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ЭКОНОМИКА

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**Дорогие читатели!**

Характерные особенности современного капитального строительства — нестабильность инвестиционного климата, крайне неравномерная загрузка строительных мощностей, низкий уровень рентабельности строительного производства. В этих условиях актуальными становятся проблемы обеспечения устойчивости, надежности, мобильности, гибкости субъектов хозяйственной деятельности как их способности выживать и функционировать под воздействием дестабилизирующих факторов.

Диверсификация, как направление повышения гибкости деятельности строительных компаний, а следовательно, и устойчивости их развития, относится как к конкретной территории строительства, так и к практическим аспектам современного развития инвестиционно-строительного комплекса России. Она бывает трех видов: конгломератной, коммерческой и горизонтальной.

Конгломератная диверсификация — это возникновение в компании направлений по выпуску нового ассортимента строительной продукции, оказанию нового вида услуг; коммерческая диверсификация — это увеличение объемов строительного-монтажных работ; горизонтальная диверсификация — это поиск новых территорий для своей продукции. Диверсификация служит стимулирующим катализатором по обеспечению финансовой стабильности и устойчивости строительной компании.

Для достижения максимальной результативности в деятельности строительных компаний важным является использование цифровых технологий и сочетание всех выше перечисленных видов их развития.

В настоящем номере журнала уделяется значительное внимание этим и другим вопросам повышения гибкости субъектов строительной деятельности, в том числе за счет повышения уровня концентрации с одновременным углублением специализации подрядных фирм и сочетанием видов диверсификации производства.

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О.В. Юденкова

АКЦЕНТЫ НОМЕРА

Лapidус А.А., Адамцевич Л.А.

Современные проекты комплексного развития территорий характеризуются технологической, организационной и информационной сложностью. Технологическая сложность обосновывается необходимостью интеграции разнородных систем, обеспечения безопасности, надежности и устойчивости жилых зданий и инфраструктурных объектов. Организационная сложность возникает из-за увеличения количества участников при реализации проектов комплексного развития территорий, а информационная — экспоненциальным ростом объемов разнородной информации, а также требованиями к скорости принятия решений

Янковский А.В.

Градостроительная концепция выступает в качестве документа, подтверждающего, что проектные решения редевелопмента способствуют достижению целей действующей городской политики. Каждый город разрабатывает планы развития, закрепленные в градостроительной документации: мастер-планах городов в среднесрочном горизонте планирования и генеральном плане на долгосрочную перспективу. Разрабатываемые проекты редевелопмента должны поддерживать общее направление развития города и способствовать достижению целевых показателей качества городской среды, уровня жизни населения

Обухов Р.В.

Реализация в современных условиях методических положений и практических рекомендаций по развитию теории конкурентоспособности строительных предприятий возможна через применение концепции динамического равновесия внутренней и внешней среды на текущем, тактическом и стратегическом уровне управления через моделирование совокуп-

1 РАЗДЕЛ — ОФИЦИАЛЬНЫЙ РАЗДЕЛ

6 Лapidус А.А., Адамцевич Л.А.

Цифровая трансформация процессов управления жизненным циклом объектов жилой и инженерной инфраструктуры в проектах комплексного развития территорий

2 РАЗДЕЛ — ТЕМА НОМЕРА

13 Янковский А.В.

Особенности разработки градостроительной концепции при редевелопменте городских территорий

3 РАЗДЕЛ — ЭКОНОМИКА И МЕНЕДЖМЕНТ НЕДВИЖИМОСТИ

19 Обухов Р.В.

Обеспечение конкурентоспособности предприятий строительной отрасли на основе концепции динамического равновесия

4 РАЗДЕЛ — ГРАДОРЕГУЛИРОВАНИЕ И УПРАВЛЕНИЕ ЖИЛИЩНО-КОММУНАЛЬНЫМ КОМПЛЕКСОМ

28 Лукинов В.А., Кирпиченков А.А.

Классификация программ по воспроизводству городского жилищного фонда

32 Коростелев Ю.С.

Измерение ценности в проектах комплексного развития территорий

38 Звонов И.А., Дудник А.П.

Пути повышения эксплуатационной надежности систем водоснабжения и водоотведения зданий

45 Кулаков А.Р.

Комплексный подход в рамках научно-технического сопровождения уникальных объектов на всех этапах жизненного цикла

52 Борискина Ю.И., Мохамед Исак Али

Девелопмент торговых центров в рамках концепции комплексного развития территорий

5 РАЗДЕЛ — ТЕХНОЛОГИЯ И ОРГАНИЗАЦИЯ СТРОИТЕЛЬСТВА**Крылов Д.С., Лapidус А.А., Сатылаев А.В.****57**

Совершенствование методологии создания архитектурной цифровой информационной модели жилого здания с применением модульного подхода

Звонов И.А.**64**

Роль функциональных требований к объектам университетских кампусов при их проектировании и эксплуатации

Рожков А.Н., Галишникова В.В.**70**

Цифровая платформа управления жизнеобеспечением: топологическая концепция

Лукинов В.А., Валяев А.О.**77**

Применение метода критической цепи как способ сокращения сроков реализации строительного проекта

6 РАЗДЕЛ – ОТЕЧЕСТВЕННЫЙ И ЗАРУБЕЖНЫЙ ОПЫТ**Беляков С.И., Соловьёв А.А., Ремизов И.Р.****83**

Анализ актуальных направлений развития проектной деятельности девелоперских компаний в контексте адаптации к кризисным явлениям

7 РАЗДЕЛ — ПРАВОВЫЕ И СОЦИАЛЬНЫЕ АСПЕКТЫ**Орехов Г.В., Балабин Ю.А., Лузгин Р.Ю., Фридовская Е.П.****88**

Технические и нормативно-правовые аспекты установления признаков аварийности многоквартирных жилых домов в рамках судебных строительно-технических экспертиз

Зайцева Л.И.**96**

Концептуальный подход к оценке экономической эффективности внесудебного разрешения строительных споров

АКЦЕНТЫ НОМЕРА

ного конкурентного потенциала по ключевым факторам успеха в условиях высокого уровня неопределенности

Звонов И.А., Дудник А.П.

Предиктивное обслуживание — это комплексный способ управления инженерными сетями и оборудованием, который включает в себя сбор информации о состоянии оборудования, ее анализ и составление прогнозов о сроках отказа оборудования разного уровня с целью своевременной подготовки и реализации мероприятий по предупреждению сбоев в работе. То есть это обслуживание, когда появляется «прогноз на поломку», без привязки к нормативно-техническим или проектным требованиям. Предиктивное обслуживание уже успешно реализуется в энергетике, на транспорте, в промышленности, в нефтегазовой отрасли, в авиакомпаниях. Система мониторинга и контроля фиксирует любые отклонения в работе оборудования и систем

Крылов Д.С., Лapidус А.А., Сатылаев А.В.

Создание цифровых информационных моделей типовых многоквартирных домов с применением модульного подхода и библиотеки ТИМ-компонентов снижает стоимость, повышает качество и сокращает сроки выполнения проектных работ

Зайцева Л.И.

Концептуальный подход к оценке экономической эффективности внесудебного разрешения споров основан на соотношении затрат на судебные и примирительные процедуры (такие как медиация проекта и внесудебная экспертиза) с учетом таких факторов, как размер судебных издержек, продолжительность разбирательства, инфляционные процессы, освобождение от уплаты пошлин и возврат средств, а также тип контракта

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SECTION 1: OFFICIAL SECTION

6 Lapidus A.A., Adamtsevich L.A.

Digital transformation of life cycle management processes for residential and engineering infrastructure facilities in complex development of territories

SECTION 2: COVER STORY

13 Yankovsky A.V.

Urban design concepts creation for urban areas redevelopment projects

SECTION 3: PROPERTY ECONOMICS AND MANAGEMENT

19 Obukhov R.V.

Ensuring competitiveness of enterprises in the construction industry on the basis of dynamic equilibrium concept

SECTION 4: URBAN REGULATION AND MANAGEMENT OF HOUSING AND PUBLIC UTILITIES

28 Lukinov V.A., Kirpichenkov A.A.

Classification of programs for renewal of the urban housing stock

32 Korostelev Yu.S.

Value assessment in integrated territorial development projects

38 Zvonov I.A., Dudnik A.P.

Ways to improve operational reliability of water supply and wastewater disposal systems in buildings

45 Kulakov A.R.

Comprehensive approach to scientific and technical support of unique facilities at all stages of the life cycle

52 Boriskina Yu.I., Mohamed Isak Ali

Shopping centres under the integrated development of territories concept

SECTION 5: TECHNOLOGIES AND ORGANIZATION OF CONSTRUCTION**ACCENTS****Krylov D.S., Lapidus A.A., Satylaev A.V.****57**

Improvement of the methodology for creating an architectural digital information model of a residential building using a modular approach

Zvonov I.A.**64**

The role of functional requirements for university campus facilities in their design and operation

Rozhkov A.N., Galishnikova V.V.**70**

Digital Platform for Life Support Management: Topological Concept

Lukinov V.A., Valyaev A.O.**77**

Application of the critical chain method as a way to reduce the time of construction project implementation

SECTION 6: DOMESTIC AND OVERSEAS EXPERIENCE**Beliakov S.I., Solovyov A.A., Remizov I.R.****83**

Analysis of current areas of project activity of development companies in the context of adaptation to crisis phenomena

SECTION 7: LEGAL AND SOCIAL ASPECTS**Orekhov G.V., Balabin Yu.A., Luzgin R.Yu., Fridovskaya E.P.****88**

Technical and regulatory aspects of establishing signs of emergency of apartment buildings within the framework of forensic construction and technical expertise

Zaytseva L.I.**96**

Conceptual approach to assessing the economic efficiency of out-of-court settlement of construction disputes

Lapidus A.A., Adamtsevich L.A.

Modern projects of complex development of territories are characterized by technological, organizational and informational complexity. Technological complexity is justified by the need to integrate heterogeneous systems, ensure the safety, reliability and sustainability of residential buildings and infrastructure facilities. Organizational complexity arises due to the increase in the number of participants in the implementation of projects of complex development of territories, and informational complexity arises from the exponential growth of heterogeneous information volumes, as well as requirements for the speed of decision-making

Yankovsky A.V.

Urban planning concept acts as a document confirming that redevelopment design solutions contribute to achieving the goals of the current urban policy. Each city develops development plans, which are fixed in the urban planning documentation: master plans of cities in the medium-term planning horizon and the Master Plan for the long term. The redevelopment projects being developed should support the overall direction of the city's development and contribute to achieving targets for the quality of the urban environment and the standard of living of the population

Obukhov R.V.

Implementation in modern conditions of methodological provisions and practical recommendations for the development of the theory of competitiveness of construction enterprises is possible through the application of the concept of dynamic equilibrium of the internal and external environment at the current, tactical and strategic management level through modeling the aggregate competitive potential for key success factors in conditions of high uncertainty

Zvonov I.A., Dudnik A.P.

Predictive maintenance is a complex method of management of engineering networks and equipment, which includes collection of information on the state of equipment, its analysis and forecasting of failure dates of equipment of different levels for the purpose of timely preparation and implementation of measures to prevent failures in operation. In other words, it is a service when a "breakdown forecast" appears, without reference to normative-technical or design requirements. Predictive maintenance has already been successfully implemented in the power industry, transportation, industry, oil and gas industry, and airlines. Monitoring and control systems detect any deviations in the operation of equipment and systems

Krylov D.S., Lapidus A.A., Satylaev A.V.

Creation of BIM models of typical residential buildings using a modular approach and a library of TIM components reduces the time required to complete design work, reduces cost and improves the quality of design work. Research methods: analysis, synthesis and modeling

Zaytseva L.I.

The conceptual approach to assessing the economic efficiency of out-of-court dispute resolution is based on the ratio of the costs of litigation and conciliatory procedures (such as project mediation and out-of-court expertise), taking into account such factors as the amount of litigation fees, the duration of proceedings, inflationary processes, fee exemptions and refund and type of a contract

■ **Lapidus A.A.**
Adamtsevich L.A.



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Digital transformation of life cycle management processes for residential and engineering infrastructure facilities in complex development of territories

Modern projects of complex development of territories are characterized by technological, organizational and informational complexity. Technological challenges stem from the need to integrate heterogeneous systems while ensuring safety, reliability and sustainability of residential buildings and infrastructure facilities. Organizational complexity arises from the increasing number of participants in complex territory development projects, while information complexity results from exponentially growing volumes of heterogeneous data and requirements for rapid decision-making.

In this regard, the issue of ensuring end-to-end life cycle management of objects and consistency of decisions for the efficient use of resources is relevance.

The purpose of the research work is to analyze digital technologies for optimizing the life cycle management of residential buildings and infrastructure facilities in projects of complex development of territories.

As part of the presented study, an analysis of publications was conducted, according to keywords defined by the authors in the context of the topic under consideration. The international Scopus database served as the basis for forming specimens, according to keywords.

The analysis demonstrates that the introduction of digital twins, IoT, Big Data, BIM and machine learning allows achieving significant optimization in managing the life cycle of residential and engineering infrastructure facilities in projects of complex development of territories. Digital transformation fundamentally changes the approach to life cycle management, moving it from reactive to predictive and adaptive, which ensures the sustainability, reliability and safety of objects, resource savings and improved quality of the urban environment.

Keywords: digital transformation, information modeling, digital twin, Internet of things, data analysis, artificial intelligence, life cycle of an object, sustainable development of territories

INTRODUCTION

Modern projects of complex development of territories are characterized by technological, organizational and informational complexity. Technological complexity is justified by the need to integrate heterogeneous systems, ensure the safety, reliability and sustainability of residential buildings and infrastructure facilities. Organizational complexity arises due to the increase in the number of participants in the implementation of projects of complex development of territories, and informational complexity arises from the exponential growth of heterogeneous information volumes, as well as requirements for the speed of decision-making.

In these conditions, the issue of ensuring end-to-end life cycle management becomes relevant and critically important to ensure the continuity of the project implementation process from the building design to its disposal, the consistency of decisions at different stages of the life cycle, as well as increasing the efficiency of resource use and ensuring sustainable development.

Thus, the purpose of this study is to analyze digital technologies to optimize the life cycle management of integrated territorial development projects.

MATERIALS AND METHODS

As part of the presented study, an analysis of publications was conducted, by keywords defined by the authors in the context of the topic under

consideration. The basis for forming specimens, by keywords, was the international Scopus database. In this case, the first specimen was formed by all publications presented in the database, and the remaining ones for a period of 10 years from 2014 to 2024. The logic of forming specimens is described below.

At the first stage, to identify key digital technologies in managing the life cycle of residential and engineering infrastructure facilities in complex territorial development projects, specimen 1 was formed, by keywords, life cycle, construction, Industry 4.0. The cluster map of the relationship of keywords is shown in the figure (Fig. 1) below.

From the figure, we can conclude that there is a close connection between the life cycle of construction projects and sustainable development, Industry 4.0 technologies. A lot of attention is paid to the issues of building materials and technologies, considering their environmental friendliness.

At the same time, based on the initial analysis of publications, the following technologies are seen as key ones in the context of digital transformation of the processes of managing the life cycle of residential and engineering infrastructure in complex territorial development projects:

- BIM at all stages for creating, managing and analyzing digital information about buildings or infrastructure (specimen 2 — BIM + life cycle);

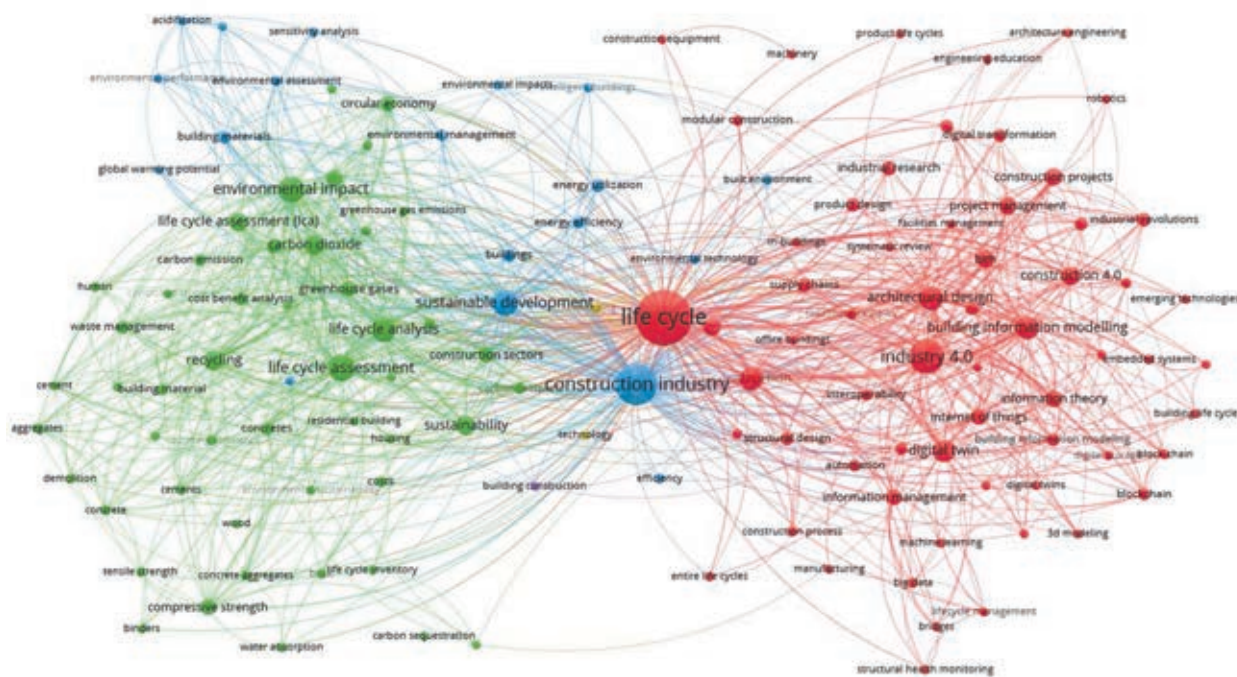


Fig. 1. Cluster map of the relationship of keywords of the formed specimen 1

- using digital twins to monitor and predict the state of an object (specimen 3 — digital twins + buildings);
- implementation of IoT and Big Data to manage the operational characteristics of an object (specimen 4 — IoT, Big Data + construction);
- using Machine Learning to assess demand for infrastructure (specimen 5 — machine learning + buildings).

