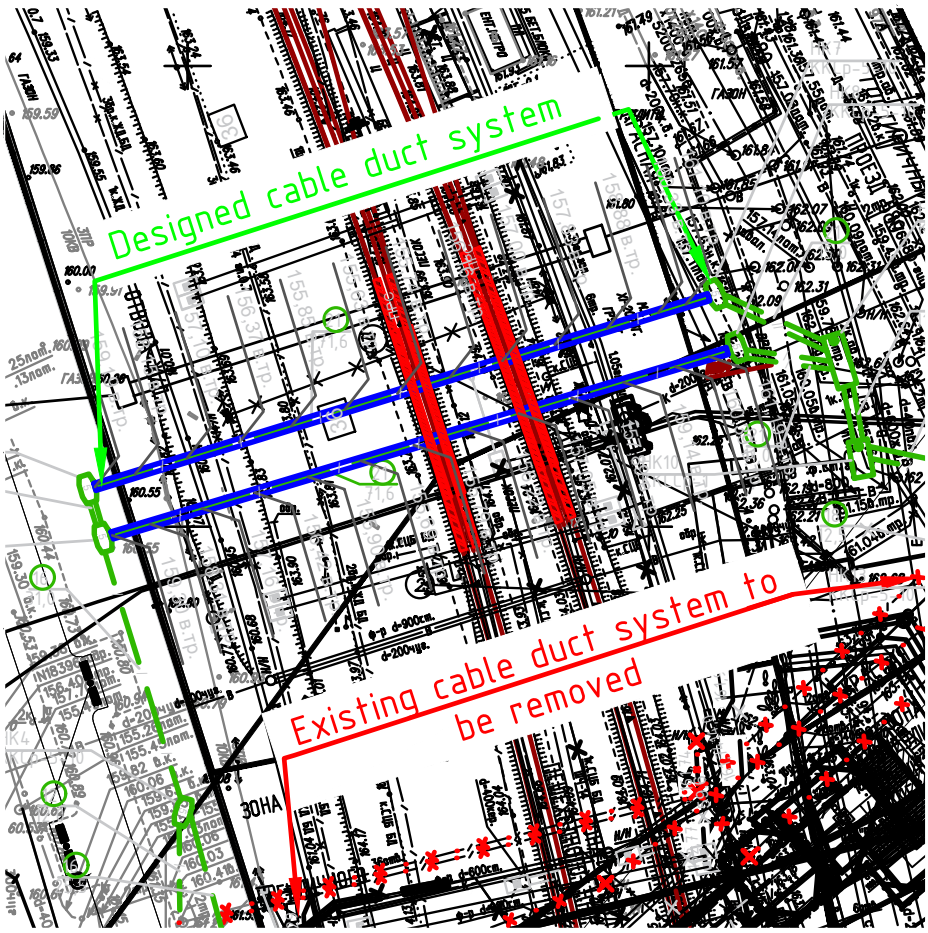


Fig. 2. Reconstruction by horizontal directional drilling at the site "Pedestrian crossing over the MCD in the Lokomotivny Proezd area. Construction of the street-and-road network"

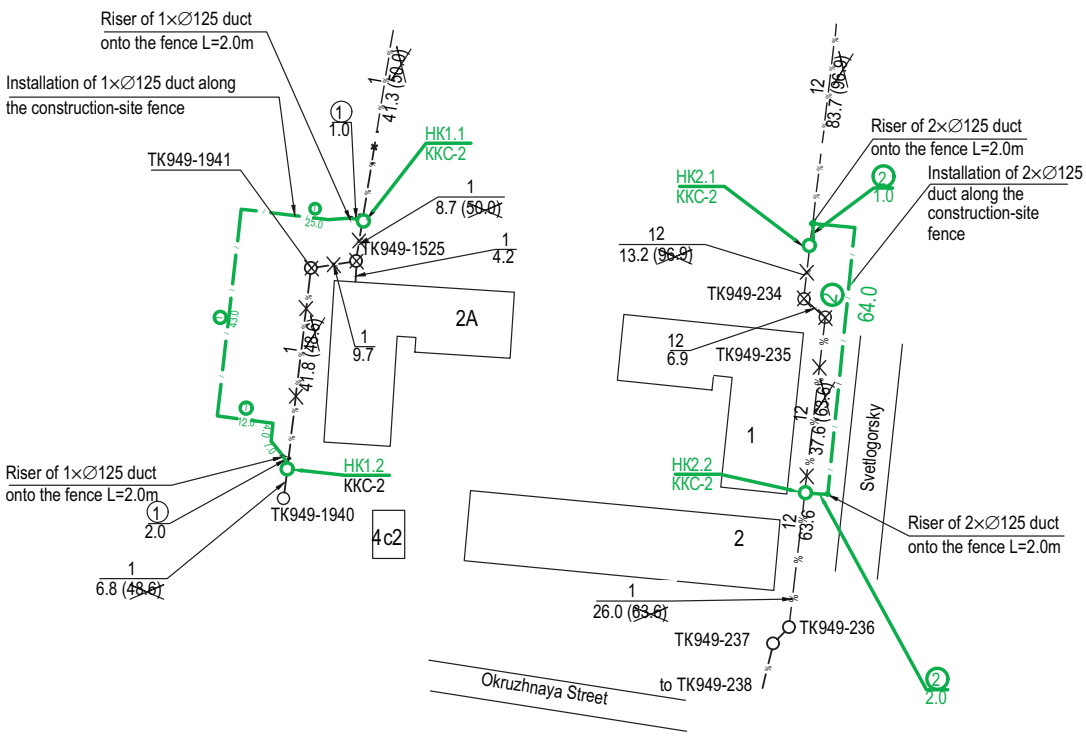


Fig. 3. First stage of communication-network reconstruction: aerial construction along the construction site fence

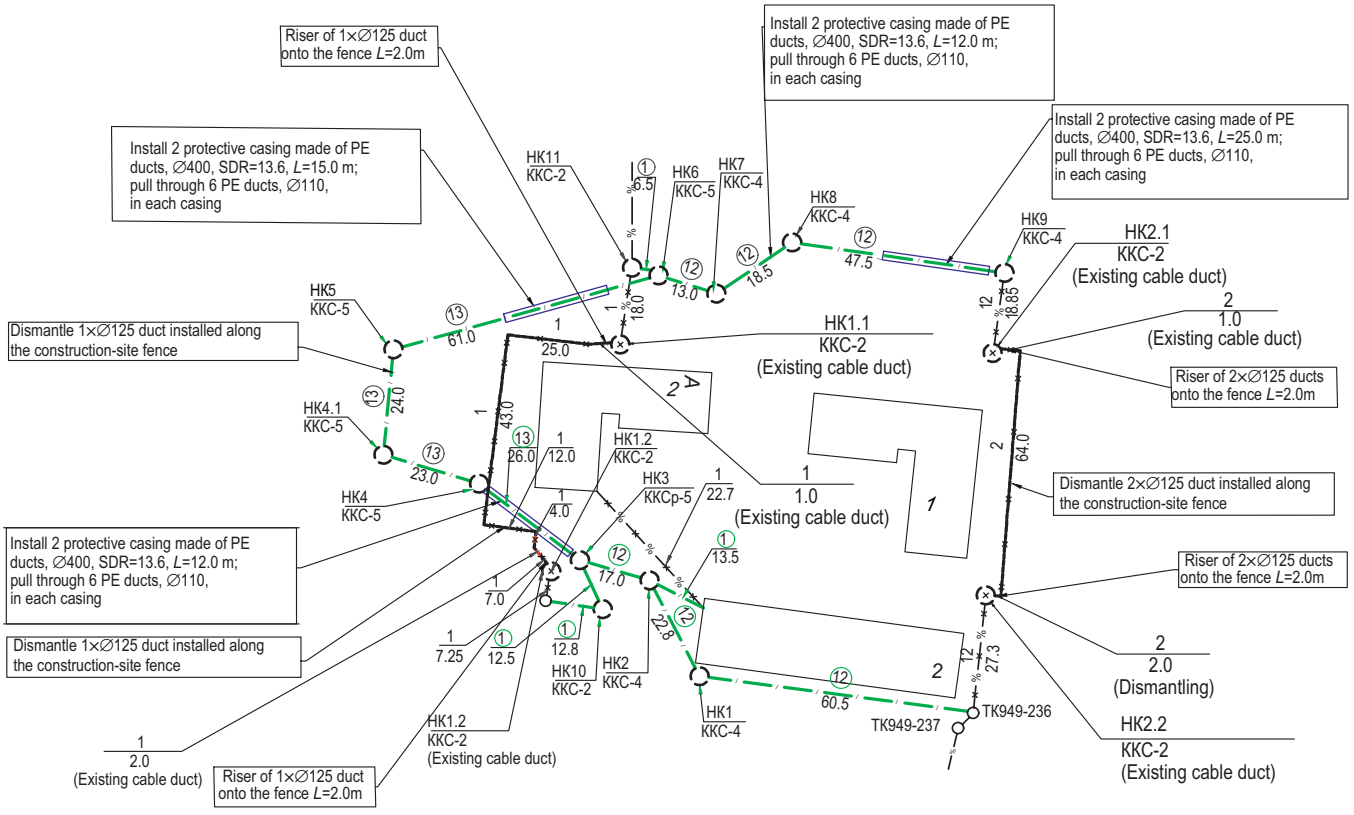


Fig. 4. Second stage of communication-network reconstruction: open-cut construction

CONCLUSIONS

Four methods of communication-network reconstruction were considered: the open-cut method, HDD, horizontal jacking, and the aerial method. Each has a clearly defined field of application, ranging from the economically efficient open-cut approach in areas with low utility density to trenchless technologies used at transport crossings and in congested underground environments. The aerial method is reasonable as a temporary solution when time is limited.

The practical cases confirm the validity of this choice: the open-cut method is suitable where utility density is low, HDD is appropriate under railway tracks with intensive traffic, and the aerial method is useful for rapid site clearance followed by later replacement.

The results of the analysis allow designers to select a reconstruction method in a justified way, taking into account technical constraints such as the 0.5 m clearance requirement, 0.6 m burial depth under roads, a slope of 3–4 mm/m, and the density of existing utilities in the reconstruction zone, as well as economic parameters. The recommendations obtained are applicable to comprehensive renovation projects in the dense urban fabric of Moscow.

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Особенности переустройства линейных сетей связи в стесненных условиях в рамках комплексного развития территории

В статье рассмотрены особенности переустройства телефонной канализации в условиях плотной городской застройки города Москвы при реализации проектов комплексного развития территории и реновации. Основное внимание уделено четырем технологиям строительства кабельной канализации: строительству открытым способом — прокладка трубопровода в траншею, строительству воздушным способом — прокладка трубопровода по воздушным опорам или прокладка кабелей в специализированные лотки, горизонтально-направленному бурению и горизонтально-направленному продавливанию. Проведен сравнительный анализ их технологических возможностей, ограничений, условий применения, а также влияния на сроки, стоимость и организацию строительных работ. Показано, что открытый способ является наиболее простым, наглядным и экономически доступным решением, однако его применение ограничивается высокой плотностью подземных коммуникаций, необходимостью последующего благоустройства территории и невозможностью использования на участках с интенсивным транспортным движением. Горизонтальнонаправленное бурение позволяет выполнять прокладку без вскрытия дорожной поверхности и особенно эффективно при пересечении железных дорог, автомобильных магистралей и других препятствий, но требует применения специализированного оборудования и характеризуется высокой стоимостью. Горизонтально-направленное продавливание рассматривается как близкая по назначению технология, обеспечивающая возможность работать в стесненных условиях, однако имеет ограничения по диаметру трубопровода и повышенные требования к прочности труб. Воздушный способ характеризуется как наиболее оперативное и временное решение, применяемое при необходимости быстро освободить строительную площадку, но он уступает остальным методам по надежности и требователен к определенным погодным условиям. На основе практических кейсов сформулирован алгоритм выбора оптимального метода строительства кабельной канализации с учетом инженерной обстановки, сроков производства работ и экономической целесообразности. Полученные рекомендации могут быть использованы при проектировании и переустройстве сетей связи в мегаполисах.

Ключевые слова: *переустройство сетей связи, реновация г. Москвы, горизонтально-направленное бурение, горизонтально-направленное продавливание, строительство открытым способом, плотная городская застройка, технические ограничения сетей связи*

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Об авторах: **Акристиний Вера Александровна** — к.т.н., доцент кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; ID RSCI: 689002, Scopus AuthorID: 57194451445, WoS ResearcherID: AAE8964-2022, ORCID: 0000-0002-6488-420X; akristiniyva@mgsu.ru;

Румянцев Данил Сергеевич — аспирант кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; rumyancevdanilka@mail.ru.

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Smirnov A.D.
Nuragdyev N.N.
Nassukha I.V.

Selecting optimal organizational and technological solutions during the pre–investment stage of an investment–construction project, taking into account natural and man–made risks and the principles of sustainable construction

The paper addresses the selection of rational organizational and technological solutions at the pre-investment stage of an investment and construction project under uncertainty caused by natural and technological risks and by the need to incorporate sustainable construction principles. A methodological approach is proposed based on the joint consideration of management alternatives, organizational and technological factors, rationality criteria and project constraints. A spatial-factor model is used to formalize the relationships between project typology, organizational and technological complexity, controllable parameters, risks and alternative solutions. The proposed approach creates conditions for improving the validity of early decisions, reducing the influence of uncertainty and increasing the organizational and technological resilience of the project.