Thus, at the next stage of the study, specimens 2–5 were collected and analyzed, and the main aspects of the digital transformation of the life cycle management processes of construction projects were identified.

At the same time, within the framework of this study, the life cycle of a capital construction project, which includes residential and engineering infrastructure facilities, is defined as the stages regulated by CP 333.1325800.2020¹. According to the document, the life cycle of a capital construction project is the following time periods:

1. Engineering surveys.
2. Architectural and construction design.
3. Construction.
4. Operation.
5. Reconstruction.
6. Major repairs.
7. Demolition.
8. Disposal.

The specified structure is presented in the Fig. 2 and is a methodological basis for the analysis of digital control technologies during the existence of the facility.

The choice of this classification of life cycle stages is justified by the fact that it includes all key stages from surveys to disposal, and CP 333.1325800.2020¹ is a current regulatory document in

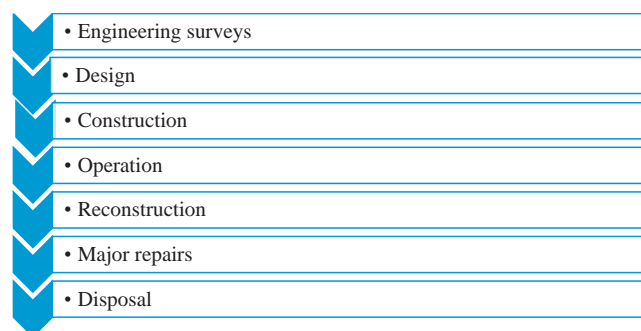


Fig. 2. Stages of the life cycle of a construction project

the Russian Federation, developed for the application of information modeling technologies.

To conduct a system analysis of the possibility of optimizing the management of objects at all stages of their existence, considering digital tools, for each of these stages, management tasks, performance indicators for the use of digital technology, as well as key problems of digital transformation of processes will be identified.

RESULTS

Specimen Analysis 2 — BIM + life cycle

During the period under review, 2729 documents are displayed in the Scopus database (Fig. 3). The dynamics of changes in the number of publications by year are presented below, in addition, the trend line indicates a growing interest in life cycle management issues using information modeling technologies. At the same time, the leaders in publications are authors from China. The figure shows the top 15 countries.

The analysis of specimen 2 allowed us to identify the main areas of BIM application at the stages of the construction project life cycle (Table 1).

¹ CP 333.1325800.2020. Information modeling in construction. Rules for the formation of an information model of objects at various stages of the life cycle.

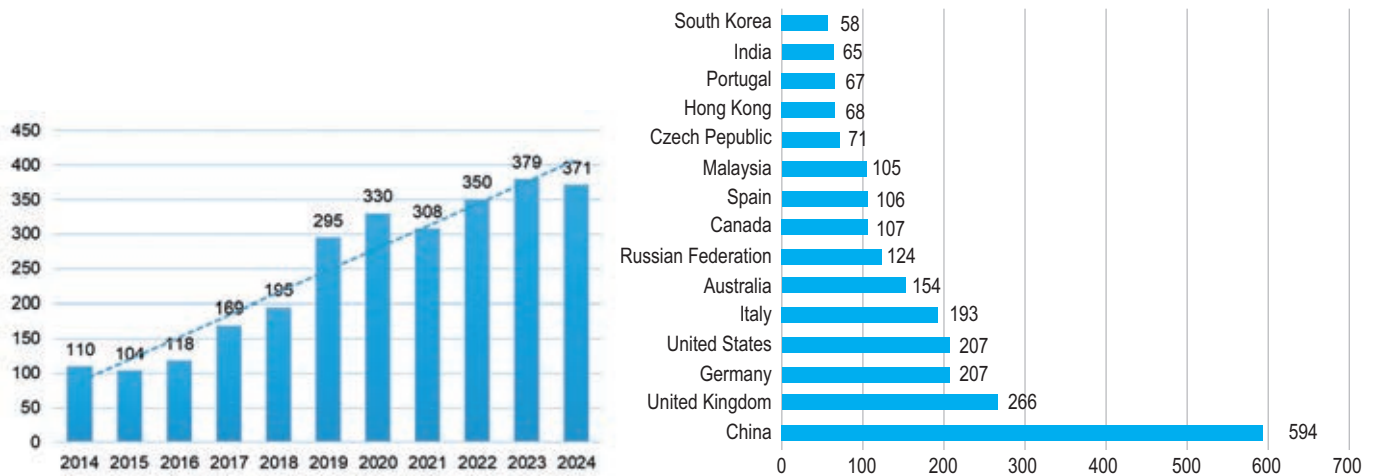


Fig. 3. Dynamics of changes in the number of publications for BIM + life cycle, top 15 countries by publications

Table 1. Application of BIM at the stages of the construction project life cycle

Life cycle stage	Application area	Examples	Links
Design	3D visualization, coordination	<ul style="list-style-type: none"> creation of detailed digital models of residential buildings and infrastructure facilities; automatic detection of collisions before construction begins 	[1–4]
	Calculations and analysis of parameters	Optimization of structures considering loads and materials; calculation and analysis of energy efficiency, illumination, acoustics, etc.	
Construction	Logistics and planning	4D BIM for work schedule optimization; 5D BIM for budget control, etc.	[5]
	Quality control	Conducting a comparative analysis of the information model with the results of laser scanning to identify deviations	
Operation	Asset Management	<ul style="list-style-type: none"> integrated use of BIM and CAFM (Computer-Aided Facility Management) systems; access to communications via AR/VR for repairs 	[6–8]
	Predictive maintenance	Monitoring the condition of structures through the integration of IoT sensors	
Disposal	Dismantling and recycling	<ul style="list-style-type: none"> analysis of the information model for the selection of environmentally friendly waste disposal methods; calculation of volumes of materials for recycling 	[9,10]

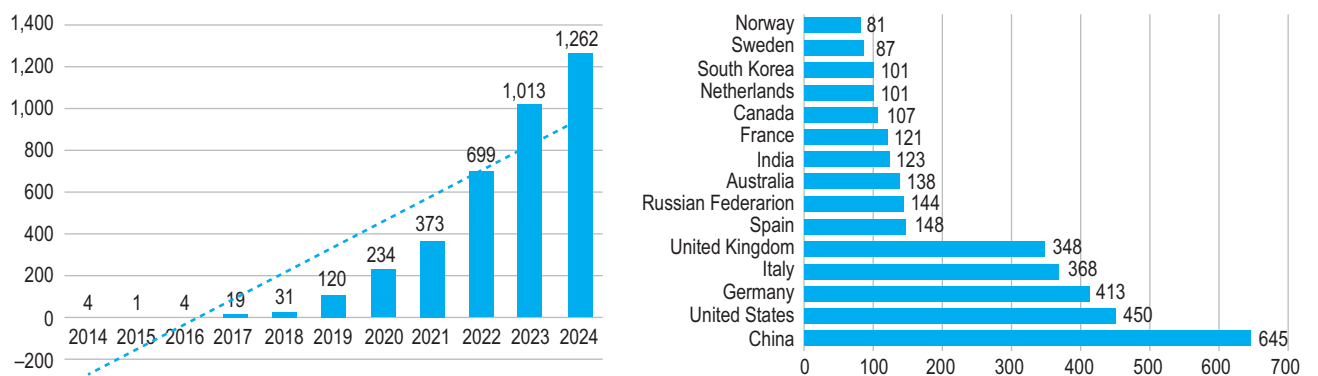


Fig. 4. Dynamics of changes in the number of publications for Digital Twins + Buildings, top 15 countries by publications

The results obtained indicate that the use of information modeling technologies is considered in combination with digital twins, machine learning methods, etc.

At the same time, the authors point out such positive aspects as a reduction in costs by up to 20 % due to the minimization of errors, as well as a reduction in time by 15–30 % due to the provision of clear coordination of contractors [8, 11, 12].

Specimen Analysis 3 — Digital Twins + Buildings

During the period under review, 3,375 documents are displayed in the Scopus database. The dynamics of changes in the number

of publications by year are presented below, in addition, the trend line indicates a growing interest in the use of digital twins of buildings. At the same time, the leaders in publications are also authors from China (Fig. 4).

An analysis of publications revealed that digital twins, which are a copy of a physical object reflecting its condition and interaction with the environment, in the context of life cycle management of residential buildings and infrastructure facilities are used for:

- monitoring the condition of an object in real time, using IoT sensors measuring temperature, vibration, humidity, etc.;

Table 2. Integrating digital twins with other technologies

Technology	Appointment in the digital twin	Links
BIM	Base for 3D model and data	[13–17]
IoT	Providing information in real time	[18–19]
Big Data + AI	Analysis and forecasting of the development of the object's state	[20–21]
Cloud Computing	Storage and processing of data	[22–23]

Table 3. Areas of application of IoT and Big Data in construction

Direction	Application	Examples
Monitoring the state of the object in real time	Using IoT sensors to collect data	Vibration, deformation and corrosion sensors in load-bearing structures
	Application of IoT sensors in engineering systems	Sensors for measuring temperature, humidity, pressure in engineering systems
	Using Big Data for Analysis	Equipment wear forecast
Optimization of energy consumption	Adaptive control systems	Dynamic regulation of heating, lighting, air conditioning systems depending on weather conditions
Predictive maintenance	Failure Prediction Using Machine Learning Models	Analysis of temperature and noise in equipment to justify spot repairs based on sensor data
Security Management	Providing comprehensive monitoring of fire safety, access control	Smoke detectors and cameras with computer vision models for open fire analysis

- predicting emergency situations, wear and tears through intelligent data analysis using artificial intelligence;
- optimizing the operation of facilities by simulating various energy consumption scenarios, analyzing the occupancy of premises — offices, hospitals, shopping centers, resource distribution, etc.;
- justifying decisions on modernization before implementing changes through virtual verification of reconstruction, assessing economic efficiency.

At the same time, several works note that the synergistic effect of the introduction of digital twins is achieved only through integration with other technologies (Table 2).

In fact, digital twins make it possible to bridge the gap between the design and operation of facilities.

Specimen Analysis 4 — IoT, Big Data + construction

This specimen reflects only 197 publications, which is generally not much given the time interval under consideration. At the same time, an analysis of current publications has shown that the joint use of IoT and Big Data allows for the transfer of residential buildings and infrastructure facilities management to a predictive

and adaptive level, minimizing costs and increasing their energy efficiency (Table 3) [20, 24–27].

Specimen Analysis 5 — Machine Learning + Buildings

During the period under review, the Scopus database displays only 848 documents. The dynamics of changes in the number of publications by year are presented below, in addition, the trend line indicates an increase in interest in the issue of using technology under consideration. At the same time, the leaders in publications are authors from the United States (Fig. 5).

In this context, machine learning is used to assess the demand for housing, transport and social infrastructure in complex territorial development projects, which allows for optimized planning.

Based on historical census data, a machine learning model can predict population growth, migration, and therefore the need for housing. The model can segment the market by solving the clustering problem and identifying the types of housing in demand.

The load on transport infrastructure can be assessed by modeling traffic flows and planning new routes.

Algorithms can predict the congestion of roads and public transport considering the density of buildings and pendulum migration routes, and graph neural networks, by analyzing the points of

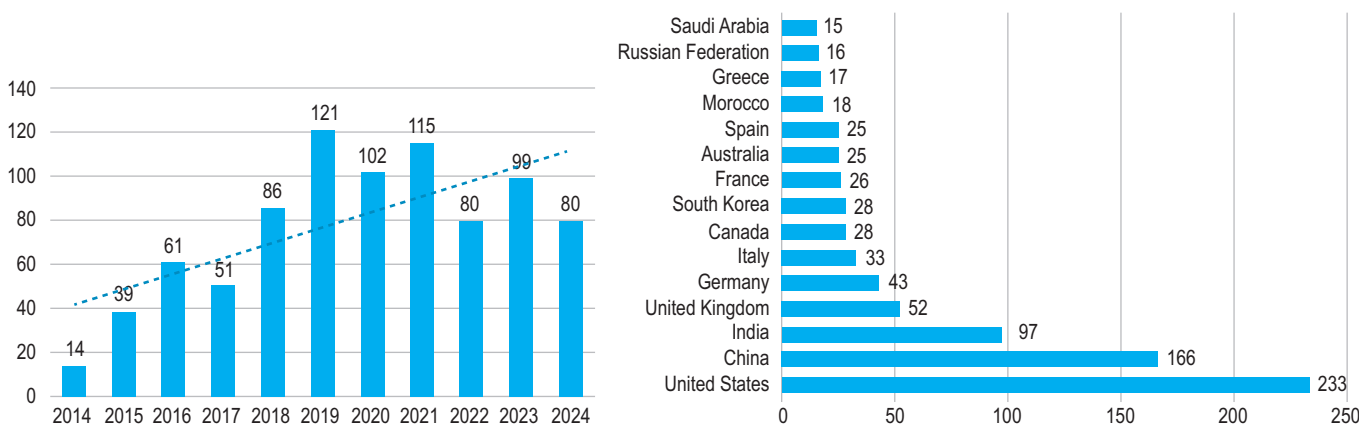


Fig. 5. Dynamics of changes in the number of publications for Machine Learning + Buildings, top 15 countries by publications

► Table 4. Directions for optimizing lifecycle management processes for residential and engineering infrastructure facilities in the context of digital transformation

Direction	Technology	Result	Effect
Reducing construction and operating costs	BIM + digital twins	Minimizing design errors	Budget cuts upto 20 %
	IoT + predictive analytics	Reduce repair costs by predicting failures	Reduce operating costs by up to 35 % through smart maintenance
Reducing project implementation time	BIM	Optimization of logistics and budget	Reduction of construction time by up to 15 %
	Planning with Artificial Intelligence	Automatic budget allocation	
Increasing reliability and safety	Digital twins + IoT	Monitoring of deformations, corrosion, etc.	Increasing the service life of objects by 20–20 %
	Machine learning	Analysis of emergency situations	Reducing the risk of accidents by up to 40 %
Energy efficiency and environmental friendliness	Digital twins	Analysis of the applicability of green solutions	Conformity Analysis LEED/BREAM
	Algorithms based on artificial intelligence	Setting up energy consumption	Reduce energy costs by up to 25 %

attraction of the population, can determine the locations for the design of public transport stops.

In addition, regression models can consider the birth rate and age composition of the population, which will allow for a forecast of the population's need for social infrastructure — schools, hospitals.

CONCLUSIONS

The analysis conducted revealed that digital transformation of life cycle management processes for residential and engineering infrastructure facilities in complex territorial development projects through the introduction of digital twins, IoT, Big Data, BIM, and machine models will ensure optimization in the following areas (Table 4).

Digital transformation of life cycle management processes for residential and engineering infrastructure facilities in complex territorial development projects changes reactive life cycle management of facilities into predictive and adaptive management, ensuring sustainability, reliability and safety of facilities.

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Цифровая трансформация процессов управления жизненным циклом объектов жилой и инженерной инфраструктуры в проектах комплексного развития территорий

Современные проекты комплексного развития территорий характеризуются технологической, организационной и информационной сложностью. Технологические вызовы включают интеграцию разнородных систем и обеспечение устойчивости объектов, организационных — полную координацию участников проекта информационных — обработку значительных объемов данных в условиях необходимости оперативного принятия решений. В этой связи особую актуальность имеет вопрос обеспечения сквозного управления жизненным циклом объектов и согласованности решений для эффективного использования ресурсов.

Целью исследования является анализ цифровых технологий для оптимизации управления жизненным циклом жилых зданий и объектов инфраструктуры в проектах комплексного развития территорий.

В рамках представленного исследования проведен анализ публикаций по ключевым словам, определенным авторами в контексте рассматриваемой темы. Базой формирования выборки по ключевым словам стала международная база Scopus.

Проведенный анализ демонстрирует, что внедрение цифровых двойников, IoT, BigData, BIM и машинного обучения позволяет достичь значительной оптимизации при управлении жизненным циклом объектов жилой и инженерной инфраструктуры в проектах комплексного развития территорий.

Цифровая трансформация принципиально меняет подход к управлению жизненным циклом, переводя его от реактивного к прогнозному и адаптивному, что обеспечивает устойчивость, надежность и безопасность объектов, экономию ресурсов и повышение качества городской среды.

Ключевые слова: цифровая трансформация, информационное моделирование, цифровой двойник, интернет вещей, анализ данных, искусственный интеллект, жизненный цикл объекта, устойчивое развитие территорий

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Прага. Посольство Российской Федерации в Чехии

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Urban design concepts creation for urban areas redevelopment projects

Modern cities face high demands on the quality of the urban environment and building construction sector. The paper is devoted to the development of urban planning concepts at the initial stage of the life cycle of any construction object as the primary document substantiating the possibility of its implementing in real life. The research question is how to organize the process of optimal and effective design solutions searching, taking into account the interests of all participants in the territory development project: developers, city authorities and the population in whose interests the territory is being developed. The analysis of the existing process of developing an urban planning concept has been carried out, the goals and objectives of the document development have been identified and systematized. The article highlights three main goals of any urban planning concept developing: as a tool for financial assessment of effectiveness, legal assessment of project feasibility, as well as a tool for coordinating design solutions with urban development plans and the requirements imposed by the city to modern buildings. The article presents a functional model for the development of an urban planning concept, which is aimed at effective coordination of the work of all participants in this process.

Keywords: urban planning concept, redevelopment, building, financial model of territory development, functional modelling

Urban redevelopment is an urgent area of urban policy in many cities around the world that are facing the consequences of urbanization. The main problem is the search for optimal design solutions aimed at achieving the goal of sustainable urban development [1, 2]. In world practice, considerable attention is paid to the issue of substantiating design solutions at the stage of developing urban planning concepts. This type of document performs several important functions:

- function of officially coordinating visions for the development of the city's territory by developers and city authorities;
- function of implementing solutions for sustainable urban development, which consists in implementing the principles of environmental safety, social comfort and economic efficiency of the design solution;
- function of forming the architectural and urban appearance of the city.

Currently, special attention is being paid to the quality of the urban environment. The national program "Housing and a comfortable urban environment", which operates in the Russian Federation, defines the formation of a comfortable and safe urban environment as a key goal.

Achieving the goal of improving the quality of building in modern cities of the Russian Federation lies in the field of integrated territorial development and taking into account the range of factors of land use, social security of the population, engineering, transport services, and environmental safety requirements. It is important to find optimal solutions that take into account the interests of all participants in the construction process — developers, city authorities and various groups of the population [3, 4].

The solution of this complex task is carried out at the stage of planning the life cycle of any construction facility as part of the development of

an urban concept for the development of territories. This document is developed at the pre-design stage of building any territory and provides a justification for choosing a further design solution [5–7].

The objectives of its development include addressing the following issues:

1. Coordination of the functional content of the developer's project proposals with the city authorities in order to coordinate planned urban development activities.
2. Approval of marginal parameters for the development of territories and, if necessary, justification for making changes to existing indicators.
3. Definition of the list of measures necessary for the implementation of the project solution with the division of financial obligations between the participants in the process.

The tasks of developing an urban planning concept include confirming the fact of full compliance of the territorial development project with the current legislation, as well as compliance with regulatory requirements for the provision of social, transport and engineering infrastructure [8, 9].

International experience emphasizes the need for a systematic analysis of the life cycle processes of a construction facility using modern methods of functional and organizational modelling [10–12].

There are many risks at each stage of the life cycle. The task of identifying and minimizing them is especially relevant for the stage of development of the urban development concept of territories, at the stage of development of which the planned effectiveness of the project is laid [13–15].

Thus, the urban planning concept is the primary document confirming the fact that design solutions, on the one hand, ensure the national goal of creating a comfortable and safe urban environment, and on the other hand, determine the effectiveness of its implementation for the developer.

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Fig. 1. Key tasks of urban planning concept for a territory redevelopment

The purpose of the study was to study the specifics of the development of an urban planning concept, taking into account the specifics of Russian reality, the allocation of which will improve the processes of building modern and sustainable cities.

The study allowed us to identify three main tasks of the urban planning concept in the life cycle of a construction facility, shown in Fig. 1.

1. Urban planning concept as a financial planning document for the effectiveness of a redevelopment project

The urban planning concept is being developed as part of the process of evaluating the financial effectiveness of the redevelopment project (Table 1). The ultimate goal of developing this document is precisely the financial assessment of the feasibility of the project, which consists of the total cost of its development and the planned income from its implementation. The cost of building a territory consists of the sum of the costs of activities at the stages of planning, design and construction.

2. Urban planning concept as a document of legal regulation of the conditions of development of the territory

At the stage of developing an urban planning concept, a primary legal assessment of a development site is carried out, which is aimed at identifying the main legal risks associated with its development. As practice shows, legal problems can arise at any stage of the life cycle of a construction facility. At the same time, the consequences of their occurrence can be severe, up to the point of stopping construction, which leads to financial losses from the unrealizability of the project.

Their timely identification and assessment is an important and complex task.

These include the following main risk groups:

- property relations regarding the land plot, legality of ownership rights, availability of easements;

Table 1. Initial data of the urban planning concept for a financial model preparation

Life cycle stage	The assessment aspect in the urban planning concept
Planning	<ul style="list-style-type: none"> • parameters of the planned development of the territory, taking into account existing restrictions; • requirements for functional content, taking into account the existing conditions of provision of social, transport and engineering infrastructure in the design area; • encumbrances on the construction of additional infrastructure
Projecting	<ul style="list-style-type: none"> • assessment of the complexity of the design solution; • requirements for the design solutions of the building area; • special design conditions
Building construction	<ul style="list-style-type: none"> • technical conditions for the organization of construction production; • technological complexity of construction

- existence of urban planning restrictions, the presence of zones with special conditions for the use of territories, the requirements of the rules of land use and development;
- environmental constraints in the area of the need to ensure environmental safety and nature protection.

3. Urban planning concept as a document for the implementation of the goals of planned urban development

In this aspect, the urban planning concept acts as a document confirming that redevelopment design solutions contribute to achieving the goals of the current urban policy. Each city develops development plans, which are fixed in the urban planning documentation — master plans of cities in the medium-term planning horizon and the Master Plan for the long term. The redevelopment projects being developed should support the overall direction of the city's development and contribute to achieving targets for the quality of the urban environment and the standard of living of the population.

The evaluation of design solutions consists of several directions:

1. Improvement of the quality parameters of the urban environment from the implementation of the redevelopment project. The effect is estimated by improving the indicators of population availability of various types of services, increasing the volume of construction of residential, public, transport, engineering and other types of infrastructure.

2. Ensuring the socio-economic impact of the redevelopment project. The effect is estimated by the number of jobs, the planned results of the project.

3. Inadmissibility of creating negative consequences of environmental degradation from construction. The most common examples are the construction of residential buildings that are not provided with social facilities, increasing the passenger load on the transport network and creating prerequisites for traffic congestion or overloading existing engineering networks.

Fig. 2 shows the main areas of attention to the implementation of urban quality indicators of the urban environment in the urban planning concept of the redevelopment project. These include the areas of social services for the population, the development of transport and engineering schemes, and preliminary decisions on the architectural and urban appearance of buildings.

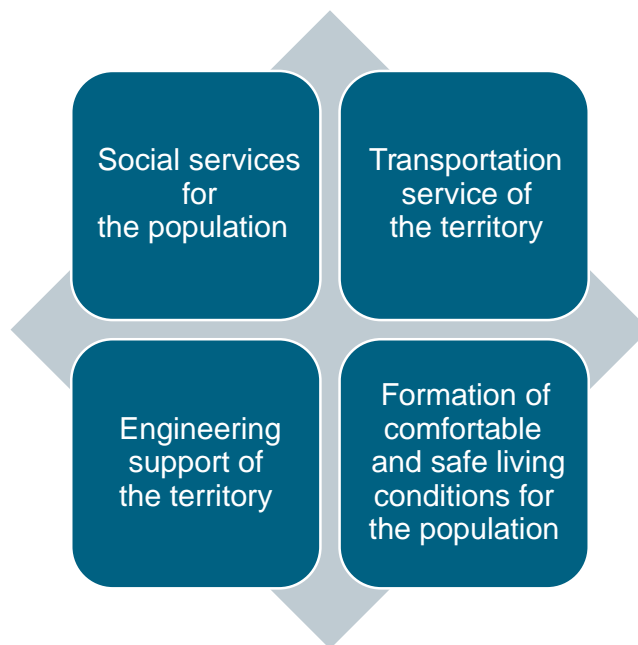


Fig. 2. Main areas of urban quality indicators consideration under the development of urban planning concepts

The designated objectives of the urban planning concept development determine the standard composition of the documentation shown in Table 2. It includes three main blocks of information:

- block 1. Information about the existing use of the territory, conditions of transport and engineering support;
- block 2. Information about the state of the territory in the zone of influence of the redevelopment project;
- block 3. Information about the legal status of the territory and the existing restrictions on its development;
- block 4. Project proposals for the redevelopment of the building site and planned technical and economic parameters of development.

An important feature of the development of the urban planning concept of the redevelopment project is the organization of the process of its development, coordination and approval.

The complexity of the urban planning concept as a document is determined by a large number of participants in this process, whose main functions are described in Table 3.

The functional modelling of the process is shown in Fig. 3. The process of developing an urban planning concept includes three main stages:

1. Study of the building site.
2. Development of options for the development of a building site. Building financial development models.
3. Selection of the development option, approval of the financial model and its further coordination.

In conclusion, it should be noted that the urban planning concept is the first document that is being developed for a building site and defines its development. It plays an important role as a tool for coordinating plans for the development of the territory by all participants in the process: developers, city authorities and the population. The key to the effectiveness of the project is an integrated approach to analyzing existing data and building predictive

Table 2. The standard structure of the urban planning concept documentation

Block 1	Information about the existing land use of the territory, conditions of its transport and engineering service	<ul style="list-style-type: none"> • building site plan; • existing land use of the building site; • the layout of the existing residential and non-residential facilities on the building site
Block 2	Information about the state of the territory in the zone of influence of the redevelopment project	<ul style="list-style-type: none"> • layout of existing and planned social services and maintenance facilities within the limits of regulatory territorial accessibility beyond the boundaries of the building site; • calculations of the existing need for social and maintenance facilities for the building site
Block 3	Information about the legal status of the territory and the existing restrictions on its development	<ul style="list-style-type: none"> • constitutive legal documents for Title documents for the building area land use; • the boundaries layout of zones with special land use conditions on the building site; • other documents of urban planning restrictions for the building site
Block 4	Project proposals for the redevelopment of the building site and planned technical and economic parameters of development	<ul style="list-style-type: none"> • the planned boundaries layout of the sustainable development of the building site and allocation of its functional elements within the planning structure the building site; • the layout of the proposed social and maintenance facilities; • information about labor places allocation within the boundaries of project development; • proposals for transportation services on the building site; • proposals for the engineering support on the building site; • activities aimed at creating comfortable and safe living conditions for the population

► Table 3. Participants in the urban planning concept development process

Participant in the process of developing an urban planning concept	Operational tasks
The General Director of the project	<ul style="list-style-type: none"> • setting the goals for building site development; • acceptance conclusion on the building site development strategy; • selection and approval of the recommended land use building site design project
Technical customer	<ul style="list-style-type: none"> • preparation of information on the technical possibilities of the building site development; • development of land use planning design solutions, calculation of technical and economic indicators and the standard output of square meters of valuable area; • calculation of construction costs
Real Estate Agency	<ul style="list-style-type: none"> • development of recommendations on the functional content of the building site based on marketing research; • land use planning solutions scenarios development
Legal Department	<ul style="list-style-type: none"> • legal assessment of the building site
Finance Department	<ul style="list-style-type: none"> • initial assessment of the efficiency prospects for the development of the building site; • financial assessment of development options for the building site
Technical and Economic Council	<ul style="list-style-type: none"> • decision-making process on further work with the development site based on the initial analysis of marketing research, technical and legal assessment; • acceptance conclusion on the building site development strategy; • selection and approval of the recommended land use building site design project

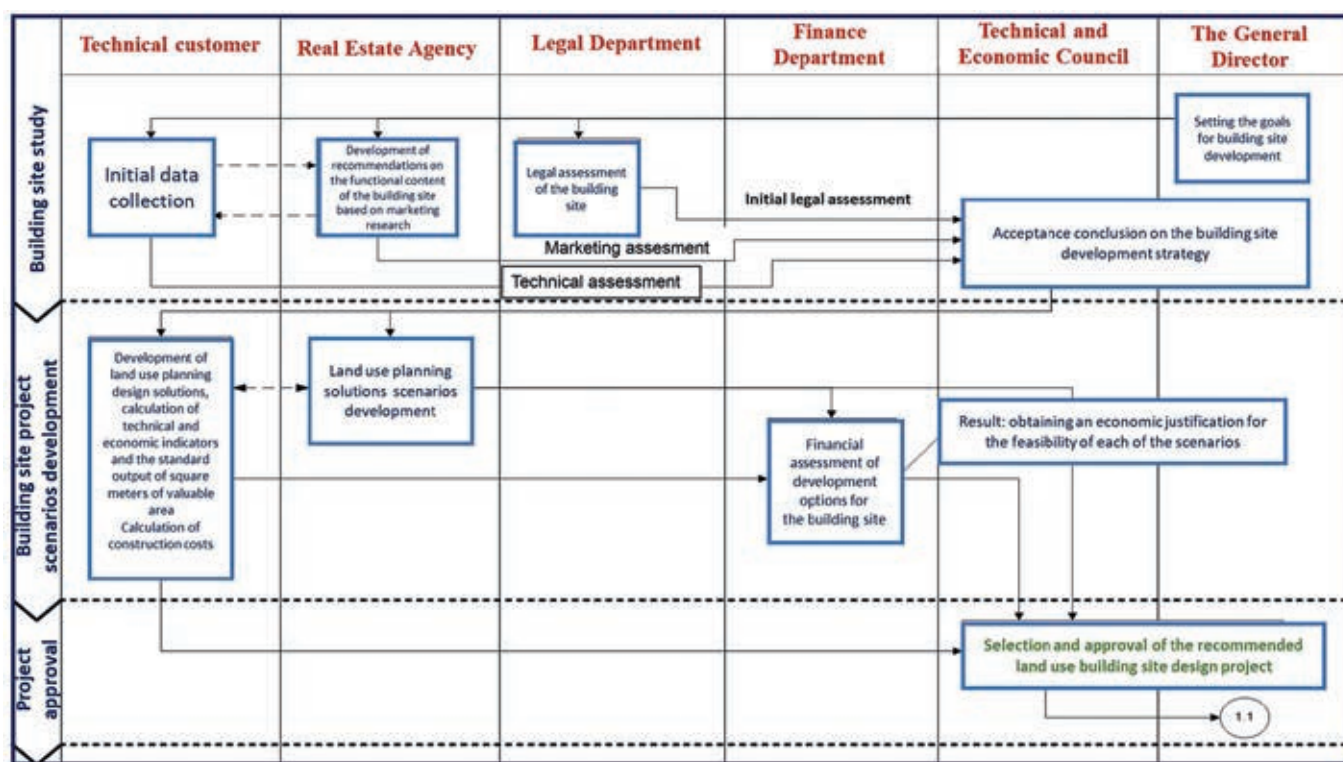


Fig. 3. Functional modelling of the urban planning concept development process

financial models of the life cycle of a construction facility. Thus, the urban planning concept plays an important role in ensuring the goal of sustainable urban development and achieving the targets of sectoral National projects of the Russian Federation.

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Особенности разработки градостроительной концепции при редевелопменте городских территорий

Современные города предъявляют высокие требования к качеству городской среды и застройке. Статья посвящена вопросу разработки градостроительных концепций на начальном этапе осуществления жизненного цикла любого строительного объекта как первичного документа обоснования возможности реализации проекта городской застройки. Исследовательский вопрос заключается в организации процесса поиска оптимальных эффективных проектных решений с учетом интересов всех участников проекта застройки территории: девелоперов, властей города и населения, в интересах которого и происходит застройка территории. Проведен анализ существующего процесса разработки градостроительной концепции, выявлены и систематизированы цели и задачи разработки документа. В статье выделены три основные задачи разработки градостроительной концепции как инструмента финансовой оценки эффективности, правовой оценки реализуемости проекта, а также инструмента согласования проектных решений с городскими планами развития и требованиями, предъявляемыми городом к современной застройке. В статье представлена функциональная модель разработки градостроительной концепции, которая нацелена на эффективную координацию работы всех участников данного процесса.

Ключевые слова: градостроительная концепция, редевелопмент, застройка, финансовая модель освоения территории, функциональное моделирование

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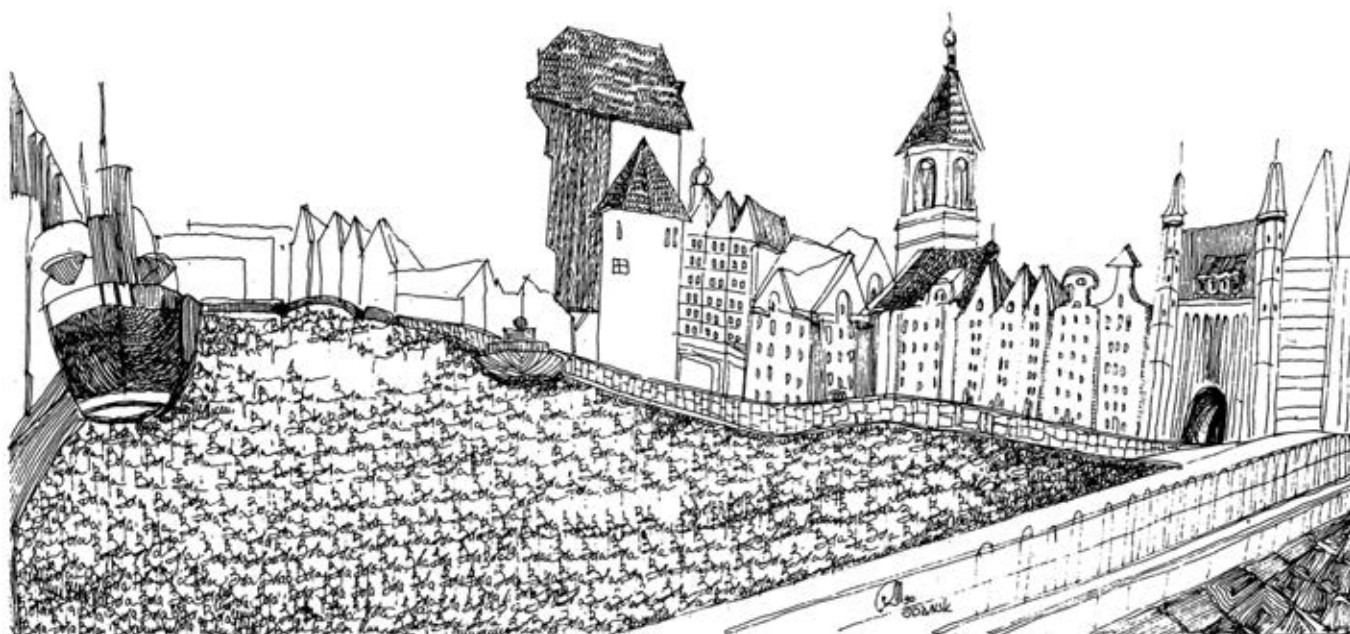
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Ensuring competitiveness of enterprises in the construction industry on the basis of dynamic equilibrium concept

Relevance of research. Research shows that a special place in the modern turbulent economy is occupied by the problems of developing the theory and practice of modelling the competitiveness of construction enterprises from the standpoint of assessment and integrated management of both its current, medium-term, and strategic competitiveness through a conceptual mechanism of dynamic equilibrium of the internal and external environment in conditions of uncertainty and risk.

Purpose of the study. To substantiate methodological approaches to ensure the processes of assessing and managing the competitiveness of construction enterprises based on the concept of dynamic equilibrium of the internal and external environment in conditions of risk and uncertainty through modelling the aggregate competitive potential for key success factors.

Methods. A set of systemically interrelated methodological approaches based on both the theory of competitiveness and the concept of dynamic equilibrium of economic systems was used. The methods of factor and trend analysis, mathematical statistics, economic and mathematical modelling and forecasting, expert assessments, uncertainty and risk theory, comparison, analysis and synthesis were also used.

Results and novelty. The article demonstrates the following main scientific results with elements of scientific novelty: clarification of the conceptual category "competitiveness" with the definition of a set of system principles for modelling and situational assessment of competitiveness using an indicative sector program; the concept of dynamic equilibrium of competitiveness for construction enterprises in the areas of productivity and cost management is modeled with the development of the conceptual category "uncertainty". A generalized classification and analysis of key success factors determining competitiveness based on the structuring of local potentials of investment, organizational, production, and financial and economic types has been performed; a methodological approach has been developed to determine calculated indicators of enterprise competitiveness; the main patterns of change in key factors of competitiveness management at the operational, tactical, and strategic management levels have been established using the example of Tunnel-2001 LLC's competitive profile.