Keywords: *investment and construction project, pre-investment stage, organizational and technological solutions, project management, natural risks, technological risks, sustainable construction, spatial-factor model, objective, rational choice*

A modern investment and construction project is a complex organizational and technological system whose operation is determined by the combined influence of economic, organizational, technological, resource-related, natural, and man-made factors [1, 2]. At the same time, a significant portion of the parameters determining the project's subsequent performance are established before the start of major construction and installation work: the basic implementation plan, the composition of participants, the organizational management structure, the sequence of preparatory work, resource requirements, and requirements for technologies and information exchange are all defined. For projects implemented according to the principles of sustainable and "green" construction, additional requirements regarding energy efficiency, resource conservation, waste management, and environmental safety are taken into account. Consequently, the quality of decisions made during the pre-investment stage is directly linked to the ability to ensure the project's sustainable operation in subsequent stages [3, 4].

DEFINING THE TASK OF SELECTING ORGANIZATIONAL AND TECHNOLOGICAL SOLUTIONS

The pre-investment stage is viewed as a phase during which it is still possible to make significant changes to the project's organizational and technological framework at a relatively low cost of adjusting the decisions that have been made [5]. As the project progresses toward the design and construction phases, the freedom of choice diminishes, and the cost of changing previously established parameters increases. Therefore, the task of early decision-making should be focused not on finding a single, universal management solution, but on determining a rational combination of solutions that corresponds to the characteristics of a specific project.

THE SYSTEM OF FACTORS AND THE SPATIAL-FACTOR REPRESENTATION

The most significant methodological limitation of the traditional approach to selecting management forms is the consideration of factors in isolation. To address this shortcoming, it is proposed to use a spatial-factor representation, in which project characteristics are viewed as an interconnected space of selection conditions. This includes the typological characteristics of the object, organizational and technological complexity, resource conditions, external constraints, parameters of stakeholder interaction, and risk factors [6, 7].

DEVELOPMENT OF A SYSTEM OF CRITERIA

Once the factor space has been defined, it becomes necessary to translate the identified relationships into a system of criteria suitable for the comparative evaluation of alternatives. It is fundamentally important not to confuse factors and criteria. A factor characterizes the state or condition of a project's implementation, whereas a criterion reflects the degree to which a specific management decision aligns with the project's objectives given a specific state of the factors. For "green" construction, the criteria must allow for consideration not only of economic and organizational-technological outcomes, but also of resource intensity, environmental sustainability, energy efficiency, and the verifiability of compliance with requirements.



Smirnov Artem Denisovich,
Postgraduate student of the department of construction organization and real estate management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; artemsmirnoff23@gmail.com



Nuragdyev Nurjelal Nurgeldievich,
Postgraduate student of the department of construction organization and real estate management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; ORCID: 0009-0003-9172-0053; nuryagdievnurjk@gmail.com



Nassukha Ilya Vladislavovich,
Postgraduate student of the department of construction organization and real estate management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; Ilia.nassuha@mail.ru

ACCOUNTING FOR NATURAL AND MAN-MADE RISKS

A key feature of the proposed approach is the inclusion of risks in the selection process prior to the final determination of the organizational form of management. This procedure allows risk to be considered as a factor influencing the structure of the decision, rather than merely as an object of subsequent monitoring. For each significant risk, it is necessary to determine the probability of occurrence, the potential impact on the organizational and technological chain, and the sensitivity of the alternative to that impact.

The pre-investment stage defines the initial conditions for the subsequent implementation of the investment and construction project: the choice of location is justified, site constraints are established, and initial requirements for design and construction are formulated. Therefore, at this stage, it is advisable to consider natural and man-made risks not only as the identification of potentially hazardous factors but also as the assessment of their ability to alter the conditions for future construction.

This approach makes it possible to determine not only the presence of a risk but also how it translates into a specific constraint on future construction. For example, flooding can lead to changes in soil conditions and restrictions on the development of certain plots; heavy precipitation can reduce the productivity of earthwork; a utility network failure can disrupt transportation or resource supply systems; and the presence of a hazardous man-made facility can restrict the location of a structure.

For the purposes of pre-investment analysis, it is proposed to consider five main types of constraints: territorial, technological, temporal, resource-related, and logistical. Taking all of these into account allows the results of risk assessment to be linked to the organization of subsequent construction activities (Table 1).

Consequently, the outcome of pre-investment assessment should be not only a list of risks, but also their organizational and technological profile, including the type of factor, the spatial area of impact, the duration, the processes affected, and the nature of the resulting constraints [8, 9].

In general terms, the extent of such an impact can be represented by the following diagram (Fig.).

The practical significance of the proposed approach lies in the fact that, when comparing options for the project's location and implementation, consideration is given not only to the magnitude of the risk but also to its potential to constrain specific construction processes. Thus, the pre-investment assessment serves as a link between the study of the site and the development of future organizational and technological solutions.

Thus, it is advisable to account for natural and man-made risks as a process of transforming information about threats into a system of project constraints. This makes it possible to identify vulnerable elements of the future construction system before work begins and to lay the groundwork for ensuring its organizational and technological stability during subsequent stages of project implementation.

PRINCIPLES OF SUSTAINABLE CONSTRUCTION IN THE SELECTION PROCESS

Incorporating the principles of sustainable construction into the model under consideration does not mean replacing economic and organizational-technological criteria with environmental ones. Rather, it involves expanding the evaluation system to include parameters that affect the long-term effectiveness of the project: the rational use of material, energy, and water resources;

Table 1. The Formation of Organizational and Technological Constraints in an Investment and Construction Project Under the Influence of Natural and Man-Made Risks

Risk category	Factor	Potential impact on the site	Impact on organizational and technological conditions	Resulting constraint	Potential project solution
Natural	Flooding	Deterioration of soil conditions; restricted site accessibility	Restrictions on earthworks and foundation works	Restriction of the work period and/or work area	Site engineering preparation; revision of construction sequence
Natural	Landslide processes	Ground deformation	Restrictions on equipment siting and movement	Prohibition or restriction of zone use	Revision of the site development boundaries
Natural	Karst processes	Loss of foundation bearing stability	Restrictions on the siting of structures	Spatial constraint	Special engineering solutions
Natural	Extremely low temperatures	Deterioration of technological working conditions	Restrictions on specific construction operations	Seasonal constraint	Special construction methods
Natural	High winds	Restrictions on safe working conditions	Restrictions on erection and work-at-height operations	Temporary work restrictions	Schedule contingency allowance
Technological	Utility network failure	Restricted access and/or resource supply	Disruption of the technological sequence	Restriction of the work area	Revision of routes and/or construction sequence
Technological	Industrial facility accident	Impact on the adjacent area	Restrictions on facility siting	Sanitary-protection and/or spatial constraint	Change of site or project layout
Technological	Transport incidents	Restricted access	Disruption of resource deliveries	Logistical constraint	Alternative delivery arrangement
Technological	Power supply limitations	Restricted site operation	Reduced production capacity	Resource constraint	Provision of backup power sources
Technological	Existing underground structures	Restrictions on site development	Modification of earthwork methods	Spatial constraint	Refinement of initial data
Technological	High failure rate of engineering infrastructure	Disruption of normal site accessibility	Risk of interruptions to production	Limitation of supply reliability	Infrastructure redundancy

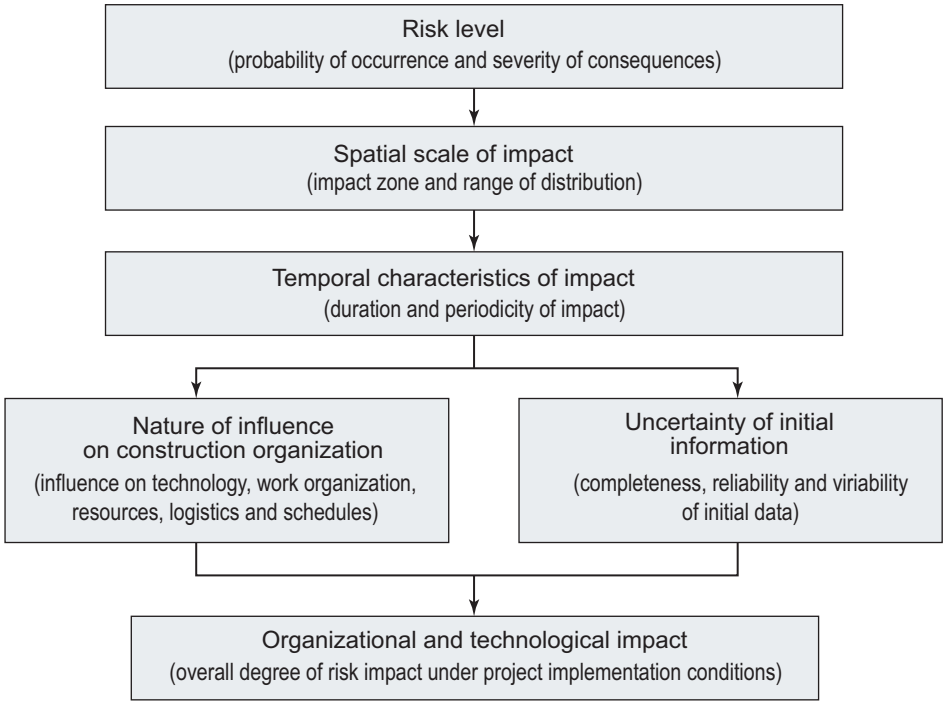


Diagram illustrating the formation of organizational and technological impacts of natural and man-made risks

Table 2. Relationship Between the Principles of Sustainable Construction, "Green" Technologies, and OTS

Principle	Green technology	Organizational and technological solution	Indicator	Verification
Resources and energy	Energy and water conservation	Resource metering; quality control of building envelope installation and commissioning	Specific consumption; envelope defects	Meters, method statements, inspection certificates, test records
Waste reduction	Separate collection and recycling	Zoning, provision of containers, and waste removal logistics	Number of waste streams; recycling rate	Construction site layout plan, register, certificates
Impact reduction	Dust suppression; runoff and noise control	Environmental control of the construction site	Number of non-compliances; rectification rate	Checklists, photographs, site logs

waste reduction; minimization of negative environmental impacts; the adaptability of solutions; and the ability to verify the achieved results [10, 11].

For organizational and technological decision-making, the principle of sustainable construction translates into specific solutions: energy efficiency — into the technology for installing and monitoring building envelopes and engineering systems; resource conservation — into standards for water and energy consumption; waste reduction — into separate collection, sorting, and managed logistics; environmental safety — into control of dust, noise, and effluents; digital traceability — into BIM and electronic recording of inspection operations. Consequently, "green" technology is viewed as an element of OTS, and its rationality is determined by a combination of technical effectiveness, work organization methods, site conditions, resources, timelines, risks, and the ability to document the results (Table 2) [12].

THE RELATIONSHIP BETWEEN METHODS AND ORGANIZATIONAL AND TECHNOLOGICAL CHALLENGES

The selection of optimal organizational and technological solutions during the pre-investment stage is based on the systematic application of interrelated methods of analysis and evaluation. The first stage involves defining the set of initial project characteristics, including facility parameters, geographical conditions, resource constraints, timeline requirements, and the nature of interactions among project participants. Next, a set of possible organizational and technological solutions is formed, which are considered as alternatives that meet the specified conditions for project implementation.

The next stage involves identifying factors capable of having a significant impact on the organization and technology of work execution. These factors are grouped according to the nature of their impact and linked to specific organizational and technological tasks. In this process, natural and man-made risks are not considered in isolation but rather through their potential impact on timelines, site accessibility, technological sequence, resource provision, and logistics.

The identified factors are transformed into a system of constraints and criteria for evaluating alternatives. This transformation allows for a shift from a qualitative description of project conditions to comparable indicators characterizing economic efficiency, technical feasibility, resource availability, timelines, environmental parameters, and risk levels. For options that involve the application of sustainable and "green" construction principles, additional consideration is given to indicators of energy efficiency, resource conservation, waste management, and environmental safety.

In the final stage, a comparative evaluation of the identified alternatives is performed. To do this, normalized values of the criteria and their weighting coefficients are used, after which an integrated assessment of each alternative is determined. The resulting outcome allows

for identifying the preferred alternative and determining the factors that had the greatest influence on its position in the final ranking.

Thus, the relationship between the methods and organizational and technological tasks is expressed by the sequence "initial conditions — factors — constraints — criteria — evaluation of alternatives — solution selection". This sequence ensures a transition from the analysis of the initial situation to a well-founded organizational and technological solution without mixing up the various stages of decision-making [13].

PRACTICAL APPLICATION OF METHODS FOR SELECTING ORGANIZATIONAL AND TECHNOLOGICAL SOLUTIONS

The practical application of the methods discussed begins after a set of alternatives has been identified and the criteria for comparing them have been established. For each alternative, compliance with the project's initial constraints, requirements for construction technology, resource allocation, and the timing and conditions for the construction site is assessed.

At this stage, the alternatives are compared based on the established set of indicators. First and foremost, solutions that do not comply with mandatory regulatory, territorial, or technological requirements are eliminated. The remaining options are compared based on economic, organizational-technological, resource, environmental, and risk characteristics. This allows for distinguishing between acceptable solutions and the preferred solution, which provides the most rational combination of the established parameters.

Verifying the stability of the result is of particular importance. Changing the weighting coefficients or individual input parameters can alter the position of alternatives in the final ranking. Therefore, a sensitivity analysis is conducted for the selected solution to determine the extent to which the result depends on the most significant factors. If a small change in the input data leads to a significant change in the final selection, the relevant parameters require further refinement.

After the preferred option is determined, the evaluation results are documented as part of the initial requirements for subsequent project phases. It is advisable to include in these requirements the organizational and technological decisions made, key constraints, criterion values, significant risks, and measures to mitigate them. For decisions related to sustainable construction, indicators of resource and energy efficiency, waste management, and methods for verifying the achieved results are also documented.