Keywords: *aggregate competitiveness, potential competitiveness, internal competitiveness assessment, management, construction company, uncertainty, dynamic equilibrium concept, internal environment, external environment, key success factors*



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INTRODUCTION

A promising area of scientific and practical development of regional construction markets is the formation of competitive and high-performance construction and economic systems.

The analysis of the national construction market shows that the issue of competitiveness is especially relevant from the perspective of the modern turbulent economy, which creates critical levels of uncertainty for all enterprises of the construction complex and generates increased risks of loss of their competitiveness.

Most construction companies are characterized by a problematic situation of significant risks of losing their current operational competitiveness due to significant threats to reduce their overall competitive potential in the medium and strategic term.

The author's research shows that there are gaps between the current and potential competitiveness of a construction company in a highly uncertain business environment. An increase in the key interest rate, inflation, adjustments to government procurement conditions, continued sanctions, insufficient staffing, low direct investment in the renovation of fixed assets, etc. have a significant impact on dynamic changes in the external environment.

A large number of scientific works by well-known foreign and domestic economists are devoted to the issues of formation, assessment and management of competitiveness of enterprises, which affect both the meaning of the concept itself and the methods of their quantitative and qualitative assessment. Thus, Professor Kh.M. Gumba [1] notes the importance of modelling the conceptual foundations of the formation of sustainable competitive advantages.

A significant contribution to the theory of competitiveness was made by Professor I.G. Lukmanova, who thoroughly studied this topic from the perspective of construction industry enterprises [2], customer orientation as a reserve for increasing competitiveness [3], in the context of the development of self-regulation processes [4], as well as in the framework of competitiveness analysis from the perspective of ensuring strategic advantages of the enterprise [5].

A study by Prof. N.Yu. Yaskova, V.I. Sarchenko and S.A. Khirevich, who predict the horizons of competitiveness of the national economy [6], model an integrated approach to the formation of a high-quality competitive urban environment [7].

Noteworthy are the author's studies on the competitiveness of development companies by S.M. Borozdina, PhD in Economics, in which she models

► the conceptual mechanisms of enterprise competitiveness in the construction industry and marketing strategies [8].

Some issues in the field of modelling the competitiveness of construction organizations were considered by Professor P.G. Grabovyy [9], including the issues of risks and uncertainty [10], as well as Prof. A.N. Larionov and Prof. V.A. Kosheev [11].

A number of authors, such as Kh.M. Gumba, S.S. Uvarova, S.V. Belyaeva, etc., explore the topical issues of forming the concept of systemic competitiveness of construction in the digital economy [12]. D.N. Silka analyzed the factors of business activity that determine the competitiveness of construction [13], and K.A. Babenchuk — competitiveness management of the regional housing market in Samara [14].

A number of studies on the competitiveness of regional business systems and leading companies in the primary market, conducted under the guidance of Prof. S.A. Baronin [15, 16].

The review analysis shows that despite significant research in this area, a very relevant problem of the development of the theory and practice of modelling the competitive potential of construction enterprises from the perspective of applying the concept of dynamic equilibrium of the internal and external environment in conditions of uncertainty of a turbulent economy remains unresolved.

In this regard, recent research in the field of modelling the dynamic equilibrium of economic systems by such authors as G.A. Batishchev, M.I. Zhuravleva [17, 18], as well as M.S. Melnik on the structural and dynamic equilibrium of socio-economic systems [19] and O.E. Kichigin [20] on the dynamic equilibrium of regional and corporate structures of the fuel and energy complex. But at the same time, the problem of applying the concept of dynamic equilibrium to the theory of competitiveness of construction enterprises is not investigated and is open.

Also, an additional analysis of research in the field of regional economics shows that a research approach is becoming more widespread, where risk theory does not dominate, but is significantly complemented by uncertainty theory.

Most researchers interpret the concept of economic uncertainty according to F. Knight sees the uncertainty of the future outcome of the event, as well as its poor predictability due to the inability to predict it based on current information. The translation of the fundamental work "Risk, Uncertainty and Profit" [21] by the American economist Frank Heineman Knight, first published in Russian in 2003, made it possible to identify uncertainty as a decisive factor in the emergence of the phenomenon of entrepreneurial profit.

The problem of uncertainty is manifested in various studies of scientists. The research of A.K. Orlov in terms of forecasting the cost of basic building materials in conditions of uncertainty deserves attention [22].

D.A. Petrova in his work also suggests assessing the level of uncertainty of economic policy [23]. When modelling the processes of assessing the competitive advantages of construction enterprises, as R.V. Obukhov points out [24], it is also necessary to take into account uncertainty when analyzing the factor space.

It is also important to take into account both the theory of life cycles in construction [25] and the concept of sustainable development of territories and green construction [26, 27], eco-oriented development [28] and the model of harmonization of construction [29].

Thus, the conducted review analysis confirmed the relevance of research on the issues of ensuring the competitiveness of enterprises in the construction industry based on the concept of dynamic equilibrium and the theory of uncertainty in a turbulent economy.

The problem under study allowed us to formulate a *scientific hypothesis* of the study. It consists in the assumption that the implementation in modern conditions of methodological provisions and practical recommendations for the development of the theory of competitiveness of construction enterprises is possible through the application of the concept of dynamic equilibrium of the internal and external environment at the current, tactical and strategic management level through modelling the aggregate competitive potential for key success factors in conditions of high uncertainty.

Construction companies operating as a competitive business environment in a turbulent economy, increased risks and uncertainty are accepted as the *object of research*.

The *subject of the research* is the category of competitiveness of a construction company and the key success factors that form the overall competitive potential at the operational, tactical and strategic management levels.

The *purpose of the study* is to substantiate methodological approaches and practical recommendations for ensuring the competitiveness of construction enterprises based on the concept of dynamic balance of the internal and external environment in conditions of risk and uncertainty through modelling the aggregate competitive potential for key success factors at the strategic, tactical and operational management levels.

METHODOLOGY

At the methodological stage of the research, the following set of methodological developments was carried out:

First, the conceptual category "total competitiveness" of a construction company is defined. It is understood as the integral and sustainable ability of investment, organizational, production, and financial and economic potentials, considered as key success factors, to make high-performance use of all types of production and economic resources while ensuring compliance with industry standards and principles of competition with major competitors and a business leader at the operational, tactical, and strategic management levels, provided that uncertainties and risks of the internal and external environment.

Secondly, a theoretical approach has been developed to determine the methodological foundations for modelling indicators of aggregate competitiveness (C_i), based on the following principles of indicative modelling:

- the formation of three local types of competitive potential as the basis for the indicator assessment of C_i : investment — Z_1 ; organizational and production — Z_2 ; financial and economic — Z_3 , which determine the aggregate (total) potential of Z_0 ;
- the principle of modelling local competitive potentials based on the identification and analysis of *key success factors* (KSF) as the main determinants or goals of C_i in the framework of the functioning of Z_1 – Z_3 in the areas of performance and cost management. Initially, experts selected 60 factors as the basis of the KSF study. Then, during the expert survey, the final significant factor space of KSF was formed from 25 factors with the coefficients of their weight α_i and the weight of local potentials λ_i ;
- the principle of ensuring compliance of KSF indicators with industry-specific production and economic norms and standards. This determines the modelling of the internal competitiveness of the operational type — C_i , as well as the possible managerial C_i in the presence of an internal corporate planning and controlling system for this indicator — C_{M_i} ;

- the principle of competition (competitiveness) with the main competitors through the level of compliance of KSF indicators of the analyzed enterprise with the indicators of the main competitors. This determines the modelling of the potential competitiveness of the tactical type — C_T ;
- the principle of competition with the main business leader within the framework of the benchmarking concept is through the level of compliance of KSF indicators of the analyzed enterprise with the indicators of the industry business leader. This determines the modelling of potential competitiveness of a strategic or reference type — C_S ;
- the principle of distinguishing internal C_i at the operational level and external potential at the tactical and strategic (reference) level;
- the principle of modelling the total (general) competitiveness C_G of a joint venture as an integral indicator depending on the indices of operational, tactical and strategic C_i ;
- the principle of preferential stability for an average type of enterprise according to indicators of operational C_i and worse indicators at the current and strategic level;
- the principle of the need to identify gaps between the current operational, tactical and strategic C_i , ensuring their minimization and management stabilization through the use of the concept of dynamic balance of the internal and external environment;
- the principle of ensuring dynamic equilibrium of Q_i and V_j as a conceptual basis for the management stabilization of C_i in conditions of uncertainty and risk according to significant indicators of KSF.

Thirdly, the author's research [30, 31] allowed us to propose the following understanding of the conceptual category of the dynamic equilibrium concept (DR_{q-v}), which should be understood as a theoretical approach to modelling the abilities of development systems to consistently identify, to restore and stabilize the losses of lost competitiveness to an acceptable level by ensuring a continuous dynamic balance of the external and internal environment through performance and cost management based on key success factors in conditions of constant uncertainty and risks.

Fourth, methodological modelling of the indicators of the total (general) competitiveness C_G through two subsystems has been carried out:

- *internal* — C_i : operational type, based on the principle of comparability of actual C_i indicators with industry standards or internal corporate standards (C_{op}); managerial type (C_M), based on the principle of comparability of actual C_i indicators with their planned indicators;
- *external or potential* — C_p , as an ability to compete with a competitive business environment (CBS) and with key business leaders. The following indicators are used to calculate the competitiveness potential;
- *tactical competitiveness* — C_T , as a comparability with the main competitors at KBS;
- *strategic (reference) competitiveness* C_S , as a comparability with an industry leader within the framework of the benchmarking concept.

The performed studies also allowed us to determine the calculation formulas of formulas and indicators of C_i , taking into account the weight of X_i in subsystems Z_1-Z_3 in the factor space KSF.

RESULTS OF THE STUDY

Nomogram of the dynamic equilibrium of construction enterprises in terms of aggregate competitiveness in the areas of productivity and cost management

To implement the accepted theoretical approach, a nomogram of the dynamic equilibrium of construction enterprises for overall competitiveness in the areas of performance management (P_i, R) and cost management (V_b, C) was developed for various levels of uncertainty W_i and five areas of dynamic equilibrium from D_{ab} to D_{cr} shown in Fig. 1.

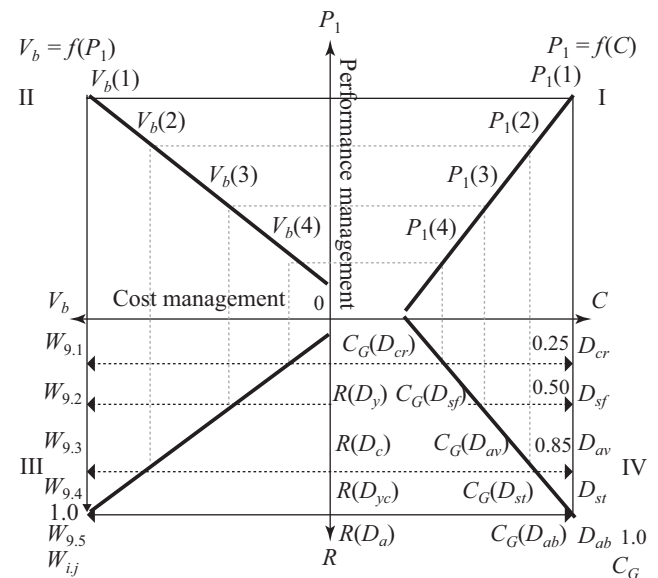


Fig. 1. Nomogram of the dynamic equilibrium of construction enterprises for overall competitiveness in the areas of performance management (P_i, R) and cost management (V_b, C) was developed for various levels of uncertainty W_i and five areas of dynamic equilibrium from D_{ab} to D_{cr}

Where C — invested capital (own and borrowed);

V_b — business value;

P_i — labour productivity;

R — company revenue;

$V_b = f(P_i)$ — the function of changing the value of a business depending on P_i ;

$P_i = f(C)$ — the function of changing labour productivity depending on C ;

$D_{ab}, D_{st}, D_{av}, D_{sf}, D_{cr}$ — zones of dynamic equilibrium of the enterprise in terms of general competitiveness C_G respectively, the absolute $C_G(D_{ab})$, stable $C_G(D_{st})$, average $C_G(D_{av})$, satisfactory $C_G(D_{sf})$ and critical level $C_G(D_{cr})$;

$W_{9,5}, W_{9,4}, W_{9,3}, W_{9,2}, W_{9,1}$ — areas of uncertainty and risks of competitiveness of enterprises are absolute, discrete, range, critical and total uncertainty, respectively.

Definition of the conceptual category uncertainty, its classification analysis and levels of its modelling

It is proposed to understand the *uncertainty* W_i in relation to C_G as the ability of construction enterprises to uncontrollably increase their instability in terms of competitiveness indicators up to a crisis state. W_i also provides for: the presence of a high intensity of changes in the external and internal environment; unpredictability,

randomness, unreliability and incompleteness of information; unpredictability and non-derivability of a reliable new competitive state from a previously known retrospective period; the presence of deliberate counteraction factors leading to a loss of competitiveness of a construction company, up to its liquidation.

The following classification of uncertainty is proposed according to the following criteria: the external environment of the enterprise (W_1); the internal environment of enterprises (W_2); the subject of management (W_3); the object of management (W_4); the target effectiveness of management (5th kind — W_5); the balance of the internal and external environment (W_6); the choice of alternatives and their multiplicity (W_7); according to the state of the system relative to its "ideal" competitiveness parameters (corporate standards, industry standards, standards of leaders, harmonic ideals) (W_8); according to the levels of uncertainty (W_9).

Within the framework of modelling uncertainty of the 9th kind of type W_9 , it is proposed to identify the following levels of modelling:

First level of uncertainty $W_{9.5}$ — "full certainty of the sustainability of the construction company". The interval — 1.00. It assumes hypothetical complete or deterministic certainty in a predictable, stable and highly stable external and internal environment with a high level of adaptation and flexibility to rare and small changes.

Second level of uncertainty $W_{9.4}$ — "discrete uncertainty of the sustainable development of a construction company with minimal uncertainty". The range is from 1.00 to 0.85. It is characterized by the presence of a number of separate local discrete situations of depreciation of current competitive advantages with the ability to determine the probability of their occurrence and the ability to predict scenarios for the formation of innovative strategic competitive advantages with minimal risks.

Third level of uncertainty $W_{9.3}$ — "range uncertainty of the sustainable development of a construction company C_i with the maximum allowable uncertainty". The range is from 0.84 to 0.51. When frequently recurring discrete situations of increasing uncertainty turn into a stable and continuous manifestation in certain time ranges, the level of uncertainty in the internal and external environment of the enterprise is transformed into a range uncertainty.

Fourth level of uncertainty $W_{9.2}$ — "critical uncertainty of the sustainable development of a construction company with unacceptable critical uncertainty". The range is from 0.50 to 0.25. In this case, a further increase in entropy in uncertainty will lead to its transformation to an unacceptably critical level. This determines the transition to anti-crisis strategies aimed at two alternatives: by moving to zone $W_{9.3}$ or to the liquidation zone.

Fifth level of uncertainty $W_{9.1}$ — "complete uncertainty of the sustainable development of the construction company in terms of competitiveness and its transition to liquidation". The range is from 0.24 to 0. This determines the possibility of implementing only one alternative strategic scenario — the liquidation of the enterprise with the development of optimal liquidation strategies with its maximum liquid value.

The controlled zones should include discrete, range, and critical.

Analysis of key success factors in modelling local competitive potentials of a construction company

The developed principles of C_G research provide for the modelling of the factor space based on KSF. Initially, experts selected 60 factors distributed by types of competitive potentials Z_1 – Z_3 as the KSF research base. Then, during the expert survey, the final

significant factor space KSF was formed from 25 factors with the coefficients of their weight α_i and the weight of local potentials λ_i . The final results of the study are shown in Table.

The study of the main patterns of transformation of local competitive potentials at the operational, tactical and strategic levels of management

The scientific result of the study is in the form of the main patterns of transformation of local competitive potentials at the operational, tactical and strategic management levels using the example of six companies in the Moscow underground construction market: Tunnel-2001 (the main analyzed enterprise); SMU No. 1; SMU No. 6; SMU No. 8; Tunnel Detachment No. 6 and SMU No. 12 for the analyzed period 2019–2023. At the same time, two types of economic trends have been identified:

Firstly, patterns of change in the average indicators of the actual KSF indicators for local competitive potentials over a five-year period have been obtained in the form of a sector diagram shown in Fig. 2.

The sectorogram shows the following values of local competitive potentials at the operational level — 0.937; at the tactical level — 0.904; at the strategic level — 0.719.

Secondly, the main patterns of change in the actual indicators of local competitive potentials Z_1 – Z_3 by the main KSF_{*i*} factors at the operational (o), tactical (t) and strategic (s) levels are determined in the form of a diagram shown in Fig. 3.

The main patterns of transformation of local competitive potentials Z_1 – Z_3 according to the main KSF factors over a five-year period are: a high stable level of internal operational competitiveness at an average level of 0.937; a significant level of tactical competitiveness with an average level of 0.904. In some cases, the indicators are greater than one, which forms tactical leadership zones, shown as ψ_1 (in 2019) and ψ_2 (in 2022). At the same time, the values of Z_1 – Z_3 at the operational and tactical levels are always at a high level of discrete uncertainty in the $W_{9.4}$ zone; the presence of a consistently low level of strategic (reference) competitiveness of local potentials from 0.630 to 0.790 with an average level of 0.719.

All values of $Z_{1,av}$ – $Z_{3,av}$ for the analyzed five-year period are in the range of uncertainty $W_{9.3}$.

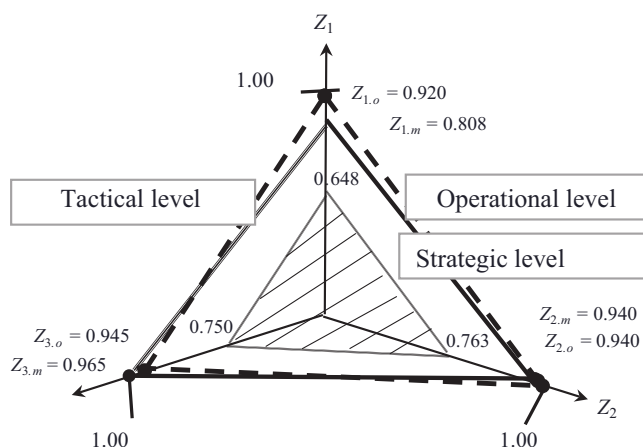


Fig. 2. A model of the sectorogram of actual competitiveness indicators for local competitive potentials Z_1 , Z_2 and Z_3 for "Tunnel-2001" LLC based on average indicators for 2019–2023

The final significant KSF factor space for the three types of competitive potential Z_1-Z_3 and its weight by X_i and subsystems

Key factor		Key X_i at the operational level K_i		Key X_i at the tactical level K_i		Key X_i at the strategic level K_i	
		+/-	Weight of α_i	+/-	Weight of α_i	+/-	Weight of α_i
1. Investment potential (Z_1) — $\lambda_1 = 0.5$							
X_1	Business value	-	-	+	0.45	+	0.45
X_2	Market share size	-	-	+	0.3	+	0.45
X_4	Return on equity	+	0.2	+	0.1	-	-
X_5	Return on borrowed capital	+	0.3	+	0.05	-	-
X_6	Return on investment capital	+	0.4	+	0.1	+	0.1
X_7	Return on production capital	+	0.05	-	-	-	-
X_8	Return on working capital		0.05	-	-	-	-
2. Organizational and production potential (Z_2) — $\lambda_2 = 0.3$							
X_{13}	Labour productivity	+	0.60	+	0.40	+	0.20
X_{14}	The level of concentration of production by volume of construction works	-	-	+	0.10	+	0.10
X_{17}	Fundreturn	+	0.40	-	-	-	-
X_{18}	The level of diversification of production activities	-	-	+	0.05	-	0.10
X_{19}	The level of application of digitalization and high-tech	-	-	+	0.20	+	0.20
X_{21}	Construction works, the degree of participation in government orders and national projects	-	-	+	0.20	+	0.30
X_{24}	Labour potential (average number of employees)	+	-	+	0.05	+	0.10
3. Financial and economic potential (Z_3) — $\lambda_3 = 0.2$							
X_{26}	The ratio of borrowed and own funds	-	-	+	0.15	+	0.15
X_{27}	Maneuverability of own funds	+	0.1	-	-	-	-
X_{28}	Provision of material reserves with own working capital	-	-	+	0.15	+	0.15
X_{29}	Financial stability	+	0.3	+	0.2	+	0.2
X_{30}	Current liquidity	+	0.25	-	-	-	-
X_{31}	Promising liquidity	-	-	-	-	+	0.3
X_{32}	Fast liquidity	-	-	+	0.2	-	-
X_{34}	Availability of own funds	+	0.15	-	-	-	-
X_{51}	Ability to restore solvency	+	0.2	-	-	-	-
X_{53}	Probability of bankruptcy according to the Taffler model	-	-	+	0.3	+	0.2

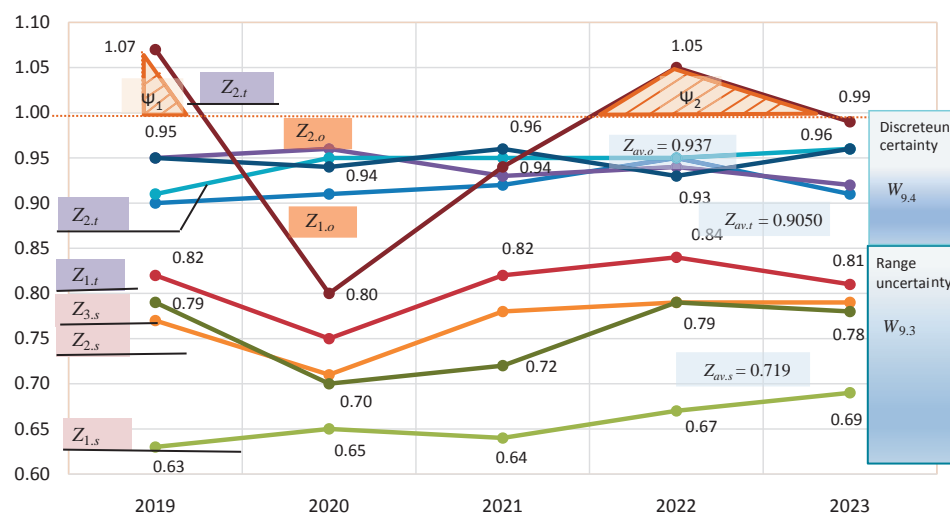


Fig. 3. Trends in the local competitive potentials of Z_1-Z_3 by CFU factors at the operational (o), tactical (t) and strategic (s) management levels of "Tunnel-2001" LLC in 1999-2023

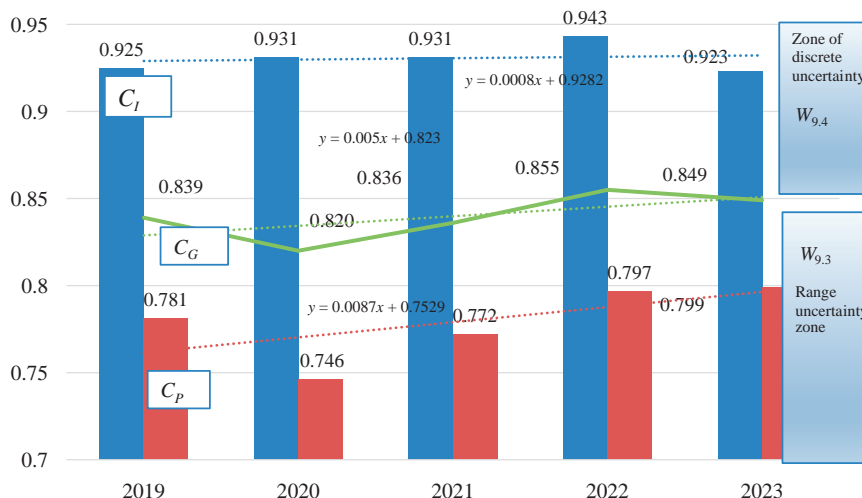


Fig. 4. The main trends in the internal (C_i), prospective (C_P) and general (C_G) competitiveness of Tunnel-2001 LLC in 2019–2023 in relation to the uncertainty zones $W_{9.3}$ and $W_{9.4}$

Analysis of the main trends in the internal, prospective and overall competitiveness of “Tunnel-2001” LLC for 2019–2023 in relation to areas of uncertainty

The approbation of the author’s methodology using the example of the competitive profile of “Tunnel-2001” LLC made it possible to determine the main trends in changes in C_i , C_P and C_G for 2019–2023 in relation to the level of uncertainty W_{ij} shown in Fig. 4. The actual patterns of change in C_i are approximated by linear trends.

It was found that the overall competitiveness C_G of the enterprise during the analyzed period moved from the range $W_{9.3}$ to the zone of discrete uncertainty $W_{9.4}$. This demonstrates the success of the sustainable competitive development of “Tunnel-2001” LLC in 2019–2023. At the same time, internal competitiveness is consistently high at an average level of 0.9306 and is located in the $W_{9.4}$ zone. At the same time, the potential competitiveness C_P over the analyzed period remained in the zone of uncertainty and risks $W_{9.3}$ and is in the range from 0.746 to 0.797 (Fig. 4).

DISCUSSION

Undoubtedly, an attempt to synthesize an indicator of the overall competitiveness of a construction organization based on the principles of dynamic equilibrium in conditions of uncertainty is of scientific and practical interest. But at the same time, when solving the task, a number of controversial issues should be noted.

First, it is necessary to model the processes of ensuring the dynamic competitiveness of construction enterprises, taking into account industry specifics. For example, both underground, residential or industrial construction, as well as other segments of the commodity construction market, require consideration of their specifics. This will undoubtedly require an adjustment of the author’s methodology.

Secondly, the methodology of aggregate competitiveness requires its development from the standpoint of modelling the life cycles of both aggregate and local types of competitiveness of a construction enterprise in the system of internal corporate management.

Thirdly, it is quite obvious that there is a need for additional development of the scientific and practical foundations of state policy in the field of bidding, tenders and auctions when selecting contractors as part of the implementation of government orders in accordance with federal law 44-FZ, taking into account indicators

of aggregate competitiveness according to the author’s methodology.

Fourth, it is important to provide a methodological calculation apparatus for competitiveness with its focus on digital information modelling technologies.

Fifth, the methodology for assessing and managing the dynamic competitiveness of construction enterprises should have a mandatory element at the final calculation stage in the form of determining specific effects and effectiveness by ensuring an increase of C_G .

The above-mentioned number of controversial issues of the methodology should be attributed not so much to the disadvantages, but mainly to the prospects for its development.

CONCLUSIONS

The research carried out on the studied issues actualizes research on the development of the theory of competitiveness of construction enterprises based on the concept of dynamic equilibrium through modelling the aggregate competitive potential for key success factors in conditions of uncertainty and risk.

The non-trivial research field is formed due to the importance of developing exploratory scientific research in the field of applying the concept of dynamic equilibria in the areas of productivity and cost management relative to the competitiveness of a construction company in a turbulent economy and increased uncertainty of the internal and external business environment in terms of factor space in the form of KSF.

The author’s methodological framework for ensuring the competitiveness of a construction company provides for comprehensive C_G modelling, and its approbation using the example of “Tunnel-2001 LLC” for 2019–2023 with the receipt of individual scientific results: a nomogram of dynamic equilibrium; a conceptual definition of the uncertainty category, its classification analysis and allocation of modelling levels; analysis of key success factors in modelling local competitive potentials. The study of the main patterns of transformation of local competitive potentials at the operational, tactical and strategic management levels; the analysis of the main trends in internal, prospective and overall competitiveness in relation to areas of uncertainty.

The author identifies controversial issues and promising research directions for ensuring the overall competitiveness of con-

struction enterprises based on the KSF dynamic equilibrium concept in conditions of uncertainty and risk in a turbulent economy.

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Обеспечение конкурентоспособности предприятий строительной отрасли на основе концепции динамического равновесия

Актуальность исследования. Исследования показывают, что особое место занимает в современной турбулентной экономике проблематика развития теории и практики моделирования конкурентности строительных предприятий с позиций оценки и интегрального управления как его текущей, среднесрочной, так и стратегической конкурентоспособностью через концептуальный механизм динамического равновесия внутренней и внешней среды в условиях неопределенности и риска.

Цель исследования. Обоснование методических подходов по обеспечению процессов оценки и управления конкурентоспособностью строительных предприятий на основе концепции динамического равновесия внутренней и внешней среды в условиях риска и неопределенности через моделирование совокупного конкурентного потенциала по ключевым факторам успеха.

Методы. Использовался комплекс системно взаимосвязанных методических подходов, основанных как на теории конкурентоспособности, так и на концепции динамического равновесия экономических систем. Применялись также методы факторного и трендового анализа, математической статистики, экономико-математического моделирования и прогнозирования, экспертных оценок, теории неопределенности и рисков, сравнения, анализа и синтеза.

Результаты и новизна. В статье продемонстрированы следующие основные научные результаты с элементами научной новизны: уточнение понятийной категории «конкурентоспособность» с определением комплекса системных принципов по моделированию и ситуационной оценке конкурентоспособности с использованием индикативной секторограммы; смоделирована концепция динамического равновесия конкурентоспособности для строительного предприятия по направлениям управления производительностью и стоимостью с разработкой понятийной категории «неопределенность»; выполнена обобщенная классификация и анализ ключевых факторов успеха, определяющих конкурентоспособность на основе структуризации локальных потенциалов инвестиционного, организационно-производственного и финансово-экономического типа; разработан методический подход по определению расчетных индикаторов конкурентоспособности предприятий; установлены основные закономерности изменения ключевых факторов управления конкурентоспособностью на операционном, тактическом и стратегическом уровнях управления на примере конкурентного профиля ООО «Тоннель-2001».

Ключевые слова: совокупная конкурентоспособность, потенциальная конкурентоспособность, внутренняя конкурентоспособность, оценка, управление, строительное предприятие, неопределенность, концепция динамического равновесия, внутренняя среда, внешняя среда, ключевые факторы успеха

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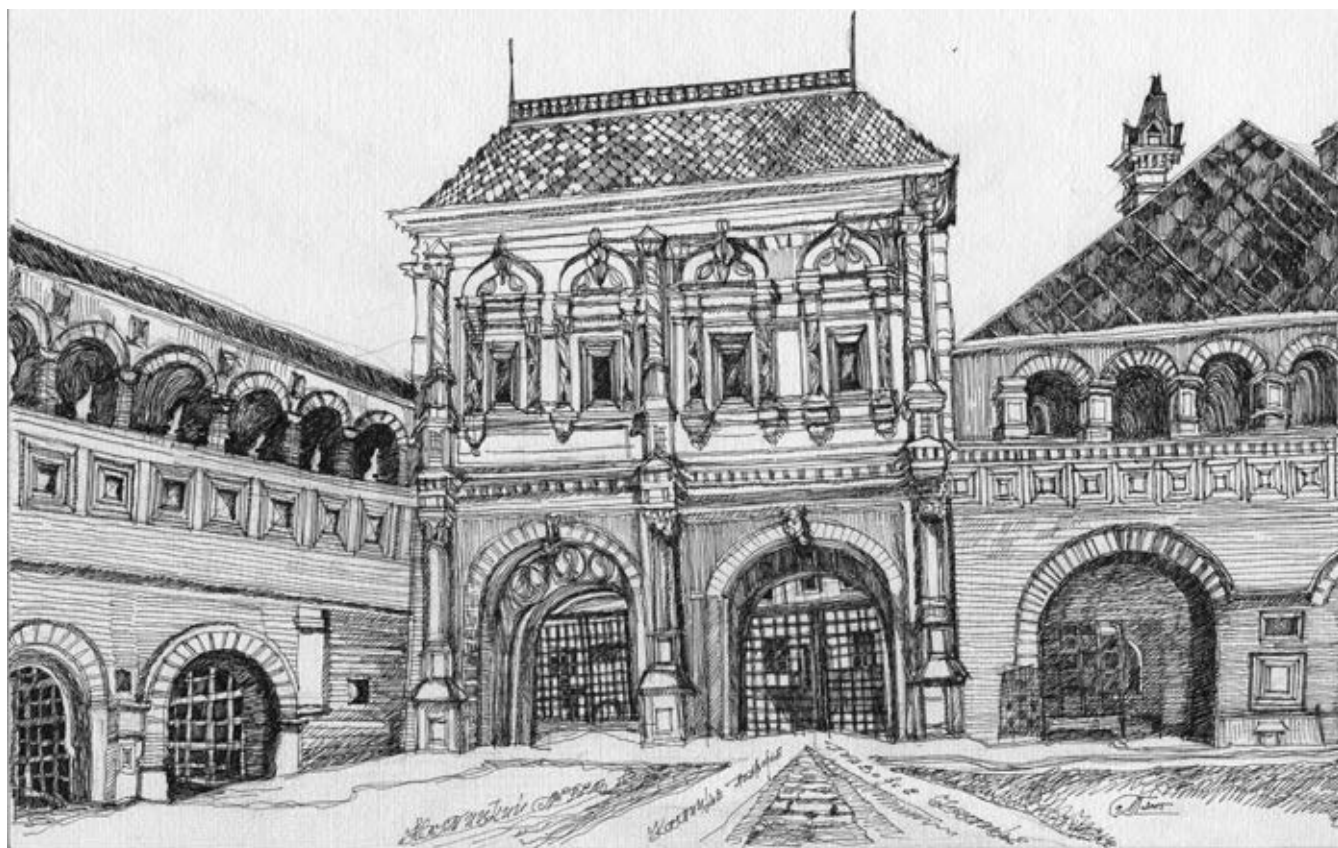
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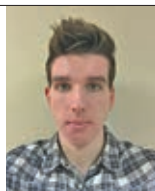
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Classification of programs for renewal of the urban housing stock

The paper considers the problem of classification of programs and projects for the development of housing stock. The classification of projects for the improvement of residential development and comprehensive renovation of entire urban areas is given. The study considers the concepts of “renovation of residential development”, “redevelopment of industrial zones of the city”, “revitalization of urban areas” in accordance with Western and Russian methodologies. The main reasons for the renovation and growth of the housing stock in Russia and abroad are indicated, the relationship between the format of the residential development improvement program and the form of housing stock renewal is analyzed. The research of the conditions of providing new housing under the Moscow renovation program is carried out, discussion issues on compliance with the provisions of the Civil Code of the Russian Federation on the process of formation of the main points of the contract of exchange (exchange) of an old apartment for a new one are noted. The author notes that the most important problem in the implementation of programs for the renewal of residential development is the search for sources of financing of capital investments. Depending on the sources of financing of the program (project) it is proposed to classify them into social, partially social or commercial. The paper formulates a conclusion about the development of a national program of renovation or redevelopment of urban residential development (areas built up with panel houses and other dilapidated and emergency houses built before 1975) in all regions of the country for the period 2026–2040 at the expense of federal and regional budgets. Each region will decide on the terms of resettlement of the population and provision of housing under the exchange agreement independently. It is also up to the discretion of the region to provide benefits to certain categories of citizens to be resettled, to determine the density of new residential buildings, comfort class and energy efficiency of new residential buildings. **Keywords:** forms of housing stock renewal, major repairs, renovation, redevelopment, revitalization of residential buildings

Many economically developed countries of the world implement state or municipal programmes for the renewal of urban housing stock due to their significant physical and moral deterioration, as well as to address social problems¹ [1, 2]. The authorities are forced to demolish residential buildings in areas of compact residence of practically unemployed population (migrants and poor citizens who do not want to work and live on the allowances of the state and public organizations), who themselves have brought house buildings into disrepair because they did not pay for housing and communal services [3, 4]. Residents of dilapidated housing and ghetto houses are relocated to new comfortable houses, as a rule, free of charge, and the compact living of migrants and the poor in new buildings and their non-payment of housing and utility bills are not allowed, so that the very revival of ghetto districts does not repeat itself. In developed countries, urban housing stock is renovated for two main reasons:

- due to significant physical and moral deterioration of residential buildings;
- for the elimination of ghetto slums for the purpose of social integration.

In Russia, the renewal of the urban housing stock is carried out only for the first main reason — because of the obsolescence of apartment buildings built before 1975, mainly panel two-five-story buildings, for which the normative terms of

their operation of 50–75 years have expired or are expiring. The housing stock of the Russian Federation is being renovated through new construction of apartment buildings and individual residential construction; new construction of apartment buildings to replace the demolition of emergency and dilapidated housing; reconstruction, modernization and major repairs of the existing urban stock.