Thus, the application of these methods at the pre-investment stage ensures not only the selection of the preferred organizational and technological solution but also the verification of its feasibility, resilience to changes in initial conditions, and readiness for transfer to subsequent stages of the investment and construction project [14, 15].

The study showed that the selection of organizational and technological solutions at the pre-investment stage should be carried out as a multifactorial procedure in which the project's characteristics, risks, constraints, performance criteria, and management alternatives are considered within a unified framework, and the proposed spatial-factor representation ensures the structuring of the factor space.

This approach allows for a systematic consideration of the diverse factors affecting project implementation and helps avoid fragmented decision-making, which often leads to increased costs and missed deadlines. The spatial-factor representation makes it possible to visualize and rank key parameters, identifying dominant factors and areas of heightened risk, which is particularly important when working with complex and large-scale projects.

A promising direction for the method's development is its adaptation to the specific characteristics of individual types of construction projects (e.g., transportation infrastructure, industrial, or residential construction), as well as the expansion of the set of criteria to include environmental, social, and operational factors. Further research could focus on developing standard factor space models for different classes of projects and on calibrating objective functions based on industry statistics and data from completed projects.

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Выбор рациональных организационно-технологических решений на предынвестиционной стадии инвестиционно-строительного проекта с учетом природных и техногенных рисков и принципов устойчивого строительства

В статье рассматривается задача выбора рациональных организационно-технологических решений на предынвестиционной стадии инвестиционно-строительного проекта в условиях природных и техногенных рисков с учетом принципов устойчивого строительства. Особое внимание уделено включению «зеленых» технологий в состав организационно-технологических решений, обеспечивающих рациональное использование материальных, энергетических и водных ресурсов, снижение объема отходов и негативного воздействия на окружающую среду. Показана необходимость взаимного учета характеристик территории, ограничений проекта, рисков, организационно-технологических факторов и требований устойчивого строительства. Предложен методический подход, основанный на формировании пространства альтернатив, преобразовании факторов в систему критериев и последующей сравнительной оценке вариантов. Определены направления документального подтверждения достигнутых результатов и взаимосвязь принятых решений с последующей организацией строительного производства. Это обеспечивает практическую связь с условиями реализации проекта и его последующими организационно-технологическими задачами.

Ключевые слова: *инвестиционно-строительный проект, предынвестиционная стадия, организационно-технологические решения, управление проектом, природные риски, техногенные риски, устойчивое строительство, зеленые технологии, ресурсосбережение, рациональный выбор*

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Об авторах: **Смирнов Артем Денисович** — аспирант кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; artemsmirnoff23@gmail.com;

Нурягдыев Нурджелал Нургелдиевич — аспирант кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; ORCID: 0009-0003-9172-0053; nuryagdievnurjk@gmail.com;

Нассуха Илья Владиславович — аспирант кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; Ilia.nassuha@mail.ru.

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Lunyakov M.A.
Kaygorodov A.S.

Soil improvement and foundation strengthening methods: A review of current technologies and prospects for their application in the Arctic Zone of the Russian Federation

The paper provides an overview of modern methods for soil consolidation and foundation reinforcement, as well as an assessment of their potential application in the Arctic zone of the Russian Federation, where the issue of insufficient housing construction is particularly relevant due to the significant amount of dilapidated and emergency housing. The relevance of this work is driven by the need to restore the operational suitability of the foundations and bases of multi-storey buildings during reconstruction, given the widespread presence of permafrost soils. The work systematizes a set of regulatory documents (SP 22.13330, SP 24.13330, SP 45.13330, SP 496.1325800, etc.) that regulate the design, production, and control of soil consolidation and foundation reinforcement. It is noted that the current edition of SP 25.13330 does not contain requirements for the consolidation of permafrost soils, which indicates a gap in the regulatory framework. The article discusses physical, mechanical, and chemical methods of soil consolidation, including thermal consolidation, artificial freezing and thawing, water drainage, compaction, as well as silicification, resinization, cementation, jet cementation, and bituminization. Separately, the methods of strengthening the foundations are analyzed: restoration of the bearing capacity of the foundations, increasing the bearing capacity of the foundation, and unloading the foundation structures. It has been revealed that the most detailed studies have been conducted on electro-thawing, hydro-thawing, and steam-thawing, freezing using thermostabilizing systems, and the installation of remote bored piles. At the same time, electrochemical thawing, injection and jet cementation, as well as drilling-injection and drilling-cast piles, which provide a wide range of applications, technological flexibility, and economic efficiency, are recognized as promising for the Arctic zone. One of the key limitations is the need for solutions to harden at negative temperatures. The results of this review can be used in the development of regulatory requirements and the selection of rational technologies for the reconstruction of buildings and structures in the permafrost zone.

Keywords: *soil stabilization, foundation strengthening, permafrost soils, Arctic zone of the Russian Federation, building reconstruction, regulatory framework, soil cementation, jet grouting, drilled-injection piles, ground thermal stabilization, electrochemical thawing, permafrost region*



Lunyakov Mikhail Aleksandrovich,
PhD in Economics, professor, Head of Corporate Department of the Minstroy RF; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; AuthorID 371455, WoS ResearcherID: ABG-9701-2021, ORCID: 0000-0001-7093-3779, SPIN-code: 7397-0731; lunyakovma@yandex.ru



Kaygorodov Andrey Sergeevich,
Expert of the Department of Regulation and Standardization in Construction; FAI "FCC"; 6 Furkasovsky Lane, Moscow, 101000, Russian Federation, andrey.kaygorodov.86@mail.ru

The quality of life of the population directly depends on the development and capacity for the effective functioning of social infrastructure and the housing stock. In the Arctic zone of the Russian Federation, the problem of insufficient housing construction is particularly acute due to the significant volume of dilapidated and unsafe housing.

The issues of soil consolidation and foundation reinforcement are regulated by the provisions of regulatory technical documentation: SP 22.13330.2016, SP 24.13330.202, and SP 45.13330.2017 [1–3].

The requirements for designing foundations during the reconstruction of buildings and structures, as well as the criteria for assessing the impact on neighboring buildings, are set out in section 5.8 of SP 22.13330 [1]. Section 5.9 of SP 22.13330 contains provisions for reducing foundation deformations and their impact on buildings and structures. When designing, measures to reduce foundation deformations should be taken into account:

- measures to protect foundation soils from deterioration of their properties;
- measures aimed at transforming the construction properties of soils;
- design measures that reduce the sensitivity of structures to foundation deformations;
- leveling of structures or their individual parts using both permanent and temporary special equipment;
- construction of foundations with effective shapes and designs.

The design issues for pile foundations in the reconstruction of buildings and structures are specified in section 7.6 of SP 24.13330 [2], which contains requirements for selecting driven, pressed, drilled-injection, and other types of piles for conditions characterized by a significant increase in the load on the foundation and the presence of weak soils within its thickness.

SP 45.13330 [3] regulates the procedure for the performance and acceptance of: earthworks, the construction of bases and foundations during the construction of new buildings, and the reconstruction of buildings and structures. Separate requirements for soil stabilization, soil compaction, reinforcement, and artificial soil freezing are set out in sections 16–19.

In the current version of SP 25.13330.2020 [4], there are no requirements for stabilizing permafrost soils and reinforcing foundations. SP 496.1325800.2020 [5] contains requirements for the performance of earthworks and the construction of foundations and bases for buildings and structures in areas with permafrost soils, including: measures to adapt building and structure designs to prevent deformations during the thawing of the foundation, as well as guidelines for the use of seasonally operating cooling devices and soil thermal stabilization systems.

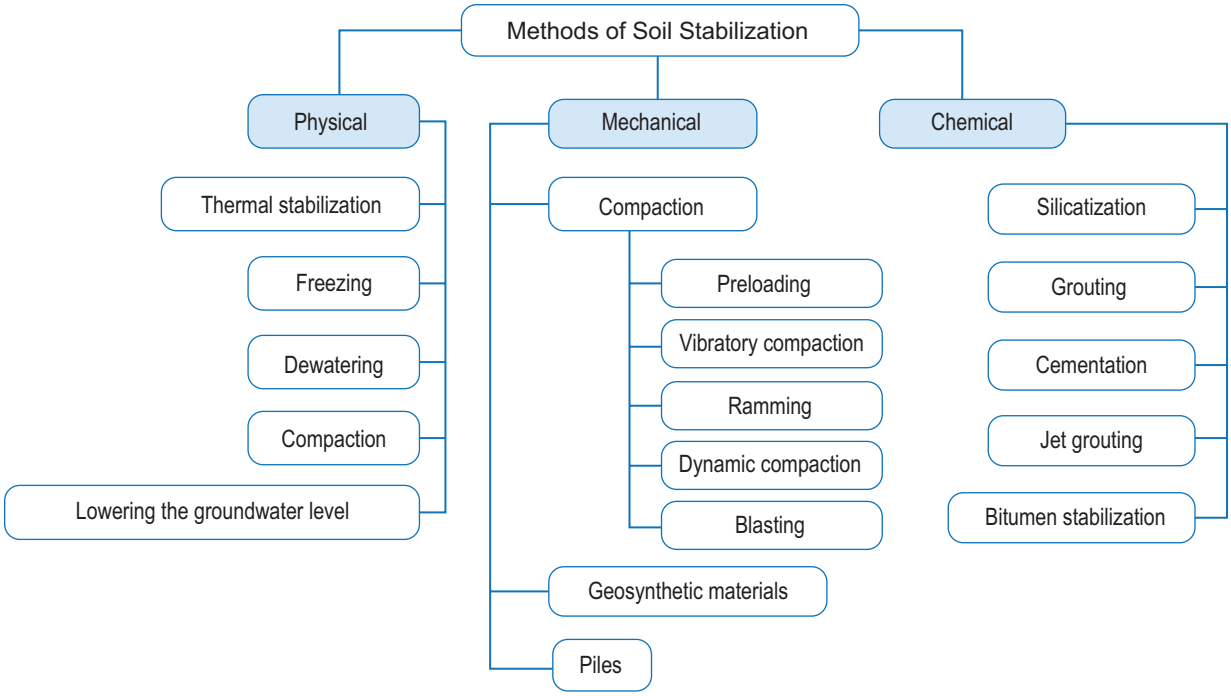


Fig. 1. Methods of soil stabilization

In 1974, the Recommendations for the Design and Construction of Foundations and Basements with Pre-Construction Thawing of Permafrost Soils [6] were developed, including methods of electrical, hydraulic, and steam thawing. The Recommendations set out methods for calculating the thawing of permafrost soils and the settlement of thawing soils in the foundation, methods and selection of thawing work technologies, recommendations for foundation design, as well as monitoring their implementation during construction and operation. In 1977, the Manual on the Technology of Physico-Chemical Strengthening of Freezing and Thawing Soils [7] was developed; it outlines methods and technologies for pre-construction improvement of the engineering properties of soils (including thawing using electricity and chemical reagents, compaction, and stabilization against frost heave).

In 1984, the Recommendations on the Design and Application of Cooling Systems Without Energy Costs [8] were developed; they cover the designs of vapor-liquid cooling systems, the technical characteristics of heat carriers, and the specifics of installation, testing, operation, and refilling. All the documents listed are used as reference materials insofar as they do not contradict the current regulatory documents.

In construction, physical, mechanical, and chemical methods are used to improve the physical and mechanical properties of soils (Fig. 1) [9].

To improve the physical properties of soils, a combination of physical, mechanical, and chemical methods of soil stabilization is used. Physical methods include thermal stabilization, artificial freezing, thawing, soaking, and lowering the groundwater level. Thermal stabilization is based on the transformation of structural bonds under the influence of high temperatures and is carried out either by injecting air heated to a temperature of 600–800 °C into the soil under pressure, or by burning fuel in hermetically sealed wells. This method is used for loess-like and non-water-saturated silty-clay soils. Artificial freezing is the transformation of structural bonds in the soil under the influence of sub-zero temperatures and is carried out using seasonally active cooling devices, refrigeration units, thermosyphons, and soil thermal stabilization systems [10]. Soil freezing is used to prevent the ingress of groundwater into excavations, as well as during construction on permafrost soils according to principle I. Artificial thawing involves the transition of frozen soil to a thawed state using electric thawing, hydraulic thawing, and steam thawing [9], as well as artificial salinization. Thawing is used for pre-construction thawing of permafrost soils when they are used for construction according to principle II. Artificial soil soaking is the destruction of the soil structure, followed by subsidence and compaction under the influence of its own weight; it is carried out from the surface of the pit bottom, and if necessary, the soaking process is accelerated through drainage wells. It has limited application, primarily for loess foundations. Lowering the groundwater level is a method of improving the physical properties of soil, based on eliminating the weighing effect of water and improving the specific gravity of the soil. It is carried out using light and ejector well points, vacuuming, and electroosmosis. It is used in the development of excavations, the construction of underground structures, and for protecting areas from flooding.