MATERIALS AND METHODS

The most developed countries carry out the renewal of urban housing stock in the format of implementation of specialized national, regional or municipal programs for urban renewal of the living environment of their citizens². Western theory and practice of real estate management distinguish four types of programs for renewal of physically and morally obsolete urban housing stock:

- carrying out major repairs of residential buildings without changing their functional purpose and parameters. As a result, the physical deterioration of houses is reduced. Capital repair programs are implemented at the expense of the owners of premises in apartment buildings and have the form of simple renewal of the housing stock;
- renovation of residential buildings as a set of projects for renovation and modernization of existing residential buildings and infrastructure without changing their functional purpose

¹ Renovation Waves for Europe. A Renovation Wave for Europe. European Commission. URL: https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en

² Samoilov E.K., Rumyantseva A.V. European and Russian approaches to the renovation of residential areas. Ekaterinburg, UrFU, 2021; 249-254. URI: <https://elar.urfu.ru/handle/10995/97901> (rus.).

and architectural appearance (insulation of facades, walls and roofs of residential buildings, full or partial replacement of communications and engineering equipment, improvement of adjacent territories, etc.). Urban renovation programs can represent simple or narrowed forms of housing renewal, carried out through major repairs and modernization (reduction of moral deterioration of residential buildings) and infrastructure facilities with improvement of energy efficiency of buildings (primarily apartment buildings);

- redevelopment of residential and industrial zones of urban development. These programs are carried out through demolition of physically and morally obsolete residential buildings, non-functioning industrial buildings and infrastructure facilities with subsequent construction of new more energy-efficient apartment buildings, buildings and structures in their place or adjacent territories, as well as reconstruction of some real estate. When reconstructing buildings, it is possible to preserve or replace their functional purpose. Redevelopment is an extended form of renewal of the housing stock;
- revitalization of the urban environment is a comprehensive revitalization and renewal of entire urban areas. Implementation of housing stock revitalization programs radically improves the condition of urban areas (significantly reduces not only the physical and moral deterioration of buildings, but also their economic deterioration) and the entire urban planning complex, and increases the level of comfort of living conditions for the population. Basically, it is an extended form of renewal of the housing stock.

In the Russian legislation there are no clear definitions of the above terms, which has caused some confusion in the names of domestic programs for the renewal of the housing stock. For example, a number of Russian scientists understand renovation as the process of demolition of physically and morally obsolete real estate objects and construction of new objects in their place or nearby based on modern technologies and consumer standards [5]. In the Program of renovation of residential development of Moscow, Moscow under renovation is understood as "a set of measures aimed at renewing the living environment and creating favorable living conditions for citizens, public space in order to prevent the growth of emergency housing stock in Moscow, to ensure the development of residential areas and their improvement"³. According to the Western methodology, the Moscow renovation program is mainly a program of residential redevelopment or revitalization of the urban environment. It is the implementation of projects of integrated development of territories, redevelopment of urban development (former industrial zones and residential neighborhoods built up in 1957–1968), as well as projects for reconstruction, modernization, restoration of individual buildings — objects of cultural heritage with their possible re-profiling. The regional programs of capital repair of the general property of apartment buildings operating throughout the country are, according to the Western methodology and in essence, programs of renovation of the housing stock, as in addition to traditional works (overhaul of building elements and engineering communications and equipment, elevator facilities), it is mandatory to carry out works to improve the energy efficiency of apartment buildings. The most important problem in the implementation of regional programs on housing stock renovation is the attraction of budgetary and non-budgetary funds for financing

³ The Status of the Capital of the Russian Federation : Law of the Russian Federation from 15.04.1993 No. 4802-1.

projects on resettlement of residents, demolition of outdated apartment buildings and construction of new housing in their place. Abroad, in developed countries, such programs are implemented in a centralized manner in accordance with national programs by specialized government agencies at the expense of budget (municipal) funds. In Russia, similar programs can be implemented only in a few economically developed regions that have budget surpluses, and the majority of the Russian Federation subjects are unable to implement renovation projects (redevelopment according to Western methodology) of their housing stock due to the lack of financial resources. Therefore, it is possible to relocate citizens living in the housing stock built before 1975 in these regions only with the allocation of federal funds, and for this purpose it is necessary to adopt appropriate laws and a federal target program for the next 15 years (2026–2040) on the demolition of dilapidated housing with a total area of about 273 million m²⁴ and the construction of new energy-efficient and comfortable housing with a total area of about 360 million m² in their place. The exception is the programs of urban environment revitalization (in domestic practice they are designated as housing stock renovation programs), which are implemented in the format of highly profitable projects for the integrated development of territories, usually in the central districts of cities. Such projects for the integrated development of territories attract investors and are implemented at the expense of private investment⁵.

RESULTS

Renovation programs (according to Western methodology — redevelopment) of housing in the constituent entities of the Russian Federation are social projects to obtain new housing on preferential terms, mainly for low-income citizens, through their free resettlement under exchange agreements from pre-demolition (dilapidated) and emergency houses to new houses, with the area of new apartments larger than the old ones. Resettled citizens will not pay the difference between the market value of new and old apartments, and also have the right to purchase an additional area (another dwelling) at a discount⁶. Part of the apartments, parking spaces and non-residential premises on the first floors in the apartment buildings built under the renovation are to be sold on the market and, accordingly, there will be income to the budget under the renovation program. Therefore, it is possible to plan the amounts of revenues (R) and expenses (E) from the implementation of the program for the regional budget, as well as the level of negative profitability (NR) of the social program by the following formula:

$$NR = (R - E)/P \cdot 100 \%, \quad (1)$$

where the numerator reflects the planned budget expenditures and revenues from the sale of non-residential premises, car spaces and part of the apartments (as additional housing for citizens being resettled) in the built houses, and the denominator reflects the planned budget expenditures on the implementation of the program.

⁴ Natalia Gustova. The volume of outdated housing in Russia will increase sharply. What does this mean. *RBC-Real Estate*. 2023. URL: <https://realty.rbc.ru/news/650d30fb9a7947a57708783d?from=copy> (rus.).

⁵ Amending the Town Planning Code of the Russian Federation and Certain Legislative Acts of the Russian Federation in order to Ensure the Integrated Development of Territories : Federal Law No. 494-FZ dated 30.12.2020.

⁶ The Program of Housing Fund Renovation in Moscow : Resolution of the Moscow City Government dated 01.08.2017 No. 497-PP.

It is proposed to classify Russian programs on renewal of the urban housing stock by the format of their organization and implementation into:

- regional address programs on resettlement of citizens from the emergency housing stock⁷;
- regional programs of capital repair of the housing stock with modernization of houses⁸;
- regional programs and/or municipal projects of redevelopment of industrial territories⁹;
- regional or municipal programs of renovation (redevelopment) of residential buildings;
- regional, municipal or private projects of integrated territorial development (revitalization of city districts).

Implementation of overhaul programs with modernization of apartment buildings allows qualitative renewal of the city's housing stock, increasing the remaining physical and economic (the length of time of profitable use of real estate) life of these buildings. These programs represent simple or narrowed forms of residential real estate renewal.

Redevelopment projects of industrial territories of urban space consist in demolition of unused buildings and structures in industrial zones and construction of residential neighborhoods in their place. Thus, the expanded renewal of the housing stock is realized.

DISCUSSION

The essence of regional residential renovation programs is the demolition of dilapidated housing (standard class) and the construction of new modern apartment buildings (comfort class) in their place with the resettlement of residents in new buildings under exchange agreements. Such activity of developers at the expense of budget funds is redevelopment of residential areas of the residential zone of cities. Moreover, the total area of apartments in new buildings of the capital is about 1.32 more than in outdated houses. Residents who are relocated do not pay for the increase in the area of new apartments, as well as the difference in the market value of a new apartment in a comfort-class house and an old standard-class one, which is a violation of the terms of the exchange agreement. According to the terms of the exchange contract, when exchanging real estate objects, one of the parties to the transaction (resettled citizens) must compensate for the difference in prices¹⁰. As a result, the construction of the house and, accordingly, the apartments in the new apartment building, is financed at 50–70 % of their market value, at the expense of budget funds. According to the terms of the Moscow renovation program, new apartments for relocated citizens are considered to be their private property. In fact, the new apartment buildings will be built or have already been built at the expense of budget funds and funds of the resettled citizens and, in essence, are common property of the resettled citizens and the region, i.e. private-public property or shared ownership in the total cost of the apartment (if it is possible to determine the share of each owner-co-investor). In the total cost of a new apartment, the citizen's share will be on average 40 %, and the share of the subject of the federation will be 60 %. According to the country's legislation,

⁷ The Housing and Utility Sector Reform Assistance Fund : Federal Law No. 185-FZ dated 21.07.2007.

⁸ The Regional Program of Capital Repair of the Common Property in MFB on the Territory of the City of Moscow : Resolution of the Moscow City Government dated 29.12.2014.

⁹ Measures for the Implementation of Non-residential Development CRT Projects in the City of Moscow : Resolution of the Moscow City Government No. 331-PP dated 23.03.2021.

¹⁰ Civil Code of the Russian Federation. Chapter 31: "Mena".

honored people, orphans and some categories of disabled people have the right to free housing. The vast majority of citizens being relocated do not have any merits and therefore they should not enjoy benefits when receiving a new apartment under renovation. The share of state or municipal property (S_m) in the total cost of a new apartment can be determined using the formula:

$$S_m = (V_n - V_d) \cdot 100 \% / V_n, \quad (2)$$

where $V_{n(d)}$ — the market value of the new (demolished) apartment under the exchange agreement as of the date of the agreement.

The introduction of the term of public-private ownership and the size of shares of a citizen and the state (municipality) in the total cost of an apartment received under renovation will contribute to compliance with the basics of the market pricing mechanism by all participants in housing relations. Otherwise, all homeowners who bought residential premises on the primary or secondary market (in houses with little wear and tear) for 100 % of their market value, including mortgages for payment terms of up to 30 years, will consider themselves cheated by developers and banks. They did not have to work hard, save on all expenses of the family budget for 10–30 years, but simply exchange to move to live in an obsolete apartment building and wait for state benefits at a low-paid job. Implementation of such programs will stimulate low labor activity of the working population. Housing stock renovation programs refer to the extended form of housing renewal. In Russia, projects for the revitalization of the urban environment should include projects of integrated territorial development (ITD), mainly in the central districts of major and large cities. In accordance with ITD projects, residential neighborhoods, public, commercial and business centers, landscape and recreational areas and the entire infrastructure of the central districts of cities will be qualitatively renewed by means of new construction of real estate objects to replace obsolete ones; major repairs of buildings with their modernization; restoration and reconstruction of cultural heritage objects and landscaping objects. The result of ITD projects, usually financed by private investment, will be a reduction in the physical, moral and economic deterioration of residential buildings and an increase in their comfort and energy efficiency. All forms of housing stock renewal are possible in the implementation of ITD projects.

CONCLUSIONS

It is recommended to classify urban housing stock development programs according to the following indicators, reflecting:

- sources of financing investments into: budgetary (fully social programs); private (commercial programs); mixed sources of financing in the format of public-private partnership or municipal-private partnership (partially social programs);
- the structure of the program (S_{prog}) for the renewal of the housing stock, characterizing the size of the total areas of various forms of housing renewal and their shares in the volume of the program: construction of new apartment buildings to replace demolished dilapidated and emergency housing (S_{ren}, P_{ren}); construction of new apartment buildings on the site of former industrial zones (S_{rd}, P_{rd}); volumes of reconstruction and restoration (S_{rr}, P_{rr}); volumes of capital repair with modernization of housing (S_{qrm}, P_{qrm}).

The total area of the program should be calculated as the sum of areas of houses belonging to different forms of renewal of the housing stock:

$$S_{prog} = S_{ren} + S_{rd} + S_{rr} + S_{qrm}. \quad (3)$$

Program structure is the Proportion of shares of different forms of housing renewal, calculated as a percentage:

$$P_{ren} + P_{rd} + P_{rr} + P_{qrm} = 100\%; \quad (4)$$

- density of construction in new city neighborhoods before the demolition of obsolete buildings and after the implementation of the program;
- the number of residents to be relocated from demolished standard-class houses to new comfort-class or standard-class houses;
- the value of the coefficient of expanded renewal of housing stock for resettled residents (C_{er}). It is calculated as the ratio of the total areas of apartments in built houses (S_n) and demolished houses (S_c) according to the formula:

$$C_{er} = S_n/S_c; \quad (5)$$

- method of payment for the difference in the market value of apartments — free of charge; free of charge, but with payment for the extra area of the new apartment compared to the old one; paid — the entire amount of the increase in the value of the new apartment is paid.

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Классификация программ по воспроизводству городского жилищного фонда

В статье рассмотрена проблема классификации программ и проектов по развитию жилищного фонда. Приведена классификация проектов по улучшению жилой застройки и комплексному обновлению целых городских районов. В исследовании рассмотрены понятия «реновация жилой застройки», «редевелопмент производственных зон города», «ревитализация городских районов» в соответствии с западной и российской методологиями. Указаны главные причины обновления и роста жилищного фонда в России и за рубежом, проанализирована взаимосвязь между форматом программы улучшения жилой застройки и формой воспроизводства жилищного фонда. Проведено исследование условий предоставления нового жилья по московской программе реновации, отмечены дискуссионные вопросы по соблюдению положений ГК РФ по процессу формирования главных пунктов договора мены (обмена) старой квартиры на новую. Автор отмечает, что важнейшей проблемой в деле реализации программ воспроизводства жилой застройки является поиск источников финансирования капитальных вложений. В зависимости от источников финансирования программы (проекта) предлагается их классифицировать на социальные, частично социальные или коммерческие. В работе сформулирован вывод о разработке национальной программы реновации или редевелопменте городской жилой застройки (районов, застроенных панельными домами и другими ветхими и аварийными домами, построенными до 1975 г.) во всех регионах страны на период 2026–2040 гг. за счет средств федерального и региональных бюджетов. Условия расселения населения и предоставления жилого помещения по договору мены каждый регион будет решать самостоятельно. Также на усмотрение региона выносятся вопросы предоставления льгот отдельным категориям расселяемых граждан, определения плотности новой жилой застройки, класса комфортности и энергоэффективности новых многоквартирных жилых домов.

Ключевые слова: формы воспроизводства жилищного фонда, капитальный ремонт, реновация, редевелопмент, ревитализация жилой застройки

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Value assessment in integrated territorial development projects

The article discusses the important problem of distinguishing and taking into account the concepts of cost and value in the process of implementing integrated territorial development (ITD) projects. The traditional approach to evaluating such projects often focuses solely on the economic cost, which can lead to ignoring other equally significant aspects that affect the quality of the urban environment. This paper substantiates the need to expand the assessment, including the multifaceted aspects of value, encompassing social, environmental, cultural and aesthetic factors. Special attention is paid to the role of the state-owned ITD operator as a potential representative of the long-term interests and values of future generations. New approaches to the assessment and integration of various aspects of value using qualimetric analysis and generative neural networks are proposed. These methods can be implemented in decision-making processes, which will take into account the interests of all stakeholders and create a more sustainable and comfortable urban environment. Thus, this study highlights the importance of an integrated approach to the evaluation of ITD projects.

Keywords: *integrated development of territories, cost, value, qualimetry, neural networks, stakeholders, sustainable development, state ITD operator*

Integrated Territorial Development (ITD) projects are a powerful tool for transforming urban space, aimed at creating a comfortable, sustainable and economically prosperous environment. ITD has become the main tool of urban planning due to its ability to solve complex problems of territorial development, attract investments and improve the quality of life of the population.

However, the traditional approach to the implementation of ITD often focuses primarily on the economic component, namely on the cost and capitalization of projects, understood as the cost of their implementation. Such an approach, focused on measurable financial indicators, can lead to overlooking other equally important aspects that determine the quality of the urban environment and the well-being of its inhabitants.

In the monograph [1], all existing methods for evaluating the effectiveness of ITD projects (the Moscow methodology, the methodology of Institute of City Economics, the ITD standard, etc.) are analyzed and an unambiguous conclusion is made that all of them are based solely on the concept of the most efficient use (MEU) and are focused on increasing the cost and profit from projects for individual participants. In the same work, a different approach to the implementation of ITD projects is proposed, which is based on the concept of rational and most efficient use (RMEU) [2]. This concept is typical for the theory and practice of land management, but is not applied or very rarely used by developers and urban planners. The concept is based on the concept of the value of the territory, not its value. Unlike the cost, the value of the territory must take into account such important aspects as social factors, environmental factors, cultural factors, aesthetic factors, etc. The lack of explicit consideration of these factors may lead to the fact that the projects of ITD, recognized as effective from the point of view of current methods, will have negative

consequences for the social, ecological and cultural value of the territory.

The problem of valuing was first fundamentally investigated in the famous work of Sarah Seis and her colleagues from the Kingston University School "Real estate appraisal: from value to worth" [3], which states that when evaluating real estate, worth in the broadest sense of the word should be taken into account.

In [1], this idea was continued in relation to urbanized territories and their development projects, which should not be limited to financial indicators and should include a whole range of non-monetary aspects that are significant for various stakeholders (stakeholders) and for future generations.

Cost in the economic sense is often reduced to the market value of real estate for typical market players¹ [4–8]. Value, in contrast to value, is a broader and more multifaceted concept [3, 4]. The value is subjective and can vary significantly for different stakeholders. In addition to residents, developers, municipal authorities, the business community, and future generations, they may also include, for example, tourists, investors, public organizations, environmental activists, representatives of cultural communities, and other stakeholders and groups whose interests may be affected by ITD projects.

In order to ensure a truly sustainable development of territories, taking into account the interests of future generations [6], through ITD, it is necessary to shift the focus from exclusively economic value to consideration of multifaceted value. This approach requires a comprehensive analysis of all the factors affecting the value of the territory and consideration of the interests of all stakeholders.

¹ Korostelev S.P. Theory and practice of economic measurements in real estate. *LitRes*. 2023. URL: <https://www.litres.ru/book/sergey-pavlovich-kor/teoriya-i-praktika-ekonomicheskikh-izmereniy-v-nedvizh-68845437/> (accessed: 11/21/2023).

Combining the different values of stakeholders into a single integral indicator is a complex task that requires taking into account different points of view and using methods such as multi-criteria analysis and weighting. The difficulty lies in the fact that different groups of stakeholders may have different, sometimes contradictory, ideas about the value of the territory. For example, maximizing profits may be a priority for developers, while preserving green areas and cultural heritage sites is more important for local residents [9, 10].