Mechanical soil compaction is the improvement of the physical properties of soil without changing its chemical composition or phase state. It is carried out by applying a load, tamping, vibrating, using explosives, or by combining these methods. Surface compaction is performed using rammers, rollers, vibrators, and load-compaction machines. This method is applicable to gravelly, sandy, clayey, organomineral, loamy, subsidence, swelling, and highly compressible soils [11]. Pile construction is a method of securing and compacting soils by installing piles and forcibly displacing the soil. Bored piles, driven piles, vibratory-rammed piles, and soil piles are used for consolidation. Pile construction for consolidation is applied in all types of soil except for rocky, coarse-grained, waterlogged, and structurally unstable soils. Among the chemical methods of soil

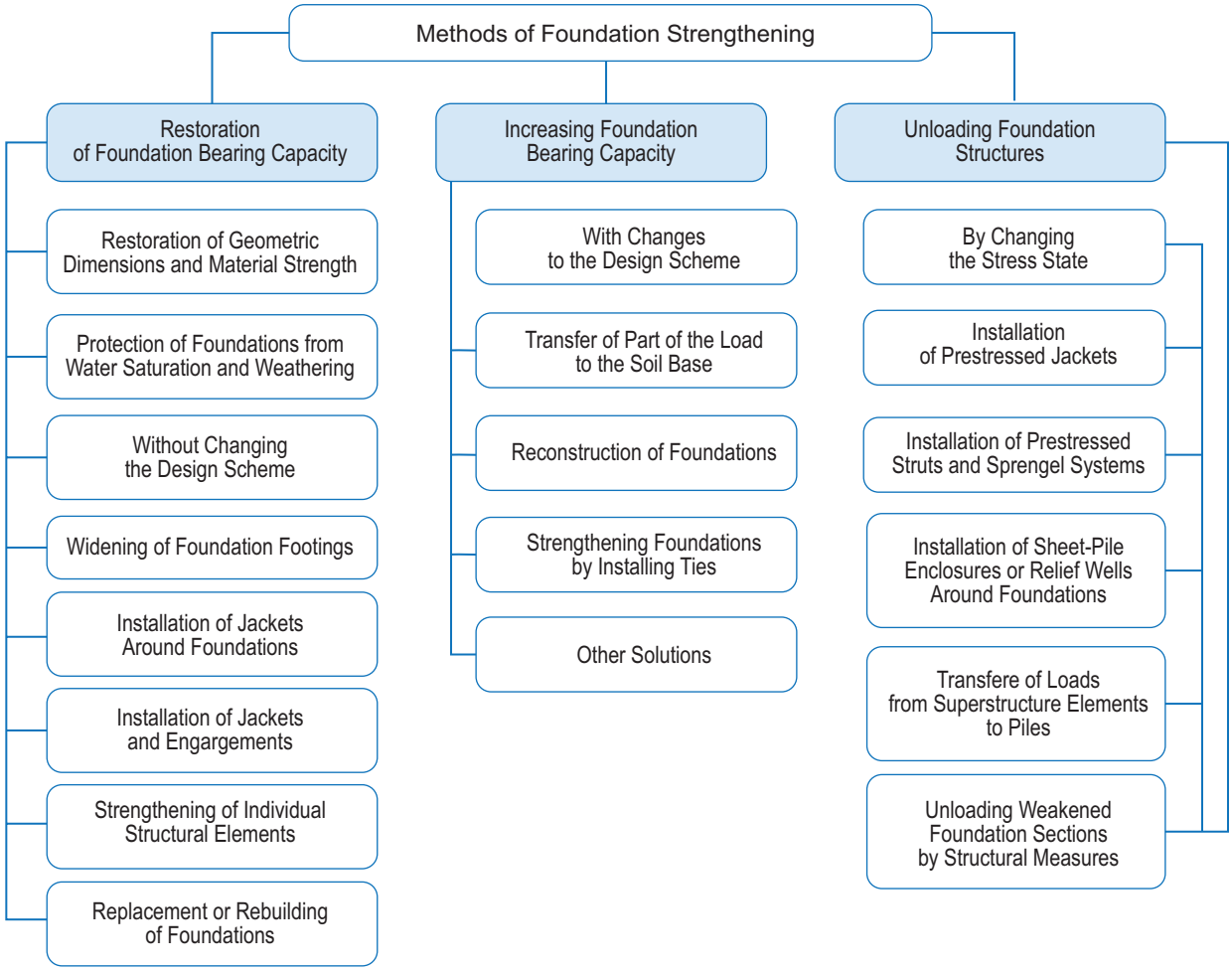


Fig. 2. Methods of strengthening foundations

consolidation, the following are distinguished: silicatization, resinization, grouting, jet grouting, and bitumenization. Silicatization involves injecting a sodium silicate solution (liquid glass) into drilled wells, which forms a gel that seals the soil pores; as a result, the soil becomes waterproof and acquires high mechanical strength. Depending on the physical and mechanical properties of the soil, single-solution, double-solution, or gas silicatization of soils (using CO_2) is applied [12, 13]. This method is effective for subsidence loess and sandy soils with a filtration coefficient ranging from 0.2 to 80 m/day. Soil resinization involves injecting an aqueous solution of urea resin (for example, oxalic acid) into the soil through injectors [14]; it increases the mechanical strength of the soil and is used for sandy and loess soils with a filtration coefficient of up to 5 m/day. Soil cementation is based on injecting and impregnating the soil pores with a solution, which, after hardening, forms a soil cement with improved strength and deformation characteristics. The injection can be carried out either under low pressure or under high pressure, with the formation of flat wedges along which the solution spreads into the massif [15, 16]. This method is used to fill large voids, fractured rocky, coarse-grained and gravelly sandy soils. Jet-grouting is based on the destruction of soil by a high-pressure jet of cement mortar with simultaneous mixing and the formation of a high-strength waterproof element after hardening [17]. There are three types of technology: single-component (Jet-1), two-component (Jet-2) and three-component (Jet-3). This method is applicable across almost the entire range of soil granulometric composition, from coarse-grained to fine-grained clay soils and silts [18]. Bitumenization, which involves injecting hot or cold (in the form of an emulsion) bitumen, ensures the filling of pores and cracks. Hot bitumenization is effective for large cracks, while cold bitumenization is effective for small ones (less than 1 mm). This method is used for both rock formations and sandy soils.

When reinforcing foundations, technical solutions are used to restore and increase the load-bearing capacity of the foundations, as well as measures to unload the foundation structures (Fig. 2).

Restoration of the geometric dimensions and strength of foundation materials is achieved through methods such as cement grouting, resinization, and other injection technologies. To protect foundations from soaking, clay dams and waterproofing are provided, and to protect against weathering, plastering, shotcrete, and other protective methods are used.

The need to restore the load-bearing capacity of foundations arises when there are defects and damage to the foundation structures, which may have been caused by manufacturing errors, improper operation, operational wear and tear, material degradation, or a decrease in its watertightness [19].

The load-bearing capacity of foundations can be increased without changing the design scheme by widening the base of the foundations, installing casings around the foundations (metal, reinforced concrete, etc.), constructing concrete jackets and

extensions, reinforcing individual foundation structures, and replacing the foundations.

The load-bearing capacity of foundations can be increased by changing the design scheme — by transferring part of the load from above-foundation structures to the base, by reworking the foundations, or by strengthening the foundations through the installation of ties (anchors, posts, cables, etc.).

The load-bearing capacity of foundations, with changes in the stress state, can be increased by installing pre-stressed casings (metal or reinforced concrete), installing pre-stressed struts and tie-back systems, or installing sheet piling or a caisson around the foundations.

An increase in the load-bearing capacity of foundations is required when the operating conditions change (e.g., a change in the building's functional purpose, an increase in loads) or when there are defects and damage to the foundation structures.

The unloading of foundation structures is carried out by transferring the load from the above-foundation structures to piles (mainly bored-injected piles) or through structural measures in weakened areas. This method is used when the stability of the foundations is compromised during operation due to waterlogging, freeze-thaw cycles, swelling, subsidence, karst-suffosion processes, and other adverse effects.

Based on the analysis of the literature, the most extensively studied technologies used in the reconstruction of buildings and structures include electrical thawing, hydraulic thawing, and steam thawing; soil freezing using ground thermal stabilization systems; and the installation of offset piles in predrilled boreholes. Each of these methods has its own advantages, limitations, and specific areas of application.

Among the methods studied for regulating the thermal regime of soils are the installation of ventilated pipes and thermal shields in ventilated crawl spaces, which make it possible to reduce the average annual air temperature and increase the air flow speed, thereby affecting the intensity of heat exchange with the soil mass.

Promising technologies that require further study include silicification, electrochemical thawing, injection and jet grouting, as well as the use of drilled-injection and drilled-cast piles for strengthening foundations.

Chemical consolidation of soils can be a more technically and economically viable solution for the reconstruction of buildings and structures whose foundation bases undergo additional uneven deformations during the thawing process, as opposed to the use of soil thermal stabilization systems aimed at preserving the frozen state of the soil (principle I). Using the electrochemical method, greater thawing efficiency is achieved compared to other methods.

Injection and jet grouting of permafrost and thawing soils can be used to consolidate the entire range of soil granulometric composition — from coarse-grained to fine-grained clayey types and silts, as well as fractured rock soils. Combined with the relatively low cost of the work and materials, these advantages make these technologies a promising area for further research.

The introduction of bored-injection and bored piles into the practice of reconstructing foundations and bases on permafrost soils offers a number of significant advantages: reduced costs for strengthening the foundation, flexibility in pile designs, the possibility of installing extensions, and the ability to work in confined spaces with a ventilated underground space.

A significant limitation of using grouting and drilled piles in some cases may be the need to ensure the hardening of cementitious materials at sub-zero temperatures typical of permafrost soils.

The review and analysis of current scientific, technical, regulatory, and methodological literature in the field of soil stabilization and foundation reinforcement made it possible to identify the advantages, disadvantages, and areas of application of existing technologies in relation to the conditions of permafrost soils.

A gap has been identified in the current regulatory framework of the Russian Federation, which consists in the absence of regulated requirements for stabilizing permafrost soils and strengthening the foundations of buildings and structures during reconstruction.

A list of promising technologies recommended for restoring the operational suitability of the bases and foundations of multi-apartment buildings in settlements within the Arctic zone of the Russian Federation has been identified. These technologies include: electrochemical thawing and soil consolidation, injection and jet grouting, as well as the use of drilled injection and drilled cast piles for strengthening the foundations of buildings and structures.

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Методы закрепления грунтов и усиления фундаментов: обзор технологий и перспективы применения в Арктической зоне РФ

Статья посвящена обзору современных способов закрепления грунтов и усиления фундаментов, а также оценке перспектив их применения в Арктической зоне Российской Федерации, где проблема недостаточности объема жилищного строительства особенно актуальна в условиях значительного объема ветхого и аварийного жилья. Актуальность работы обусловлена необходимостью восстановления эксплуатационной пригодности оснований и фундаментов многоквартирных домов в условиях реконструкции при повсеместном распространении многолетнемерзлых грунтов. В работе систематизирован комплекс нормативных документов (СП 22.13330, СП 24.13330, СП 45.13330, СП 496.1325800 и др.), регламентирующих проектирование, производство работ и контроль при закреплении грунтов и усилении фундаментов. Отмечено, что в действующей редакции СП 25.13330 отсутствуют требования к закреплению многолетнемерзлых грунтов, что указывает на пробел в нормативной базе. Рассмотрены физические, механические и химические способы закрепления грунтов, включая термическое закрепление, искусственное замораживание и оттаивание, водопонижение, уплотнение, а также силикатизацию, смолизацию, цементацию, струйную цементацию и битумизацию. Отдельно проанализированы способы усиления фундаментов: восстановление несущей способности фундаментов, увеличение несущей способности фундамента и разгружение конструкций фундаментов. Выявлено, что наиболее детально проработаны электрооттаивание, гидрооттаивание и пароотаивание, замораживание с использованием термостабилизирующих систем и установка выносных буроопускных свай. При этом перспективными для Арктической зоны признаны электрохимическое оттаивание, инъекционная и струйная цементация, а также буроинъекционные и буронабивные сваи, которые обеспечивают широкий диапазон применения, технологическую гибкость и экономическую эффективность. К числу ключевых ограничений отнесена необходимость твердения растворов при отрицательных температурах. Результаты обзора могут быть использованы при разработке нормативных требований и выборе рациональных технологий для реконструкции зданий и сооружений в условиях криолитозоны.

Ключевые слова: *закрепление грунтов, усиление фундаментов, многолетнемерзлые грунты, Арктическая зона РФ, реконструкция зданий, нормативная база, цементация грунтов, струйная цементация, буроинъекционные сваи, термостабилизация грунтов, электрохимическое оттаивание, криолитозона*

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Об авторах: **Луняков Михаил Александрович** — доктор экономических наук, профессор, заведующий Корпоративной кафедрой Минстроя РФ; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; AuthorID 371455, WoS ResearcherID: ABG-9701-2021, ORCID: 0000-0001-7093-3779, SPIN-код: 7397-0731; lunyakovma@yandex.ru;

Кайгородов Андрей Сергеевич — эксперт Управления нормирования и стандартизации в строительстве; **ФАУ «ФЦС»;** 101000, г. Москва, Фуркасовский переулок, д. 6; andrey.kaygorodov.86@mail.ru.

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Москва. Дьяковские ворота и Георгиевская колокольня в Коломенском. Рисунок, тушь, перо

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Grigoryeva A.A.
Murzina E.A.

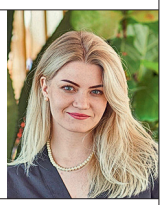
Identifying discrepancies between the actual use of land plots and urban planning regulations

The paper examines the issue of identifying and qualifying discrepancies between the actual use of land plots, information contained in the Unified State Register of Real Estate, and the requirements of urban planning regulations. The relevance of the study is determined by the fact that inconsistency between these informational and legal blocks may lead to errors in cadastral works, the preparation of urban planning documentation, the implementation of state and municipal land control, as well as in decisions made by owners regarding the use of real estate. The issue acquired additional significance after amendments to land legislation entered into force on March 1, 2026, introducing a separate chapter on the types of permitted use of land plots into the Land Code of the Russian Federation. The paper systematizes the regulatory and spatial sources of information used to verify a land plot: data from the Unified State Register of Real Estate, land use and development rules, the classifier of types of permitted use, information from the National Spatial Data System, remote sensing materials, and the results of field surveys. A step-by-step algorithm for establishing discrepancies is proposed, including object identification, determination of the territorial zone, recording of the actual use of the plot, comparison of legal and actual regimes, analysis of the temporal factor, and classification of the identified discrepancy. It is shown that the mere existence of a discrepancy does not always indicate an offense: it is necessary to consider the moment when rights arose, the previously established type of permitted use, the legal regime of capital construction facilities, and the specifics of transitional regulation. The article develops a typology of discrepancies and proposes a form of analytical table suitable for practical use by land management and cadastral specialists. It is concluded that legal and geoinformation methods must be used comprehensively, since a reliable assessment is possible only through simultaneous verification of registry, urban planning, and factual data.

Keywords: *land plot, actual use, urban planning regulation, type of permitted use, Unified State Register of Real Estate, land use and development rules, cadastral works, spatial data, land control*



Grigoryeva Anastasia Andreevna,
Master's student of the Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation;
ORCID: 0009-0002-0269-7174;
nastya.balmashnova@mail.ru



Murzina Ekaterina Aleksandrovna,
Master's student of the Department of Construction organization and Real Estate management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation;
ORCID: 0009-0001-0838-6951;
catherine_maslova@mail.ru

A land plot is simultaneously a real estate object, a spatial unit of territory, and an object of legal regulation. Therefore, its use is assessed not only according to its actual condition, but also according to a set of legally significant characteristics. In accordance with the Land Code of the Russian Federation, right holders are obliged to use land plots taking into account the established legal regime, while modern regulation of types of permitted use is concentrated in Chapter II.1 of the Land Code of the Russian Federation [1]. For settlement lands, urban planning zoning is of substantial importance: land use and development rules include an urban planning zoning map and urban planning regulations that determine the permissible parameters for the use of territory [2].

The problem arises in cases where the legally established characteristic of a plot and its real economic function diverge. For example, the Unified State Register of Real Estate may indicate a type of permitted use related to individual housing construction, whereas the plot is actually used for vehicle servicing, storage of materials, or trade. A more complex situation is also possible: the actual use is allowed by the urban planning regulation of the territorial zone, but the corresponding main type of permitted use has not been selected and is not reflected in the Unified State Register of Real Estate. Finally, there are cases where the current urban planning regulation does not coincide with use that lawfully arose before its approval. These situations require different legal assessments.

From March 1, 2026, the approach to types of permitted use was significantly clarified by Federal Law No. 295-FZ of July 31, 2025. The law introduced systematic regulation into the Land Code of the Russian Federation concerning the establishment, modification, selection, and use of types of permitted use of land plots [3]. As a result, when examining a plot, it is especially important to distinguish between the permissible uses provided for by the territorial zone and the selected use, information about which has been entered into the Unified State Register of Real Estate.

The purpose of this study is to develop a consistent methodology for establishing discrepancies between the actual use of land plots and urban planning regulations. To achieve this purpose, the following tasks are addressed: regulatory and informational sources are identified; criteria for comparing information are formed; typical types of discrepancies are systematized; the significance of spatial methods is established; and an algorithm for documenting the result is proposed. The object of the study is land plots to which urban planning regulations apply, while the subject is the set of legal and spatial features that make it possible to assess the compliance of actual use with the established regime.

The key source of legally significant information about a real estate object is the Unified State Register of Real Estate. Federal Law No. 218-FZ of July 13, 2015 provides for the inclusion in the real estate cadastre of characteristics of a land plot, including information about its category and type or types of permitted use [4]. Consequently, an extract from the Unified State Register of Real Estate serves as the starting point for verification; however, by itself it does not provide a complete answer regarding

the permissibility of actual activity, since it must be considered together with urban planning zoning documents.

To unify terminology, the classifier of types of permitted use of land plots, approved by Order of Rosreestr No. P/0412 of November 10, 2020, is used. In its current version, the classifier contains names of uses, their descriptions, and numerical codes. At the same time, types of permitted use established before legislative amendments cannot be mechanically recognized as invalid solely because their wording does not coincide with the classifier [5]. Therefore, a specialist must examine not only the literal name of the type of permitted use, but also the date of its establishment, the content of title documents, and transitional provisions of legislation.

The spatial component of the study is based on legislation on geodesy, cartography, and spatial data. Federal Law No. 431-FZ of December 30, 2015 defines the foundations for the creation, provision, and use of spatial data and cartographic information [6]. For the purposes of establishing discrepancies, this is important because the legal assessment of actual use is almost always connected with a spatial question: where exactly the activity is located, whether its contour coincides with the plot boundaries, in which territorial zone the object is located, and whether there are intersections with other zones and territories.

The State Program of the Russian Federation "National Spatial Data System" is aimed at developing a unified digital infrastructure of spatial information, increasing the completeness and quality of real estate data, and ensuring interaction between state information resources [7]. In practical work, the use of such digital sources reduces the time required for preliminary analysis and makes it possible to compare data from different registers and cartographic layers in a single coordinate system.

The procedure for information interaction with the federal state geographic information system that ensures the functioning of the National Spatial Data System is specified by Order of Rosreestr No. P/0031/24 of February 20, 2024 [8]. The existence of regulated spatial data exchange forms the basis for further automation of checks of compliance between actual and permitted use.

The control component is regulated by the Regulation on Federal State Land Control, approved by Resolution of the Government of the Russian Federation No. 1081 of June 30, 2021. This document defines the organization of land supervision and a risk-oriented approach to control activities [9]. At the same time, establishing the actual use of a plot has direct evidentiary significance, since it is precisely the actual conduct of the right holder that is compared with mandatory requirements.

The legal consequence of using a land plot not in accordance with its designated purpose or not in accordance with its permitted use may be administrative liability under Article 8.8 of the Code of Administrative Offenses of the Russian Federation [10]. Therefore, the methodology for identifying discrepancies must exclude a simplified approach in which any visually established difference is automatically recognized as a violation. A substantiated conclusion requires verification of title and registry information, urban planning regulations, the nature of actual activity, and the circumstances of its emergence.

Non-use of a plot should be distinguished from use not in accordance with the established regime. Resolution of the Government of the Russian Federation No. 826 of May 31, 2025 established signs of non-use of land plots within settlement lands, as well as garden and vegetable garden land plots [11]. This distinction is methodologically important: the absence of required development and the performance of another activity not provided for by the regime are different legal situations and must be recorded separately (Table 1).

Within the framework of this study, a discrepancy is understood as a discrepancy established as a result of comparison between the actual use of a land plot and one or more elements of its legal or urban planning regime. This definition is broader than the concept of an offense. A discrepancy is a diagnostic result of analysis, after which legal qualification is required. This makes it possible to separate technical or informational inconsistency from unlawful use.

Methodologically, it is advisable to consider three interconnected blocks: information from the Unified State Register of Real Estate; requirements of the urban planning regulation; and actual use. If all three blocks are consistent, the plot is used in a regime that is reflected in the register and permitted by the territorial zone. If two or three blocks diverge, it becomes necessary to determine the nature of the inconsistency. This model is shown in Fig. 1.

The legal position of the Constitutional Court of the Russian Federation on the need to consider the balance between public requirements for land use and the rights of the owner is of particular importance. Resolution No. 35-P of November 14, 2019 emphasizes the public nature of requirements to comply with the designated purpose and legal regime of land plots [12]. For a cadastral specialist, this means that assessment is not reduced to a formal



Zvonov
Ilya Alexandrovich,
Senior Lecturer of the Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; SPIN-code: 6197-7370, Scopus AuthorID: 57204363101, ORCID: 0000-0002-4854-9903; ZvonovIA@mgsu.ru



Kildeeva
Tatiana Igorevna,
Candidate of Economic Sciences, Associate Professor of Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; ID RSCI: 9487-6761, Scopus AuthorID: 57194454597, WoS ResearcherID: GOH-0800-2022, ORCID: 0000-0001-8290-9784; Slepkovaprofi@gmail.com

Table 1. Main Sources of Information Used to Establish Discrepancies

Source	Information Checked	Practical Function	Limitation
Unified State Register of Real Estate	Permitted land use, category, boundaries, real estate objects	Recording the registered regime	The information does not describe actual activity
Land Use and Development Rules	Territorial zone, urban-planning regulations	Determination of the permitted regime	An up-to-date version of the document is required
Classifier of Permitted Land Uses	Name, description, and code of permitted land use	Substantive identification of the type of use	Previously established permitted land uses must not be ignored
National Spatial Data System and other GIS	Spatial layers and cartographic base	Integration of registry and urban-planning data	The quality of the conclusion depends on how up to date the layer is
Orthophotos/satellite images	External indicators of use	Preliminary identification of the actual use	Does not always allow the purpose of the activity to be determined
Field survey	Objects, activity, condition of the land plot	Confirmation of actual use	Records the condition as of a specific date

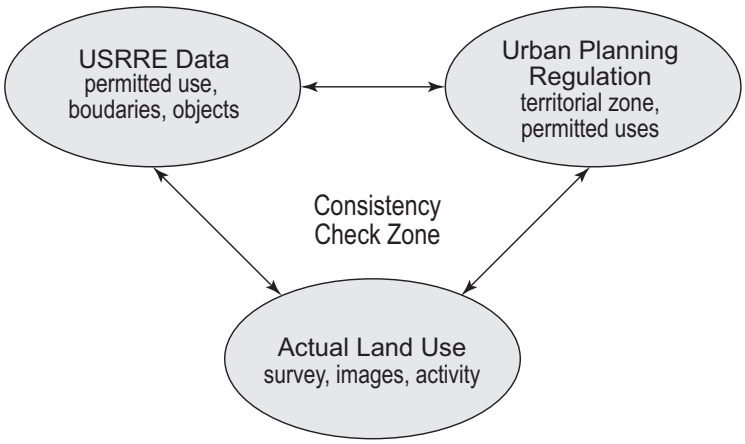


Fig. 1. Three-component model for checking the consistency of land plot use

comparison of names: actual activity must be considered in the context of the legal regime of the specific object.

Resolution of the Constitutional Court of the Russian Federation No. 42-P of October 16, 2020 considered the issue of selecting and implementing types of permitted use and applying liability under Article 8.8 of the Code of Administrative Offenses of the Russian Federation [13]. Despite subsequent changes in legislation on types of permitted use, this practice retains methodological significance: it demonstrates how important it is to distinguish between the established regime, actions of the right holder, and the procedure for reflecting relevant information. After the 2026 reform, this verification must be carried out taking into account the new Chapter II.1 of the Land Code of the Russian Federation.

In scholarly literature, urban planning zoning is considered an important source of information support for cadastral works. D.A. Gura notes the need for high-quality integration of cartographic and urban planning information when working with settlement lands [14]. This confirms the appropriateness of using a GIS approach: a discrepancy often cannot be reliably established solely from text documents without spatial overlay of boundaries and zones.

Actual use is the activity actually carried out on a land plot and the established manner of exploiting the territory. To determine it, it is necessary to record stable signs rather than isolated actions. For example, temporary parking of a car on a plot does not indicate the formation of an independent function of “vehicle storage”, whereas an equipped site, permanent placement of vehicles, signage, and relevant economic activity together may indicate a different nature of use.

The first level of research is desk analysis. The specialist analyzes information from the Unified State Register of Real Estate, publicly available spatial data, current land use and development rules, and aerial and satellite imagery. At this stage, a hypothesis regarding actual use is formed and plots requiring detailed verification are identified. The advantage of the desk stage lies in the ability to examine large territories and compare objects according to uniform criteria.

The second level is a field survey. Its purpose is to confirm or refute the desk-analysis hypothesis. Existing buildings and structures, sites, access roads, stored materials, signage, and other external signs of activity are recorded. If necessary, photography is carried out with reference to observation points. For the correctness of the result, the survey date must be indicated in the materials, since actual use may change.

The third level is substantive interpretation. External signs are translated into a functional description, which is then compared with the description of the type of permitted use according to the classifier and urban planning regulation. Mixed cases are the most complex, when several functions are implemented simultaneously on one plot. In such cases, it is necessary to determine which activity is primary, which is auxiliary, and which is unrelated to the established regime.

The spatial localization of activity is checked separately. If the actual area of use extends beyond cadastral boundaries, the issue is no longer limited to the type of permitted use and

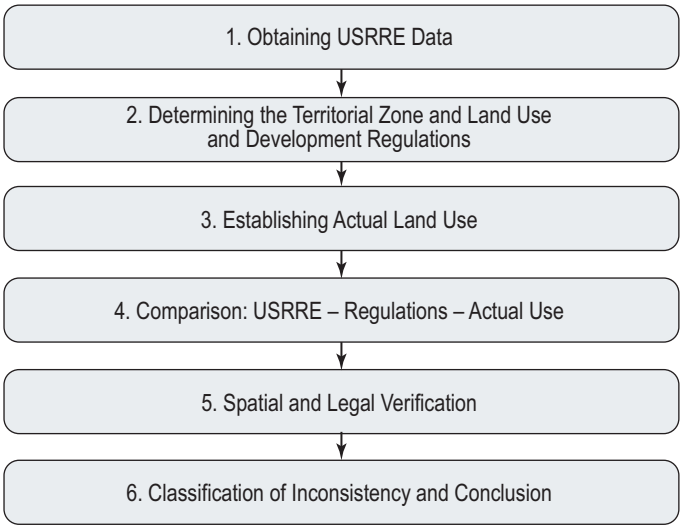


Fig. 2. Algorithm for establishing discrepancies between actual use and urban planning regulation

may include signs of occupation of adjacent territory. Similarly, the placement of an object within the plot does not guarantee its compliance with urban planning regulation if part of the plot falls within another territorial zone or is subject to special restrictions.