In this context, a special role, as indicated in [4], can be played by the recently introduced state operator of ITD (SO ITD) into the urban planning process. Acting as a representative of the state and a guarantor of the rational use of land for future generations, the operator can ensure that long-term values are taken into account, which may not fully reflect the short-term economic interests of developers. However, in order to effectively fulfill this role, the operator must have not only the authority, but also the appropriate methodological framework and the necessary methods for assessing the value of territories. These methodologies should take into account the long-term impacts of the implementation of ITD projects, including changes in the environmental, social and economic spheres.

The analysis carried out in [1] showed that it is not possible to make a correct assessment of the value of the territory using economic measurement tools [4]. For this procedure, it is necessary to apply quantitative quality assessment methods, in particular, qualimetry methods.

Qualimetry, as a scientific discipline dealing with the quantitative assessment of quality [11–13], can serve as a methodological basis for assessing various aspects of the value of an urban area within the framework of ITD projects. Applied to urban areas, qualimetry allows:

- to translate the qualitative characteristics of the territory into quantitative indicators;
- to create a hierarchical system of quality indicators;
- to develop mathematical models for a comprehensive assessment of the territory;
- to ensure the objectivity and comparability of the evaluation results.

Qualimetry, as a science, was formed back in the 60s of the last century, its developer and active guide to the practice of measurements was Prof. G.G. Azgaldov². However, the theory of qualimetry has not become widespread. First of all, because of the complexity of conducting research.

To develop a Quality Assessment Methodology (QAM) based on the methodology of Prof. G.G. Azgaldov it is necessary to create three main groups of participants:

- Organizational Group (OG). It is formed for methodological guidance of QAM development and is headed by the person developing QAM (PDM). The OG may include one or two experts on the assessed object;
- Technical Group (TG). This group is being created “to provide technical support for the creation of QAM, the execution of typewriting, drawing, computing (including machine counting) work” [12]. The TG is subordinate to the PDM or another member of the OG at his direction. Usually, an item instance consists of one or two people, sometimes three with a short development time for complex QAM;

- Expert Group (EG). It is necessary to obtain expert assessments in the quality assessment process. For a simplified quality assessment method, the appropriate number of EG is from 7 to 10 people, depending on the complexity of the facility. *“The selection of experts for the EG is made by OG by selecting specialists who know the type of object being evaluated well, followed by a personal conversation to assess their competence, confidence, objectivity, efficiency and interest”* [11–13].

All methods require the involvement of leading experts in various industries in research, taking them away from their main activities for several days or even weeks.

The general evaluation algorithm for the simplified qualimetry method [13]:

1. Definition of the nomenclature of the evaluated properties of the object and construction of a tree of properties of the object.
2. Choosing a method for determining the values of property indicators.
3. Definition of the assessment situation.
4. Determination of the basic (reference) values of the property indicators.
5. Determination of coefficients of relative importance of properties.
6. Determination of reference and rejection values of indicators.
7. Determining the values of property indicators.
8. Determination of the values of quality indicators in general.

The algorithm described above turned out to be very costly and time-consuming, as it was formed without taking into account modern technologies. The emergence of artificial intelligence (AI) can significantly reduce the complexity of quantifying quality [14], especially in the context of the rapid growth of new models of generative neural networks (GNN). They have now reached such a level that they can easily replace experienced experts. Such GNNs as DeepSeek and Gemini 2.0 Flash have achieved a particularly high level of training and expertise.

The main problem of the researcher when working with the GNN is to compile the correct assignment for the GNN, which is called a prompt. The correct prompt can be created interactively by testing on already known examples.

A bot named “Qualimetry” was created to test the qualimetric software in the environment of the GNN Monica integrator using GNN DeepSeek V3. All known, published works on qualimetry were uploaded to the bot's knowledge base, first of all, the works of G.G. Azgaldov, the founder of the scientific discipline. GNN learned from these materials, and then the first software was written to perform the procedures for compiling property trees and performing all the necessary calculations to determine the weights of simple properties into which the problem under study is decomposed (simple properties are called properties that can be measured analytically or expertly). These weights for simple properties are defined in the methodology as a tiered normalized coefficient (TNC).

To test the possibility of using of GNN in the practice of qualimetric value research and to debug prompt in the Qualimetry bot, the author conducted an experiment with reproducing an example from the books of Prof. Azgaldov G.G. [2, 7] on the creation of a qualimetric methodology for determining the winners of the National Award in the field of franchising “Golden Brand” in the nomination “Golden Franchise” (as of 2007). In the example, 10 experts were involved in solving the qualimetric problem (p. 125 [12]). Due to the limited time required to complete the work, an analysis of the experts' qualifications was not carried out, which further affected the results of the study. The complexity of the work was estimated by

² URL: <http://www.labrate.ru/>

Table 1. Tree of properties from an example of the efficiency of enterprises-nominees in the field of franchising from the book [12]

Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5	
Franchise efficiency	18. Results obtained — 1.1.	16. Franchise organization — 1.1.1.	13. Generalized franchise characteristics — 1.1.1.1.	12. Prevalence by number of franchises — 1.1.1.1.1.	1. Number of franchisees with multiple franchises — 1.1.1.1.1.1. 2. Total number of franchisees — 1.1.1.1.1.2.	
			14. Success of franchising — 1.1.1.2.	3. Prevalence by region — 1.1.1.1.2.	4. Number of cancelled franchises — 1.1.1.2.1. 5. The number of terminated franchises in % — 1.1.1.2.2.	
			6. Total sales volume — 1.1.2.			
			7. Franchisor's expenses for franchise advertising — 1.2.1.1.			
			15. Franchisor's expenses for franchise advertising — 1.2.1.2.			
	19. Generalized cost characteristics — 1.2.	17. Franchise costs — 1.2.1.	8. Costs related to franchisee assistance — 1.2.1.2.1.		9. Waste costs upon termination of the franchise — 1.2.1.2.2.	
			10. Cost of increasing goodwill in franchise advertising — 1.2.1.3.			
			11. Share of franchise costs in total advertising costs — 1.2.2.			
			1.1.1.1.1.1.			
			1.1.1.1.1.2.			
			1.1.1.2.1.			

the authors as follows (p. 128 [12]): "With six calculations (which can also act as experts) and with all the initial data, this complexity will amount to approximately 9 people-day (not counting the PDM time cost)".

To test the possibility of using GNN in practice, the following property tree was created in this study based on 19 criteria (Table 1), which is "based on information provided to PDM by the organizers of the competition" (p. 128 [12]).

The above numbering of properties by tiers in the book, which requires renumbering the entire tree when changing properties on one tier, turned out to be not applicable to the bot, which required changing the encoding of each property when the bot was running. In Table 2, the new numbering is shown at the end of each property.

Next, the bot was trained interactively. If the bot made a mistake, it was asked to write a prompt so that these identified errors

would not be repeated, and this part of the prompt would be inserted into the main prompt. Thus, it was possible to train the bot and teach it to perform correct calculations using the qualimetry methodology. As a result, the prompt was 16,380 characters (including symbols).

After receiving satisfactory training results, the bot was given the task to reproduce an example from the book [12]. During interactive interaction with the bot, he revealed some inconsistency between the rules for compiling such trees developed in the example of the property tree. Nevertheless, he was instructed to reproduce the example from the book in full and calculate the weights according to the rules of qualimetry, which he did. The results of comparing the output parameters of the example (TNC) and the values calculated by the bot are presented in Table 2.

From the Table 2 It can be seen that the results obtained are very close. Some discrepancy is explained by the fact that

Table 2. Comparison of the results of the qualimetric analysis of the example and the calculation of the bot

Name	Number on tree	The values of the group and tier Gi importance coefficients (an example from the book)			Values of the group and tier Gi importance coefficients (calculated by the bot)			
		Average data value экспертов	Normalized values of group q.v.	Calculated TNC by example	Encoding	Assigned weight of the GNN bot	Normalized values of group q.v.	Calculated TNC by bot
Number of franchisees with multiple franchises	1	74	0.426	0.0637	1.1.1.1.1.1	75	0.429	0.0624
Total number of franchisees	2	100	0.574	0.0858	1.1.1.1.1.2	100	0.571	0.0832
Prevalence by region	3	77	0.435	0.1153	1.1.1.1.2	80	0.444	0.1165
Number of cancelled franchises	4	51	0.456	0.0720	1.1.1.2.1	90	0.474	0.0745
The ratio of terminated franchises to the total number	5	61	0.544	0.0860	1.1.1.2.2	100	0.526	0.0828
Total franchise sales	6	47	0.324	0.2022	1.1.2.	49	0.329	0.2055
Costs related to franchisee assistance	8	100	0.778	0.0972	1.2.1.2.1	100	0.769	0.1024
Losses in case of termination of contracts	9	29	0.222	0.0278	1.2.1.2.2	30	0.231	0.0307
Franchisor's expenses for franchise advertising	7	60	0.290	0.0937	1.2.1.1	70	0.286	0.0932
Share of expenses for increasing goodwill	10	67	0.324	0.1048	1.2.1.3	75	0.306	0.0998
Share of franchise costs in advertising costs	11	16	0.138	0.0516	1.2.2.	15	0.130	0.0489
Checking the 5th tier				1.0000	-	-	-	1.0000

Table 3. Decomposition of the parent property "Success rate of franchising" in the example

Name	Number on tree	Values of group non-normalized i-th importance coefficients for different experts							Average value
		Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp. 5	Exp. 6	Exp. 7	
Number of cancelled franchises	4	10	100	10	20	20	100	100	51
Ratio of terminated franchises to the total number	5	100	10	100	100	100	10	10	61

the values of the group coefficients in the example were taken as averages according to experts, and in the calculation they were assigned by the bot. Moreover, the average data of experts in some cases contradicted the rules of qualimetry. For example, for the parent property "Success rate of franchising", the following group non-normalized coefficients were obtained (Table 3).

From the Table 3 it can be seen that in this decomposition, the experts gave the exact opposite result, which may indicate the competence of the experts. In this case, the rules of qualimetry require a second round of evaluation to coordinate the positions of experts, but this was not done, which led to a calculation error. In this regard, the bot's calculation turned out to be more correct and consistent with the rules.

Thus, it was proved that the bot can correctly, interactively, create property trees and perform the necessary calculations according to the rules of qualimetry. This conclusion allowed us to proceed

to the assessment of the value of the territories, which was discussed at the beginning of the article.

For this purpose, a bot was created in another, more advanced version of GOOGLE's GNN Gemini 2.0 Flash. The created prompt was transferred to the Qualimetry_GM bot and materials on the theory and practice of qualimetry and territory assessment were uploaded. The bot was given the task to build a property tree and calculate the weighting coefficients for tiers and for simple, measurable properties at the end of the calculations, provided that the three basic properties of value are equal — economic, environmental and social. The interactive mode was disabled and the bot had to independently decompose all the parent properties until simple, measurable properties were achieved and the weights of these properties were calculated.

To solve the problem, it was sufficient for the bot to decompose into 3 tiers (Table 4).

Table 4. Final decomposition of the territory's value

Tier 0	Tier 1	Tier 2	Tier 3		TNC	TNC, %
Value of the territory for ITD	Economic value (100 %)	Diversity of the local economy (100 %)	1.1.1.1	Availability of retail facilities	0.0289	2.89
			1.1.1.2	Development of the service sector	0.026	2.6
			1.1.1.3	Representation of public catering	0.0231	2.31
			1.1.1.4	Availability of small and medium-sized businesses	0.0202	2.02
		Infrastructure for business activity (90 %)	1.1.2.1	Availability of office space and coworking spaces	0.0327	3.27
			1.1.2.2	Quality of telecommunication infrastructure	0.0294	2.94
			1.1.2.3	Availability of service infrastructure for businesses	0.0261	2.61
		Transport accessibility and connectivity (80 %)	1.1.3.1	Development of the public transport network	0.0231	2.31
			1.1.3.2	Availability and quality of pedestrian infrastructure	0.0208	2.08
			1.1.3.3	Availability and quality of bicycle infrastructure	0.0184	1.84
			1.1.3.4	Accessibility of motor transport	0.0161	1.61
		Potential to create new jobs (70 %)	1.1.4.1	Availability of free space for business development	0.0256	2.56
			1.1.4.2	Attractiveness of the territory for entrepreneurs	0.023	2.3
	1.1.4.3		Meeting demand in the labor market	0.0205	2.05	
	Environmental value (100 %)	Environmental condition (100 %)	1.2.1.1	Level of atmospheric air pollution	0.0289	2.89
			1.2.1.2	Water quality	0.026	2.6
			1.2.1.3	Soil pollution level	0.0231	2.31
			1.2.1.4	Noise pollution level	0.0202	2.02
		Availability and accessibility of green areas (90 %)	1.2.2.1	Area of green spaces per capita	0.0327	3.27
			1.2.2.2	Share of the territory occupied by green areas	0.0294	2.94
			1.2.2.3	Assessment of the quality and improvement of green areas	0.0261	2.61
		Biological diversity (80 %)	1.2.3.1	Species richness of flora	0.026	2.6
			1.2.3.2	Species richness of fauna	0.0289	2.89
			1.2.3.3	Presence of rare and protected species	0.0231	2.31
Energy efficiency and sustainability (70 %)		1.2.4.1	Share of use of renewable energy sources	0.0256	2.56	
		1.2.4.2	Energy efficiency of buildings and structures	0.023	2.3	
		1.2.4.3	Resource efficiency	0.0205	2.05	

Tier 0	Tier 1	Tier 2	Tier 3		TNC	TNC, %
Value of the territory for ITD	Social value (100 %)	Level of social infrastructure development (100 %)	1.3.1.1	Availability of educational institutions	0.0265	2.65
			1.3.1.2	Provision of healthcare facilities	0.0265	2.65
			1.3.1.3	Provision of cultural and sports institutions	0.0239	2.39
			1.3.1.4	Availability of social security institutions	0.0212	2.12
		Security and law and order (90 %)	1.3.2.1	Crime rate	0.0327	3.27
			1.3.2.2	Residents' sense of security	0.0294	2.94
			1.3.2.3	Effectiveness of law enforcement agencies	0.0261	2.61
		Social cohesion and engagement (80 %)	1.3.3.1	Availability of public spaces	0.0291	2.91
			1.3.3.2	Activity of local communities and organizations	0.0262	2.62
			1.3.3.3	Level of participation of residents in decision-making	0.0233	2.33
		Comfort of living (70 %)	1.3.4.1	Landscaping	0.0144	1.44
			1.3.4.2	Housing affordability	0.016	1.6
			1.3.4.3	Quality of housing stock	0.0144	1.44
			1.3.4.4	Development of engineering infrastructure	0.0128	1.28

As a result of the calculation, the main parental property (MPP), the value of the territory for ITD, was decomposed into 41 simple, measurable properties with their own normalized weights (TNW).

CONCLUSION

Taking into account the multifaceted value along with the economic value is a key factor for the success and long-term sustainability of integrated territorial development projects. Qualimetry provides methodological tools for quantifying various aspects of value and integrating them into decision-making processes. The state-owned ITD operator, acting as a representative of long-term interests, can play a crucial role in ensuring a balance between cost and value, contributing to the creation of truly sustainable and comfortable urban environments for present and future generations. The article shows and proves the fundamental possibility of using AI in the form of GNN for conducting research and measurements using qualimetry. Further research should be aimed at developing practical methods for assessing and integrating value into the practice of implementing ITD projects.

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Измерение ценности в проектах комплексного развития территорий

В статье рассматривается проблема разграничения и учета понятий стоимости и ценности при реализации проектов комплексного развития территорий (КРТ). Анализируется

традиционный фокус на экономической стоимости и обосновывается необходимость расширения оценки за счет включения многогранной ценности, охватывающей социальные, экологические, культурные и эстетические аспекты. Особое внимание уделяется роли государственного оператора КРТ как потенциального представителя долгосрочных цен-

ностей и интересов будущих поколений. Предлагаются подходы к оценке и интеграции различных аспектов ценности с использованием квалиметрического анализа и генеративных нейронных сетей в процессы принятия решений в рамках КРТ.

Ключевые слова: комплексное развитие территорий, стоимость, ценность, квалиметрия, нейронные сети, стейкхолдеры, устойчивое развитие, государственный оператор КРТ

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Ways to improve operational reliability of water supply and wastewater disposal systems in buildings

Ensuring operational reliability of engineering systems of buildings, regardless of their functionality, is one of the most important problems of the state, regions, municipalities and specialized business. At the same time, operational reliability is not only a technical and technological category, but also an economic and social one, because the increase in the terms of safe and reliable operation, reduction of repair costs are equivalent to the effects that can be obtained only from the construction of new buildings. This implies the need for a targeted study of the operational reliability of engineering systems by solving a number of applied problems.

The global picture of drinking water losses and environmental pollution from wastewater is very sad. The figures are measured in billions of cubic meters per year. In Russia, with its difficult climate, and where a significant part of the engineering infrastructure of buildings is worn out, and new buildings are often delivered with corresponding deficiencies, this problem is particularly acute. Despite numerous discussions of theoretical provisions, analysis and systematization of experimental data in available publications, these issues remain on the periphery of scientific interests of specialists, and the indicators of operational reliability have not been fully investigated. In this article the key aspects and modern solutions of the way of formation and increase of operational reliability of water supply and drainage systems (hereinafter referred to as WSS) of buildings are considered. The authors analyzed the normative and technical regulation of these issues, the existing methods of determining reliability and ways to improve it, the prospects and projected effects of new technologies on this path, the challenges and opportunities of transition to predictive maintenance.

Keywords: *operational reliability of engineering systems, system failure, system accidents, sensors, predictive maintenance, system maintenance, system management*



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INTRODUCTION

Reliability of centralized WSS systems is one of the key requirements for modern buildings of any functional purpose. This applies to both cities and any settlements. The tasks in the sphere of water supply at the state level are reliable provision of consumers with quality drinking water, measures to reduce uncontrolled emergency wear and tear of water supply networks, leading to significant losses. And among the tasks in the field of wastewater disposal it is necessary to note the focus on reducing uncontrolled emergency wear of wastewater disposal networks, leading to the ingress of untreated wastewater into the terrain and water bodies¹. Internal WSS systems in comparison with other systems are the most expensive to create and maintain and at the same time very vulnerable, but they largely determine the functional suitability, sanitary and epidemiological condition and comfort of buildings in which we live, study, work. Ensuring their stable and uninterrupted operation is the task of management organizations, city and district resource supplying organizations, operation services. To ensure their functions, water supply systems should be characterized by the necessary strength, durability, safety. All these properties determine the reliability of the systems.