The proposed algorithm includes six interconnected stages (Fig. 2). Its fundamental difference from a simple comparison of the type of permitted use with the visually observed function lies in the sequential verification of registry, urban planning, factual, and temporal aspects.

At the first stage, the object is unambiguously identified by cadastral number and coordinate description of boundaries. Current information from the Unified State Register of Real Estate is obtained regarding area, land category, type of permitted use, rights, and real estate objects located on the plot. If the boundaries have not been established with the required accuracy, this circumstance is separately noted as a factor limiting spatial analysis.

At the second stage, the territorial zone is determined according to the current urban planning zoning map. The main, conditionally permitted, and auxiliary types of use, as well as maximum parameters, are extracted from the urban planning regulation. It is important to use the version of the land use and development rules in force on the date of the study, and in a disputed situation, to additionally examine previous versions.

At the third stage, the actual use of the plot is established. The result is formulated neutrally and demonstrably: for example, “placement and operation of a retail facility”, “open storage of construction materials”, or “operation of an individual residential house with a household plot”. Such wording is more convenient than prematurely assigning a classifier code.

At the fourth stage, substantive comparison is carried out. It is checked whether the actual use corresponds to the type of permitted use selected in the Unified State Register of Real Estate; whether it is permitted by the urban planning regulation; whether conditional permission is required; and whether the activity may be considered auxiliary. Compliance of capital construction facilities and the nature of their operation is also analyzed at this stage.

At the fifth stage, spatial and temporal circumstances are examined. The boundaries of the plot, territorial zones, and actual contours of use are overlaid. At the same time, it is established when the relevant use arose and when the land use and development rules were approved or amended. This stage is necessary to identify previously established lawful states that cannot be assessed solely according to the current regulation.

At the sixth stage, the final qualification is formed. The result must contain not only a “complies/does not comply” mark, but also the type of discrepancy, the evidentiary basis, the degree of reliability, and the recommended subsequent action: clarification of information, change of the type of permitted use if there are legal grounds, additional survey, or transfer of materials to the authorized body (Table 2).

One of the most common methodological errors is assessing any plot only according to the current version of the land use and development rules. Urban planning regulation develops over time: zone boundaries, lists of types of permitted use, classifier wording, and the procedure for selecting types of use change. Therefore, a plot that today appears “non-compliant” with the new structure of the regulation may have been formed and used lawfully earlier.

To avoid erroneous qualification, it is necessary to construct a brief chronology: the date when the right to the plot arose; the date when the type of permitted use was established; the date of creation and registration of the capital construction facility; the dates of approval and significant amendments to land use and development rules; and the date when the actual activity arose. If the key use arose before the regulatory change, the specialist must examine transitional norms and documents confirming the lawfulness of its emergence.

Temporal analysis is especially important when working with historically established development. In such territories, the modern functional model may not coincide with the original purpose of objects. The task of cadastral research is not a retrospective assessment of urban planning policy, but an accurate determination of the legal status of the object on a specific date.

The Constitutional Court of the Russian Federation has repeatedly addressed issues of proportionality of liability and obligations of right holders in the field of land use. Resolution No. 50-P of November 6, 2024 considered issues of liability for non-use of plots intended for construction, gardening, and vegetable gardening, and confirmed the importance of balancing public and private interests [15]. For the topic under consideration, this position is important because it demonstrates the need to establish not only the external result, but

Table 2. Typology of Identified Discrepancies

Type	Nature of discrepancy	Example	Required verification
A	Actual use ≠ USRRE; actual use is not permitted under the Land Use and Development Rules	A production facility is actually operating on a land plot designated for individual housing construction	Permitted use type, Land Use and Development Rules, nature of activity, date of occurrence
B	Actual use ≠ USRRE; actual use is permitted under the Land Use and Development Rules	Actual retail activity is permitted as the main permitted use type of the zone, but a different permitted use type is recorded in the USRRE	Procedure for selecting/changing the permitted use type and entering it into the USRRE
C	USRRE ≠ current structure of the Land Use and Development Rules	A previously established permitted use type is absent from the new list for the zone	Date of establishment of the permitted use type, transitional provisions
D	Function is permitted, but parameters do not comply	A permitted facility is located in violation of the maximum allowable parameters	Urban-planning regulations and characteristics of the facility
E	Spatial inconsistency	The actual site extends beyond the boundaries of the land plot	Coordinates, orthophoto, geodetic verification
F	Information inconsistency	Different information resources contain inconsistent data	Priority of official data, date of relevance

also legally significant circumstances with which the legislator connects the obligation of the right holder.

The use of GIS makes it possible to transform analysis from a set of disparate documents into a unified spatial model. A basic project may include a layer of cadastral boundaries, territorial zones, zones with special conditions for the use of territory, capital construction facilities, and a raster base of current imagery. For each land plot, an attribute record is created with the type of permitted use according to the Unified State Register of Real Estate and the result of interpretation of the actual use.

Formal checks can primarily be automated: determining the territorial zone by spatial intersection; identifying plots that intersect several zones; comparing the code of the type of permitted use with the list of permissible main uses; searching for objects located outside cadastral boundaries; and forming a list of plots for visual control. However, final qualification should not be fully transferred to an algorithm, since the lawfulness of use depends on the history of the object, the content of documents, and transitional regulation.

Risk-oriented selection of objects for survey is promising. Plots may be ranked not by an arbitrary "violation score", but by the presence of objective indicators: discrepancy between the registered type of permitted use and the list of the zone; presence of commercial or production facilities under a residential type of permitted use; significant changes in development on multi-temporal images; observed activity extending beyond boundaries; and lack of consistency between several official information layers. This approach does not replace proof of violation, but helps to rationally allocate survey resources.

An important condition for digital verification is documenting the origin of data. For each layer, it is necessary to record the source, date of relevance, coordinate system, and scale. Without this information, even a visually convincing overlay may be methodologically weak. For example, a shift of the raster base relative to cadastral boundaries may be mistakenly interpreted as an object extending beyond the plot (Table 3).

For practical application, it is recommended to present the results of the study in the form of a register of discrepancies. Each row corresponds to one land plot and contains the cadastral number, address or location description, type of permitted use according to the Unified State Register of Real Estate, territorial zone, list of relevant types of permitted use according to the land use and development rules, description of the actual use, confirmation sources, survey date, type of discrepancy, and final comment. If GIS is used, the register is linked to the spatial object by cadastral number.

The wording of the conclusion should be cautious. If the study is not carried out by an authorized control body, it is more appropriate to state that "signs of inconsistency between actual use and information from the Unified State Register of Real Estate and urban planning regulation have been identified", rather than to establish an administrative offense. The latter requires a legally prescribed procedure and evaluation of evidence by the competent authority.

Table 3. Criteria for the Final Assessment of a Land Plot

Criterion	Verification Question	Positive Result	Risk of Inconsistency
Registry-related	Which permitted use type is recorded in the USRRE?	The information is up to date and unambiguous	Outdated/incomplete record
Urban-planning	Does the Land Use and Development Rules permit the relevant function?	The function is provided for by the regulations	The function is absent or requires a special procedure
Factual	What is actually being carried out on the land plot?	The actual use corresponds to the established regime	Persistent different activity
Spatial	Where is the activity located?	Within the boundaries of the land plot and the corresponding zone	Encroachment beyond boundaries or overlap of zones
Temporal	When did the use arise?	Lawfulness is confirmed by the chronology	Current assessment without regard to transitional provisions
Evidentiary	Are the sources sufficient?	Several consistent sources	The conclusion is based on only one image/indicator

If the discrepancy is related only to informational data, the conclusion indicates the need to clarify them. If the actual use is permitted by the land use and development rules but does not correspond to the selected type of permitted use, the possibility of changing the type of permitted use is analyzed separately. If the activity is not permitted by the urban planning regulation, the lawfulness of the previously established use and the existence of special grounds must be examined. This format makes the results transparent and suitable for subsequent legal or cadastral analysis.

Establishing discrepancies between the actual use of land plots and urban planning regulations is a complex task at the intersection of land law, urban planning regulation, cadastral activity, and geoinformatics. A reliable conclusion cannot be obtained by comparing only two indicators: the visually observed function and the name of the type of permitted use in an extract from the Unified State Register of Real Estate. It is necessary to simultaneously consider the content of land use and development rules, register information, the classifier of types of permitted use, the spatial location of objects, and the history of the formation of the legal regime.

The proposed three-component model "Unified State Register of Real Estate — urban planning regulation — actual use" makes it possible to systematize the initial data, while the six-stage algorithm enables a consistent transition from object identification to qualification of the detected discrepancy. A significant element of the methodology is temporal verification, which makes it possible to distinguish unlawful changes in use from a lawfully established state that arose under different regulation.

The development of the National Spatial Data System and digital GIS tools creates prerequisites for the automated identification of potential discrepancies. At the same time, automation should be used as a means of preliminary selection and spatial analysis, rather than as a substitute for legal qualification. The most substantiated approach is a combination of registry data, urban planning documentation, remote sensing, and field survey.

The practical significance of the proposed approach lies in the possibility of its use in cadastral works, territorial inventory, preparation of materials for local self-government bodies, and preliminary analysis of compliance with the land and urban planning regime. A unified structure for recording results increases the reproducibility of the study and reduces the risk of erroneous conclusions based on incomplete or non-comparable data.

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Установление противоречий между фактическим использованием земельных участков и градостроительными регламентами

В статье рассматривается проблема выявления и квалификации противоречий между фактическим использованием земельных участков, сведениями Единого государственного реестра недвижимости и требованиями градостроительных регламентов. Актуальность исследования обусловлена тем, что несогласованность указанных информационно-правовых блоков способна приводить к ошибкам при кадастровых работах, подготовке градостроительной документации, осуществлении государственного и муниципального земельного контроля, а также при принятии собственниками решений об использовании недвижимости. Дополнительное значение проблема приобрела после вступления в силу с 1 марта 2026 г. изменений земельного законодательства, которыми в Земельный кодекс Российской Федерации введена отдельная глава о видах разрешенного использования земельных участков. В работе систематизированы нормативные и пространственные источники сведений, используемые для проверки земельного участка: данные ЕГРН, правила землепользования и застройки, классификатор видов разрешенного использования, сведения Национальной системы пространственных данных, материалы дистанционного зондирования и результаты натурного обследования. Предложен поэтапный алгоритм установления противоречий, включающий идентификацию объекта, определение территориальной зоны, фиксацию фактической функции участка, сопоставление правового и фактического режимов, анализ временного фактора и классификацию выявленного несоответствия. Показано, что само наличие расхождения не всегда свидетельствует о правонарушении: необходимо учитывать момент возникновения прав, ранее установленный вид разрешенного использования, правовой режим объектов капитального строительства и особенности переходного регулирования. В статье разработана типология противоречий и предложена форма аналитической таблицы, пригодная для практического применения специалистами в области землеустройства и кадастров. Сделан вывод о необходимости комплексного использования правовых и геоинформационных методов, поскольку достоверная оценка возможна только при одновременной проверке реестровых, градостроительных и фактических данных.

Ключевые слова: *земельный участок, фактическое использование, градостроительный регламент, вид разрешенного использования, ЕГРН, правила землепользования и застройки, кадастровые работы, пространственные данные, земельный контроль*

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Об авторах: **Григорьева Анастасия Андреевна** — магистрант кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; ORCID: 0009-0002-0269-7174; nastya.balmashnova@mail.ru;

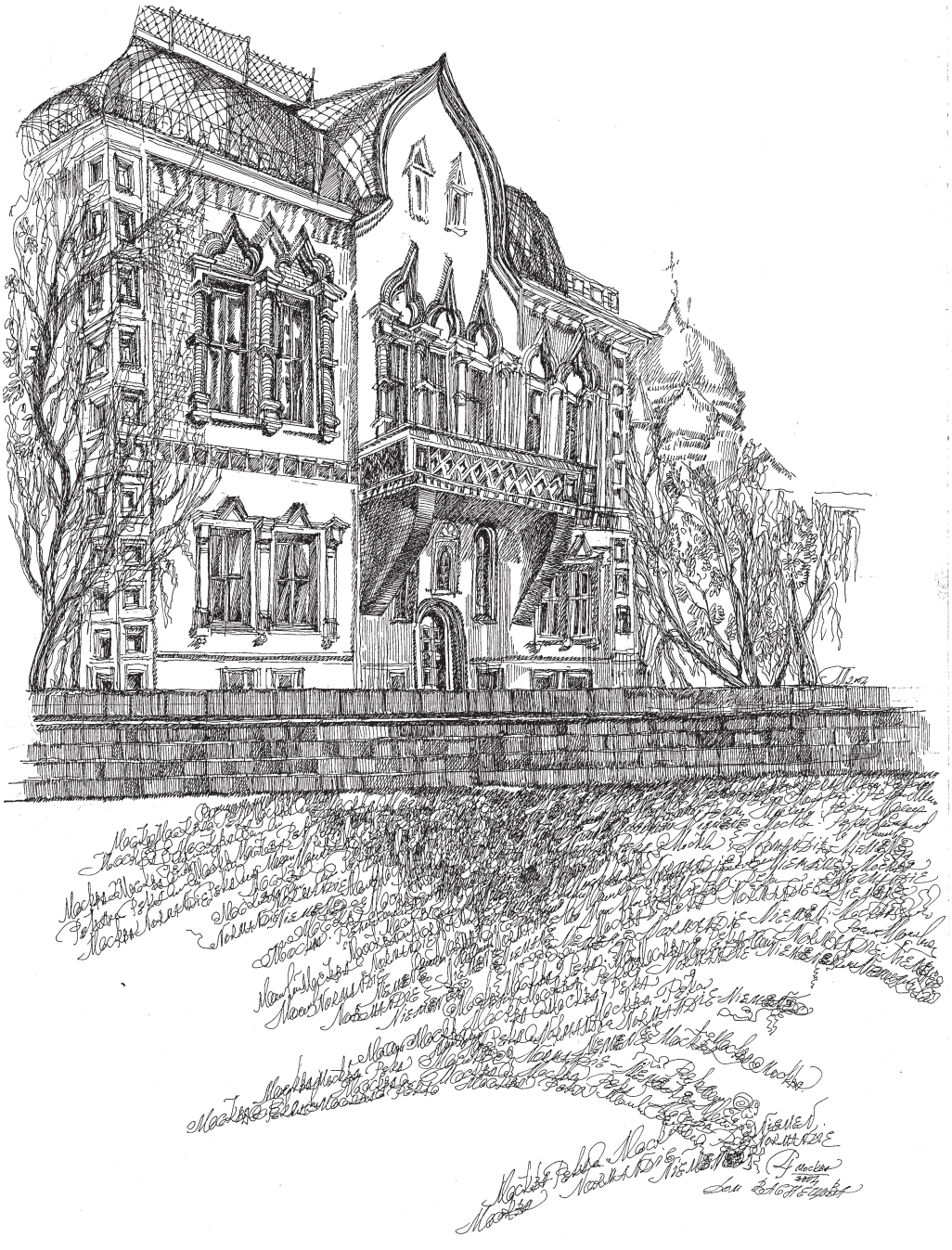
Мурзина Екатерина Александровна — магистрант кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; ORCID: 0009-0001-0838-6951; catherine_maslova@mail.ru;

Звонов Илья Александрович — ст. преподаватель кафедры ОСУН; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; SPIN-код: 6197-7370, Scopus AuthorID: 57204363101, ORCID: 0000-0002-4854-9903; ZvonovIA@mgsu.ru;

Кильдеева Татьяна Игоревна — канд. эконом. наук, доцент кафедры ОСУН; Национальный исследовательский **Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; РИНЦ ID: 9487-6761, Scopus AuthorID: 57194454597, WoS ResearcherID: GOH-0800-2022, ORCID: 0000-0001-8290-9784; Slepkovaprofi@gmail.com.

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Tkachenko V.B.
Palieva O.N.

Appointment and conduct of fire–technical examinations in arson investigations

The conduct of fire-technical examinations is one of the most common procedural actions carried out as part of the investigation of criminal cases involving arson. During the review of materials, officials almost always order fire-technical examinations, since the question of the causes of the fire is of paramount importance. The expert's conclusion indicating the causes of arson is a starting point in a criminal case and allows the investigator (examiner) to form investigative hypotheses and carry out initial and subsequent investigative actions, thereby gathering a set of evidence in the case.

The paper examines problematic issues related to the purpose and conduct of fire-technical examinations as one of the complex expert studies. Statistical data on fires and arson are provided, and an analysis is carried out of the regulatory and legal framework governing this institution, including departmental acts regulating the criminal acts under consideration.

The positions of various authors regarding the methodology of investigation and the tactics of conducting investigative actions are examined, and the law enforcement practice of investigating criminal cases involving arson is analyzed.

This made it possible to identify the errors most commonly made by officials when assigning fire-technical examinations and to offer some recommendations regarding the inspection of the fire scene, formulating questions for experts, sending objects for examination that contain significant trace information, and selecting an expert institution.

Keywords: *fire and technical expertise, arson investigation, initial and subsequent investigative actions, conducting examinations, causes of fires, reasons for committing arson, methods of investigating arson, forensic fire and technical expertise, methods of mathematical modeling in forensic fire and technical expertise, fire supervision by the Federal Fire Service, competence of experts in the field of fire and technical research*



Tkachenko Vladimir Borisovich,
Candidate of Economic Sciences, Associate Professor, Department of Construction Organization and Real Estate Management; Moscow State University of Civil Engineering (National Research University) (MGSU); 26 Yaroslavskoe shosse, Moscow, 129337, Russian Federation; ID RSCI: 451978; Tkachenkovb@mail.ru



Palieva Oksana Nikolaevna,
Candidate of Economic Sciences, Associate Professor, Head of Department; Rostov Branch of Russian State University of Justice; 76 Nefedova st., Rostov-on-Don, 344013, Russian Federation; ID RSCI: 5822-4942; palievaoksana@mail.ru

In recent years, the number of fires has increased significantly. Most often, these are fires that occur under conditions of non-obviousness. Fires arise both due to natural factors and due to human error. When considering the types of fires based on possible causes, arson accounts for a relatively small percentage. This is primarily due to the preparation and careful planning involved in committing the criminal acts. The motives behind arson can vary. Based on the aforementioned grounds, arson can be distinguished as being committed out of a sense of revenge, to receive payments for insured property, and to destroy documents, to obtain new housing, to clear a plot of land of buildings with the subsequent acquisition of those buildings as property (indicators of law enforcement practice). Arson may also be committed to conceal another crime, such as murder, theft of another person's property, misappropriation of another person's property, and similar offences [1].

Given the intellectual component of the method used to commit the crime in question, as well as the variety of methods used to commit it and conceal its traces, arson is rightly regarded as a crime that is difficult to detect and prove. This is confirmed by clearance rates showing that only one in three cases of arson is identified and successfully proven.

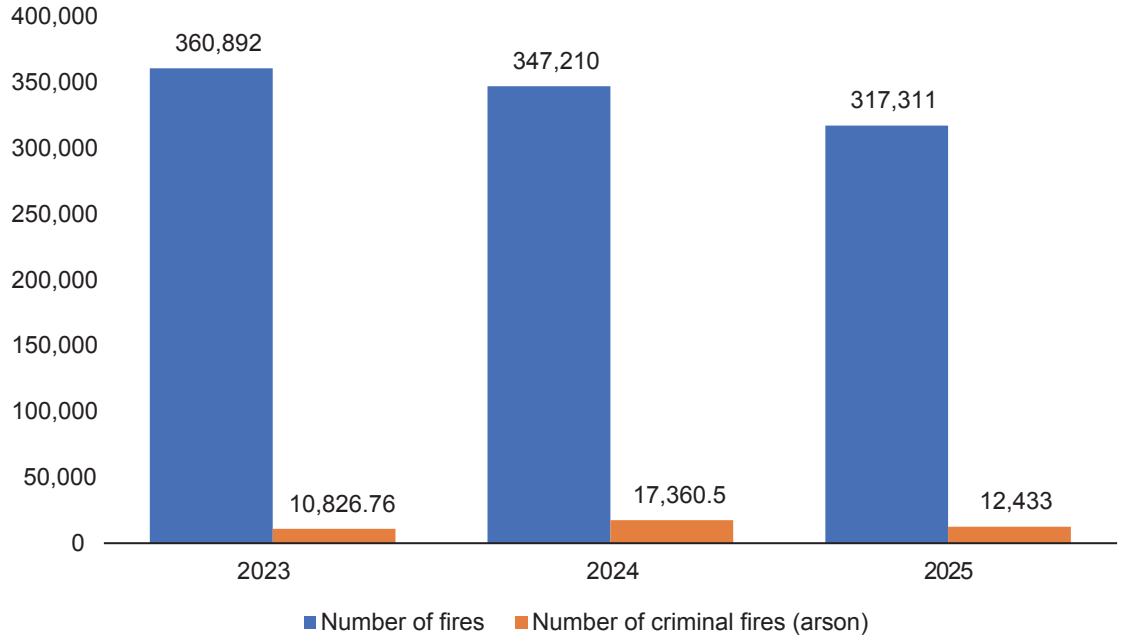
Between 2023 and 2025, an increase in the number of fires was recorded across the Russian Federation, both in anthropogenic zones (industrial enterprises, warehouses, residential buildings) and in natural ecosystems (steppe areas, forest lands, taiga regions). The main causes of fires are anthropogenic factors, extreme meteorological conditions (abnormally high temperatures during the summer period), and man-made events (including the crash of unmanned aerial vehicles), as well as the actions of individuals who deliberately set fires, which initially appear to be accidental.

At the initial stage of investigating the causes of a fire, specialists need to determine which fire is accidental and not related to human activity (short-circuiting of electrical wiring, spontaneous combustion, etc.) and which is the result of the intentional actions of criminals, which must be classified as a crime. In science and investigative practice, such unlawful human actions are referred to as "arson" [2].

Arson is a serious threat: it not only destroys property and helps conceal other crimes but can also cost people their lives. Investigative practice shows that such crimes sometimes lead to mass casualties. The incidence of arson is high, and the damage they cause often reaches very large proportions (Fig.).

Arson causes significant material damage — both ordinary citizens and organizations suffer. Moreover, such crimes undermine the overall security of the state.

The Criminal Code of the Russian Federation provides for liability for arson in the following Articles: 167 of the Criminal Code (intentional destruction or damage to other people's property), 205 of the Criminal Code (terrorist act), 218 of the Criminal Code (violation of the rules of accounting, storage, transportation and use of explosives, flammable substances and pyrotechnic products), 219 of the Criminal Code (violation of fire safety requirements), 261 of the Criminal Code of the Russian



Quantitative analysis of fires and arson [3]

Federation (destruction or damage of forest plantations), 267 of the Criminal Code of the Russian Federation (rendering unusable vehicles or communication routes), 281 of the Criminal Code of the Russian Federation (sabotage) and others [4]. This is an approximate list of crimes committed by arson (in fact, there are more of them). In the disposition of these articles, arson is specified as a constituent element of the crime.

When investigating criminal cases related to arson, specialized knowledge is required; without it, it is impossible to establish the circumstances of the crime.

At the scene of the fire, a specialist examines the fire scene and, first and foremost, records the fact of the fire. Furthermore, the professional training of specialists and experts in the field of fires is used when conducting fire-technical examinations, which are assigned both at the stage of pre-investigative checks and at the investigative stage, as well as within the framework of the judicial consideration of a criminal case.

The specialist's visit to the fire scene involves implementing a set of measures aimed at recording the fact of the fire and collecting data for subsequent expert analysis. The primary task is to document the circumstances of the incident, including identifying ignition indicators, assessing thermal damage, and seizing objects containing traces of the fire.

Fire and technical expertise is a key element of the investigation. Experts determine the origin of the fire, the cause of the ignition, and analyze traces of materials found at the fire scene to determine whether fire safety rules were violated. Modern technologies make it possible to accurately determine the origin and even the time when the fire began, based on traces of prolonged smoldering.

When examining the content of forensic fire-technical examination carried out during the investigation of criminal cases, one can identify the main regulatory framework governing its activities, which includes Chapter 27 of the Criminal Procedure Code of the Russian Federation [5], and the relevant departmental order of the Russian Ministry of Emergency Situations dated August 19, 2005, No. 640 "On Approval of the Instructions for the Organization and Conduct of Forensic Examinations in Forensic Expert Institutions and Expert Units of the Federal Fire Service" [6].

According to the Instructions, an expert from an expert institution must study the materials of fire-related criminal cases. His tasks include determining how and why the fire started, how it spread, whether fire safety rules were violated, and resolving other technical issues related to the case.

Based on expert methodologies and the introduction of new qualitative knowledge related to phenomena and objects of reality, experts draw the necessary conclusions based on the study.

A non-procedural form of interaction with an expert is possible, in the form of consultations and inquiries. This form will be useful if an inquirer or investigator contacts an expert before appointing an expert examination, for example, in order to clarify the correctness of the questions raised, the availability of research objects and the expediency of sending them for examination, the quantity and quality of objects sent for research, the timing of research and testing, etc.

Conducted expert research is aimed at establishing the reasons for the occurrence of fires, the identification of the causes of their occurrence, the elaboration of issues and versions that exclude intentional actions related to arson, as well as deliberate violation of the rules of operation of equipment, withdrawal (damage) of equipment, energy-consuming devices aimed at causing a fire.

S.Yu. Karpov, S.S. Shishanova and a number of other authors rightly identify the main tasks of fire-technical examination by experts. The main areas of research include:

1. Determining the origin, spread, duration, and temperature of the fire.

2. Establishing the technical cause of the fire or ignition.

3. Determining the temperature and traces of heating of objects, materials, and substances.

4. Detecting signs of emergency fire-hazardous operating modes of equipment.

5. Identifying traces of substances and determining the fire-technical characteristics of substances, materials, and mixtures.

6. Identifying violations of the rules governing technical equipment, technical operation, and fire safety, as well as establishing the connection between the identified violations and the occurrence and development of a fire [7, p. 34; 8, p. 58].

Based on the above-mentioned expert tasks, two categories of tasks can be distinguished:

Diagnostic tasks are aimed at identifying and recording. They are outlined in the aforementioned Instructions and include:

- properties and characteristics of the object (physical, chemical, and others);
- state of the object (original, altered, damaged, etc.);
- mechanism of the emergence and development of processes that led to the observed changes (the mechanism of destruction, corrosion, ignition, deformation, etc.);
- cause-and-effect relationships between the actions (incidents of ignition) and the resulting consequences [6].

Identification tasks include:

- establishing the individual identity of objects — comparing a specific sample of a substance or product with a reference object or an object seized from the scene of the incident;
- determining the group affiliation (for example, based on the material composition, typical defects, or spectral characteristics);
- reconstructing the whole from parts — restoring the original structure, shape, or composition of an object based on the analysis of its fragments or residues.

Law enforcement practice indicates that recently, methods of mathematical modeling and artificial intelligence have become more widely used, which has significantly affected the quality of the examinations conducted. The aforementioned authors note that "with the development of scientific and technological progress, the range of tasks for this type of examination is expanding. Increasingly, during examinations aimed at determining cause-and-effect relationships, violations of fire safety requirements are identified, and mathematical modeling is used" [8, p. 61].

Currently, new technologies are being actively used that allow for "virtual inspection of an object", and this can be done repeatedly. Experts use high-detail photo and video recording, including from drones, as well as laser scanning and photogrammetry. As a result, an accurate digital model of the situation is obtained. "This type of inspection makes it possible to determine exactly where the zones of maximum thermal damage were, how the fire spread, and how the traces relate to the building's layout and engineering utilities — and all of this without having to return to the site" [9].

At the same time, it is always important to remember that the latest technologies are undoubtedly a powerful tool that enables various approaches to research, but they do not replace an expert's professional experience and critical thinking. The expert selects methods tailored to the specific situation at hand, verifies the initial data and possible algorithms, and makes the final decision independently.

Conducting a forensic fire-technical examination is directly related to obtaining new information as a result of the study or to its complete exclusion. At the same time, objective conclusions depend on the presence of specialized knowledge, professional training, and the availability of the objects under study, which were obtained as a result of the procedural actions carried out. As noted earlier, a competent formulation of questions for the examination and the selection of objects for expert study play an important role in establishing the causes of the fire. As practice shows, the completeness of the expert conclusion is related to the information obtained at the initial stage of the investigation. This is determined by the actual presence of the objects under study, seized from the scene of the incident, and the "working through" of various versions of how the fire started.

Conducting examinations at a later stage, for example, after a criminal case has been initiated, may lead to the loss or damage of objects that could be subject to examination, both for objective reasons (exposure to the elements, rain, snowfall, etc.) and for subjective reasons (destruction of evidence by interested parties).

An examination into a fire is appointed by an official, an investigator, or an interrogator. The choice of an expert institution is the right of the official investigating the crime. At the same time, if a suspect in the case is known at the time the examination is ordered (which is quite rare), he has the right to file a petition with questions for the experts and make a statement that implies the possibility of choosing an expert institution at his own discretion. Today, the choice of expert institutions is considerable. Organizations conducting expert research as part of fire-technical examinations include both state-owned and non-state entities. The legal regulation of expert research (activity) is established by the basic law, in particular, Federal Law No. 73-FZ dated 05/31/2001 "State Forensic Expertise in the Russian Federation" [10]. It regulates the activities of all expert institutions. Expert activity is regulated in detail by the criminal procedure legislation.

There are not many specialists in the field under consideration (in the field of fires). "All of them are concentrated in special laboratories of the Russian Ministry of Emergency Situations. In addition, specialists from the Expert and Criminalistic Centre of the Russian Ministry of Internal Affairs, the forensic examination department of the Russian Ministry of Justice, as well as employees of industrial enterprises with the relevant specialized knowledge, are involved" [11]. Fire and technical expertise is carried out by specially trained experts — people with in-depth knowledge in the field of fire safety, combustion physics, chemistry, and others. The most common group consists of experts from the fire testing laboratories (FTLs) of the Russian Ministry of Emergency Situations. There is a network of such laboratories operating in the country. They have the necessary equipment for research, conduct both field inspections and laboratory analyses, and issue official conclusions.

Experts from the Fire Expertise Research Centre (FERC) and other specialized units of the Russian Ministry of Emergency Situations participate in the investigation of major, high-profile fires, such as the "Winter Cherry" and "Lame Horse" fires. The Centre also provides training and certification for experts.

Less frequently, experts and specialists from independent private organizations are involved in the investigation of criminal cases. As a rule, this applies when there is a need to conduct an additional or repeated examination. Such experts must have a license to carry out such work and confirmed qualifications.

A fire-technical expert can independently conduct an examination that does not involve particularly complex issues. If there is a need to investigate more complex issues that require knowledge in other fields, commission-based expert examinations are appointed. M.S. Zhuk explains this by saying that "in the investigation of arson, a large number of diverse issues arise that can only be resolved by using a combination of various specialized knowledge from the relevant branches of science and technology — primarily

fire engineering, thermophysics, chemistry, electrical engineering, construction, pyrotechnics, and criminology" [12].

The questions put to the experts may vary and depend on the circumstances of the investigation.

The main categories of questions are as follows:

- those relating to the cause of the fire;
- those concerning the fire safety condition of the premises and compliance with fire safety regulations;
- relating to the determination of the location of the fire's point of origin and the factors that led to the particular course of the fire;
- enabling a causal link to be established between a breach of fire safety regulations and the resulting consequences [8, p. 58].

The most important question concerns establishing the causes of the fire, namely whether the fire was the result of arson.

In one of the criminal cases, the court established that the warehouse manager embezzled the equipment entrusted to him, which was stored in a warehouse in the city of Kaliningrad. On October 30, 2025, they set off a large-scale fire: they used pre-prepared bottles filled with an incendiary mixture. As a result, the fire completely destroyed the property of the tenant company. The material damage exceeded 57 million rubles. The court classified the manager's actions under Part 4 of Article 160 of the Criminal Code of the Russian Federation (embezzlement and misappropriation on an especially large scale) and Part 2 of Article 167 of the Criminal Code of the Russian Federation (arson), and the perpetrator (T.) — only under Part 2 of Article 167 of the Criminal Code of the Russian Federation. E. received 4 years of imprisonment in a general regime colony, and T. received 1 year and 6 months in a settlement colony. The court also fully satisfied the claim for compensation for material damage[1].

An analysis of law enforcement practice allows us to conclude that investigators and judges do not always pose questions to experts in the correct way. For example, questions of the following type are completely unacceptable: "Was a deliberate arson committed by a specific person?", "Did a specific person violate fire safety requirements?", "Were forest plantations destroyed as a result of careless handling of fire?" [13]. These questions relate to legally significant circumstances and should not be examined by an expert. "The correct formulation of questions is of fundamental importance for experts conducting research. An important factor is the validity of the questions within the scope of the experts' competence. The questions should not go beyond the experts' specialized knowledge" [14].

Thus, in one of the criminal cases, a group of individuals, acting in concert, committed murder using a dangerous method against N.Ya.S. and the minor N.D.S., and then, in order to conceal the crime, placed the bodies in a bathhouse and deliberately set it on fire. After setting the fire, the criminals fled the scene. As a result of the fire-technical examination, the origin of the fire was established within the boundaries of the bathhouse and the dressing room located at a specific address. The fire was caused by deliberate ignition using flammable liquids [15].

The objects submitted for fire-technical examination include multiple traces of the crime, which are seized from the scene of the incident. The full list of objects is determined by the circumstances of the fire that occurred. There is no point in listing them in full, as they can be any items carrying any information related to the fire. The technical documentation of the burned-out object is also submitted for examination; it is subject to thorough analysis by experts, as are the protocols of investigative actions that were carried out by the time the examination was ordered.

To obtain objective conclusions, objects containing information that will be subject to expert examination are submitted for analysis. A.G. Markelov and D.V. Ivanov propose submitting the following documents for expert examination: "the incident scene inspection report; sketches and photographs; plans of the burned-out premises; video recordings from the incident scene; diagrams of the electrical wiring, gas supply, sewage, water supply, and heating systems; expert conclusions; a fire report or an order; the conclusion of a technical specialist and other regulatory (supervisory) bodies; various expert studies and expert conclusions; diagrams, photo and video materials; and other technical documents that are relevant to the criminal case, and other materials" [8, p. 58].

This is not the complete list of objects that may be submitted for fire-technical examination. Everything depends on the specific fire and the circumstances of the case. Providing the expert with the necessary materials guarantees a comprehensive and thorough investigation. For example, during the combustion process, crime-related traces are subject to change, but with the help of special knowledge and instruments, it is possible to "read" the original information.

Before ordering a fire-technical examination, the investigator must carry out certain work to identify and select objects for examination. An important initial investigative action in fire investigations is the examination of the scene. It seems that it would be advisable for the expert conducting the examination to visit the scene of the incident. A direct inspection of the fire site by the expert is an important element of the examination process, as studying the incident scene inspection report, examining photographs, video materials, and other objects will not provide a complete picture or understanding of what happened. Personal perception is necessary. Therefore, the official investigating the arson case should also analyze this important aspect and recommend that the expert visit the fire site.

When assigning a fire-technical examination, investigators may make a number of tactical and procedural errors that affect the reliability of the expert's conclusions and the quality of criminal investigations. In this context, we can talk about incompleteness or the absence of important data in the incident scene protocols. Often, officials do not record the signs of the fire source or any details that could establish the cause of the fire. For example, they do not record traces of flammable liquids, the arrangement of objects at the time the fire was detected, or the condition of electrical equipment.

The case may contain mutually exclusive information (for example, in the inspection protocol and in witness statements regarding the location of objects or the nature of the damage). This inevitably may lead to incorrect conclusions.

Investigators pack objects seized from the fire scene carelessly and do not seal them, which leads to their alteration or loss.

The inspection protocol for the scene of the incident lacks signatures from the persons participating in the investigative action (witnesses, specialists). This violates the procedural requirements of the law and may call into question the legitimacy of the collected materials.

[1] Two people convicted in Kaliningrad Region for arson of a home appliance warehouse. TASS Editorial Staff. August 27. URL: https://tass.ru/proisshestviya/28049999 (rus.).

In law enforcement practice, some officials do not order a fire-technical examination but attach a fire report to the materials of the criminal case and refer to it as evidence in the case. An employee of the State Fire Supervision Service or the firefighting manager prepares a fire report in two copies in the prescribed form after the fire has been extinguished.

When preparing a fire report, a number of important details are documented. First, the composition of the commission is indicated, and the object where the fire occurred is described in detail — its exact address, name, and ownership (who is the owner or user). Next, the chronology of the incident is recorded: when and where the fire was noticed, who noticed it, and when the information was reported to the fire department. The time of the firefighters' arrival, the containment of the fire, and its final extinguishment is necessarily recorded. The document also reflects the situation at the scene at the time the rescuers arrived, information about the victims, and the consequences of the fire, as well as the circumstances that exacerbated its development. If necessary, other relevant data are included [16]. Depending on the circumstances, other examinations may be ordered. If there are injured or deceased people due to the arson, a forensic medical examination is ordered. To examine physical evidence (for example, traces on the suspect's clothing), a forensic examination is assigned.

Thus, a forensic fire-technical examination is replaced by a fire report, which, in our view, is incorrect and does not comply with the procedural rules for investigating a criminal case. A fire report is drawn up based on the results of the fire, in accordance with departmental instructions. A fire report contains information that has been collected and cannot provide answers to all the questions of interest to the investigation. Only a thorough, scientific study can provide specific answers and draw specific conclusions about the cause of the fire, the method of arson, and other circumstances. Based on the above, the appointment and conduct of a fire-technical examination within the framework of the criminal case under investigation is of paramount importance.

The expertise of experts in the field of fire-technical research is in demand at all stages of criminal proceedings, both within the framework of the pre-investigation check (the examination makes it possible to establish the presence of signs of a crime, i.e., arson) and to make a well-founded decision to initiate a criminal case, and at the stage of the preliminary investigation. The examination results serve as an evidentiary basis for determining the causes of the fire, reconstructing the events, and identifying the perpetrators.

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Особенности назначения и производства пожарно-технических экспертиз при расследовании поджогов

Производство пожарно-технических экспертиз одно из наиболее распространенных процессуальных действий, которые выполняются в рамках расследования уголовных дел по поджогам. В ходе проверки материалов должностные лица практически всегда назначают пожарно-технические экспертизы, так как вопрос о причинах произошедшего пожара является первостепенным. Заключение эксперта, указывающего на причины поджога, является отправным моментом в уголовном деле и позволяет дознавателю (следователю) строить следственные версии и проводить первоначальные и последующие следственные действия, таким образом собирая совокупность доказательств по делу.

В статье рассматриваются проблемные вопросы, назначения и проведения пожарно-технических экспертиз, как одного из сложных экспертных исследований. Приведены статистические данные по пожарам и поджогам, а также проведен анализ нормативного правового регулирования указанного института, в том числе ведомственных актов, регламентирующих рассматриваемые преступные деяния.

Рассмотрены позиции различных авторов по методике расследования и тактике проведения следственных действий, а также проанализирована правоприменительная практика расследования уголовных дел по поджогам.

Это позволило выявить ошибки, чаще всего допускаемые должностными лицами при назначении пожарно-технических экспертиз, и предложить некоторые рекомендации относительно осмотра места происшествия пожара, постановки вопросов экспертам, направления объектов для исследования, представляющих значимую следовую информацию, и выбора экспертного учреждения.

Ключевые слова: *проведение экспертизы, причины пожаров, расследования поджогов, причины осуществления поджогов, методы расследования поджогов, судебная пожарно-техническая экспертиза, методы математического моделирования в судебной пожарно-технической экспертизе, пожарный надзор федеральной противопожарной службы, компетенция экспертов в области пожарно-технических исследований*

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Об авторах: **Ткаченко Владимир Борисович** — кандидат юридических наук, доцент кафедры организации строительства и управления недвижимостью, эксперт (адвокат) по вопросам имущественных споров, строительства, управления недвижимостью, вопросам жилищно-коммунального регулирования; **Национальный исследовательский Московский государственный строительный университет (НИУ МГСУ)**; 129337, г. Москва, Ярославское шоссе, д. 26; РИНЦ ID: 451978; Tkachenkovb@mail.ru;

Палиева Оксана Николаевна — кандидат юридических наук, доцент, заведующий кафедрой уголовного права и процесса; **Московский университет им. С.Ю. Витте (филиал в г. Ростове-на-Дону)**; 344013, г. Ростов-на-Дону, ул. Нефедова, д. 78; РИНЦ ID: 5822-4942; palievaoksana@mail.ru.

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