¹ Strategy for the development of the construction industry and housing and communal services of the Russian Federation for the period up to 2030 with a forecast up to 2035.

NEGATIVE TRENDS

As of today, there is a high level of existing accumulated wear and tear of fixed assets and network facilities in urban and municipal WSS systems both in Russia and worldwide. There is a significant increase in the number of serious accidents, while minor accidents and leaks are not counted at all. This leads to large volumes of drinking water losses, which determines significant economic, social infrastructure risks, and not less loss of polluted water, which determines a number of environmental and engineering risks. Not to be overlooked is the risk of scouring of subgrade soils, overwatering of structures, and damage to finish coatings, which are always a concomitant result of severe or long-term leaks. Although the number of major accidents in the WSS system has been decreasing in recent years, their absolute value is still very high. For water supply it is more than 28.5 thousand, and for wastewater disposal more than 5 thousand accidents per year². The overall wear and tear of engineering networks is steadily increasing. More than 80% of pipelines in Russia have 50 to 80 % wear and tear due to corrosion, mechanical damage and natural aging, degradation under the influence of soil, temperature differences and hydrostroke and require replacement.

Among the main environmental problems resulting from leaks in the sewage system are the probability of contamination of drinking water,

² Unified Interdepartmental Information and Statistical System (EMISS). URL: <http://www.fedstat.ru/indicator/34186>

discharge of chemicals, reagents and medical products into the system³. Even hidden sewer leaks inside buildings lead to bacterial contamination and development of black mold, threatening the health of residents. The role of negative design factors in the formation of unhappy statistics is great. Errors in determining the schemes, diameters, slopes, parameters of precipitation of engineering systems and buildings during design are becoming a frequent phenomenon. Errors in installation, replacement of materials or equipment with analogs, selection of applied laying technology are no less frequent.

It is impossible not to mention the lack of funding for programs and activities to modernize and repair systems. Most municipalities in our country are facing budget deficits, which makes it difficult to carry out repairs, replacements, and the introduction of new technologies. Attraction of private investments is complicated due to long payback periods of projects in this sector. And there are no incentives for insurance of this type of activity.

The most frequent culprits of any accidents in the systems are local management, resource supplying or maintenance organizations. The problem of low-quality maintenance services has been topical for years. Clogs, bursts, odors are on the lips of almost all residents of apartment buildings. In most cases, the population is unaware of the distribution of responsibility for the quality of drinking water between water utilities and management companies. And if the former ensure quality in external networks, the latter ensure quality in internal networks, and their poor condition also leads to the provision of poor-quality service⁴.

OPERATIONAL RELIABILITY OF WSS SYSTEMS

In accordance with SP 517.1325800.2022⁵, reliability of centralized systems and structures of WSS of buildings is defined as their property to preserve in time, within the established limits, the values of all parameters characterizing the ability to perform the required functions in the given modes and conditions of application, maintenance, storage and transportation of water. Reliability indicators are quantitative characteristics or parameters for each of the properties that make up the reliability of the system. For example, for a water supply system, the reliability indicator is the number of interruptions in water supply as a result of accidents, damages, violations. And for wastewater disposal system — specific number of accidents or blockages in terms of the length of the system⁶.

At the same time, as for other building systems, the reliability of WSS is necessary during the operation period, which can be defined as a stage of life cycle, at which their operable state is realized, maintained and restored. It takes into account the work of specialists, equipment, technical systems to maintain, restore

³ Environmental problems of wastewater disposal systems in the 21st century — News from TD Eurotrading LLC. URL: <http://WWW.GIDROLICA.RU/NEWS/EKOLOGICHESKIE-PROBLEMY-SISTEM-VODOOTVEDENIYA-V-21-VEKE/?YSCUID=MCDQJH MUN401858333>

⁴ The Russian Association of Water Supply and Sanitation — RABBI about dilapidated pipes, tariffs, the consequences of the largest accident in Volgograd and other problems of water utilities in an interview with the publishing house "NewIndustryMedia" for the Housing and Communal Services Administration project. URL: <http://raww.ru/pressroom/association-news/21-12-ravv-o-vetxix-trubax,-tarifax,-posledstviyax-krupnejshj-avarii-v-volgograde-i-drugix-problemax-vodokanalov-v-intervyu-izdatelskomu-domu->novyje-otraslevyie-media-dlya-proekta-upravdom-zhkh.html?ysclid=mcdqx0byjih22870671>

⁵ SP 517.1325800.2022. Operation of centralized systems, water supply and sanitation facilities. Ministry of Construction of Russia

⁶ On Approval of the List of indicators of reliability, Quality, and Energy Efficiency of Centralized Hot Water Supply Facilities, procedures and Rules, and determination of planned values : Order of the Ministry of Construction of the Russian Federation dated April 4, 2014 No.162/pr. Ministry of Construction of Russia.

engineering systems, minimize damage from accidents. Against the background of failure statistics, their causes, scope, risks of recurrence come first. Therefore, the definition of operational reliability becomes more capacious and informative.

Some authors define reliability of WSS systems as the probability that the system fulfills its functions in accordance with given requirements during time t . And if the system should supply 100 % of water, then this ability should be evaluated, rather than calculating the possible water supply of the system at given reliability indicators of its elements [1]. Approximating this and a number of other definitions, we can conclude that the operational reliability of an engineering system can be defined as "the technical capability to use the system for its intended purpose at the right time and with the required efficiency".

It follows from the obtained definition that along with strength and durability, the WSS systems should have in their maintenance manufacturability, maintainability and cost-effectiveness. It is these properties that make engineering systems more flexible and efficient, and thus reliable in operation. These properties make it possible to take into account collected and systematized data on all damages and accidents in the systems, to identify their causes, to plan changes in operational measures, to apply information technology and to carry out operational control more effectively. Fulfillment of all requirements imposed on the water supply system ensures normal level of operational reliability.

The level of operational reliability can be considered as a key indicator that determines the ability of a system to maintain its functional characteristics throughout its service life. Increasing the level of operational reliability reduces operating costs, reduces the risk of accidents and extends the lifetime of systems. Establishing, ensuring and assessing compliance of operational reliability levels is fully consistent with the current transition to the parametric method of standardization in construction, which is defined as a method of establishing regulatory requirements, in which the establishment of key requirements is applied only to the functional and (or) operational characteristics of the object of standardization, including in the form of requirements for quantitative parameters, regardless of its design and performance⁷. The normative also determines that the ways to achieve the key requirements are established with the possibility of using acceptable and (or) alternative solutions.

ASSESSMENT AND IMPROVEMENT OF OPERATIONAL RELIABILITY

WSS systems are multifunctional, as they provide not only supply or withdrawal of given amounts of water for consumers of different categories, but also the required water quality, pressure, and flow rate at the required points. As already mentioned, operational reliability can be achieved only within the framework of an integrated approach throughout the entire life cycle. Establishment of functional and operational characteristics in the design task, development of design solutions on their basis, selection of appropriate equipment, preparation and carrying out of installation and commissioning works, realization of effective operation and management. It is a set of measures for the operation of systems, provides water supply of the required quality, head and quantity, prevent losses in the system, eliminate the overgrowth of pipes and corrosion, possible freezing, to realize the current repair if necessary [2].

⁷ SP 555.1325800.2025. The system of regulatory documents in construction. Basic provisions. Ministry of Construction of Russia.

Existing methods of reliability assessment contain theoretical or statistical methods of determining the distribution function of up-time, which determine the degree of probability of system operation without failures for a certain period of time. They are probabilistic in nature and are measured in fractions of a unit or percent. For example, reliability can be assessed by the ratio of the total duration of periods of decline in the quality of functioning to the total duration of operation. Or the degree of decline in certain indicators and the frequency of periods of deterioration in performance.

To calculate the reliability of WSS systems, it is necessary to obtain a large amount of data on their actual operation. Indicators are determined for individual sections of the operated systems as a result of long-term observation of their operation during operation, recording and processing statistical data on all damages and accidents. Very important is a continuous registration of accidents and damages [3].

When carrying out calculations, when only some important factors are taken into account or average values are used, inadmissible errors occur, which makes the forecast of accidents incorrect, and consequently incorrect maintenance plans, repair volumes, frequency of inspections, leads to increased costs for repair and maintenance works. In addition, the complexity of assessment and forecasting of water supply systems is that today there are no tools for their diagnosis for individual elements and equipment. Therefore, at present, it is considered optimal to assess with the collection of statistical data on the operation of the water supply system and their subsequent processing. At the same time, the service life of the water supply system is long enough and the results of statistics collection are presented for a very long period⁸. These conditions reduce the reliability of statistics in this issue.

Other researchers propose a different methodology for assessing the reliability of water supply systems based on the probability of accident occurrence based on Poisson's law. To estimate the probability of X accidents in a certain $(t + i)$ year, it is necessary to use statistics for t years and determine the value of $t + 1$. To do this, determine the value of the average acceleration b , and the change in the value l , which is the accumulated initial value. After that, the calculated values are compared with the existing physical values and changes with accident occurrence statistics [4]. This method is also not absolutely accurate, since almost no one maintains the history of accidents with their clear ranking.

It should be remembered that low operational reliability of engineering systems and the building as a whole, leads to higher costs of current and capital repairs, as well as reconstruction. Reliable operation of engineering systems depends on factors that reduce reliability and those that increase it. Measures that increase reliability can be divided into two groups: increase of failure-free operation and increase of maintainability. Basically they go by using more reliable and durable pipes, valves, electric protection installations, providing redundancy of system elements, organization of effective operation and purposeful improvement of control systems of processes occurring in the system. More modern methods allow to predict the basic properties of reliability taking into account the variability of system characteristics during operation, heterogeneity of requirements of different equipment or elements. Here in a complex can be applied: optimization of functional schemes, unification of solutions, modern technologies of installation and repair works, more accurate accounting of negative factors, increasing maintainability, increasing the effectiveness of prevention.

⁸ Bykov A.A., Bersugir M.A. *Methods of forecasting accidents in water supply systems*. URL: sv543343.pdf

A number of objective and not so objective factors, such as: lack of clear rules of operation, lack of qualified personnel, negligence in the work of employees of operation services, low quality of equipment and elements, lack of uniform terminology and formulations, lack of quantitative assessment of reliability of elements, haphazardness in the formation of information about repairs and maintenance, lack of continuous information about the state and wear of systems and their elements.

The development of modern technologies in the field of construction monitoring and engineering analysis makes it possible to significantly improve operational reliability, safety and efficiency of engineering systems. One of the directions on this path is the transition to predictive maintenance.

PREDICTIVE MAINTENANCE OF BUILDING ENGINEERING SYSTEMS

Predictive maintenance (hereinafter referred to as PdM) is a complex method of management of engineering networks and equipment, which includes collection of information on the state of equipment, its analysis and forecasting of failure dates of equipment of different levels for the purpose of timely preparation and implementation of measures to prevent failures in operation. In other words, it is a service when a "breakdown forecast" appears, without reference to normative-technical or design requirements. PdM has already been successfully implemented in the power industry, transportation, industry, oil and gas industry, and airlines. Monitoring and control systems detect any deviations in the operation of equipment and systems.

Sensors and sensors are the key elements of PdM. Based on the information from them, the status of system elements is constantly analyzed. The data is transmitted to the controllers of the monitoring system and, if the monitored parameters exceed the permissible values, the relevant equipment, elements, parts are included in the scope of the nearest scheduled maintenance. A forecast of the situation development is also made, and complexes of measures for replacement, repair or maintenance are developed. Thus, even the most complex engineering systems can function predictably and smoothly for a long period of time. The choice of sensors depends on the types of monitored equipment, elements, as well as the types of potential faults and the requirements of SCADA systems. They can be pressure, deformation, angle deviation, humidity and temperature, component wear, leakage sensors, remote visual inspection tools, acoustic, ultrasonic, infrared sensors.

The objectives of PdM include:

- engineering systems management;
- improvement of management processes;
- improving the operational reliability of systems;
- optimization of maintenance costs;
- reducing accident risks;
- planning of replacement and repair costs;
- increasing the functionality of systems;
- improvement of systems.

Implementation of PdM systems is most effective in the conditions of software and hardware complexes (hereinafter PAC), which provide real-time collection of information on the state of system elements, on processes in them, on deviations from the set parameters, on the need for maintenance, etc. PdM can be recommended when working with large engineering systems with equipment and elements with different characteristics, service life, modes of operation, maintenance and repair conditions. PdM can be rec-

Table 1. Comparison of service methods

Method	Advantages	Disadvantages
By resource	<ul style="list-style-type: none"> ensuring standard service life of equipment and standard downtime; reducing resource consumption; reducing the number of failures 	<ul style="list-style-type: none"> mismatch of equipment resource utilization with actual operating conditions; the need to invest in maintenance personnel and technology; continuing probability of serious failures; possible premature maintenance
By state	<ul style="list-style-type: none"> reduction of resource consumption; matching the service life of the equipment to the actual operating conditions; reduced probability of serious failures 	<ul style="list-style-type: none"> the need to provide personnel for diagnosticians; the need for diagnostic equipment; the need for software; unexpected occurrence of failures and accidents; long downtime associated with repairs
PdM	<ul style="list-style-type: none"> possibility to analyze data on the operation of equipment and elements in real time; timely detection of faults and wear; prediction of faults before failures occur⁹; reduction of costs for serious and urgent repairs; extension of service life of separate equipment and elements of engineering systems; increased building safety; increase of labor safety of the personnel; the possibility of corrective maintenance; planning of the most cost-effective volumes and terms of repairs and replacements; reduction of the number and duration of downtime 	<ul style="list-style-type: none"> the need to implement SCADA systems and IoT platforms; the need to implement statistical analysis tools, machine learning or neural networks; necessity to verify sensors

ommended when working with large engineering systems that include equipment and elements with different characteristics, service life, operating modes, maintenance and repair conditions.

The application of controllers based on IoT and machine learning is promising; it allows collecting data from sensors and sensors, analyzing them in real time, providing the possibility of central monitoring, quickly responding to emerging problems¹⁰.

In accordance with SP 255.1325800.2016¹¹ there are two main methods of maintenance:

- “by resource” or preventive maintenance, which implies scheduled maintenance with the planning of measures for the resource of engineering equipment and structural elements (e.g., standard service life by operating time, by the number of failures, etc.);
- “condition-based” or preventive maintenance, which implies scheduled maintenance with planning of measures based on the values of actual (current) parameters of the technical condition of engineering equipment elements of buildings.

PdM, compared to these methods, is able to provide cost savings by performing only those justified tasks and at a time when it is justified. Let us compare the advantages and disadvantages of these three methods (Table 1).

As can be seen from the comparison, PdM has significantly more advantages than the disadvantages or advantages of other methods. The main difference, however, can be seen as working with accurate information about the state of the system, based on actual data rather than average or expected values.

Nowadays, the development of customized models for PdM implementation is starting to gain popularity in the industry. They allow to incorporate a whole range of data and parameters from different

sensors. Conduct operational adjustments under changing conditions of engineering tasks. And during operation, not only to monitor the exceeding of control values of parameters, but also to detect fluctuations in values, dynamics of deviations development, connection with changes in other parameters. In the field of operation of building WSS systems, such PACs can also be expected to have significant effects. For example, detection of dripping leaks in the joints of water pipes at the time of the lowest water consumption, i.e. at night and drying during the day. This cannot be detected by conventional floor sensors or daytime inspections, and the situation may indicate that a serious nighttime leak is approaching.

It is quite difficult to build your own PdM system for building engineering equipment. It is necessary to solve the problems of proper placement of sensors, organization of storing the necessary amount of incoming data, setting up the analytics and forecasting system, providing machine learning, and warning of failures. Several methods are most often used to analyze sensor data. From simpler statistical analysis, to complex neural networks. For maximum efficiency, sensors can be integrated with ERP (Enterprise Resource Planning) or CMMS (Computerized Maintenance Management System) systems. This integration allows for the creation of a unified information environment that always has up-to-date data and the ability to embed digital services. For example, assistance in the formation and maintenance of electronic passports, assistance in the maintenance of building information models.

We would especially like to note the possibility of integration with the information model of the capital construction object. After all, data from PdM systems can supplement the information model with models of behavior of engineering systems in real conditions of construction and operation. And this is already a serious step towards the application of digital twins, which are now defined in the professional environment as “information models of capital construction objects, further developed through the addition of models of processes related to the creation, operation and use of this object”¹². Here we can even talk about mechanisms of integration

⁹ On the development of predictive maintenance using the example of transformer diagnostics. Habr. URL: http://habr.com/ru/companies/etmc_exponenta/articles/744174/

¹⁰ Predictive maintenance of engineering systems using IoT. TRIASK. URL: <http://triask.ru/prediktivnoe-obslyuzhivanie-inzheneryh-sistem-s-ispolzovaniem-iot/>

¹¹ SP 255.1325800.2016. Buildings and structures. Operating rules. Basic provisions (Order of the Ministry of Construction of Russia dated August 24, 2016 No. 590/pr). Ministry of Construction of Russia.

¹² Digital twins of capital construction facilities. URL: <http://niisf.org/biblio/glavnaya/tsifrovye-dvojniki-obektov-kapitalnogo-stroitelstva>

Table 2. Projected effects as part of operational measures from the implementation of NeoDetect's smart system

Types of operational activities	Forme defects
Maintenance	<ul style="list-style-type: none"> • reduction of the number of scheduled periodic inspections of routes, chambers, wells; • reduction of the number of inspections of the technical condition of system elements; • increasing the accuracy of inspections and checks; • localization of cleaning places
Analysis of network operation modes	<ul style="list-style-type: none"> • development of the hydraulic electronic model of the system; • refinement of pressure gauge survey; • clarification of water consumption values; • refinement of the results of the analysis of system operation modes; • tracking changes in the existing zoning structure; • identification of deviations from the operation modes
Overhaul	<ul style="list-style-type: none"> • possibility to take more accurate account of the results when planning capital repairs; • assessment of pipeline reliability indicators obtained on the basis of statistical processing and analysis of operational data; • analyzing the technical condition of pipeline sections based on the results of SCADA system data; • ranking of system elements according to the impact of negative factors and actual condition; • analysis of risks of material and environmental damage
Reconstruction	<ul style="list-style-type: none"> • justification of changes in initially established indicators of systems functioning; • restoration of the required functional characteristics
Provision of automated process control system (APCS)	<ul style="list-style-type: none"> • easy integration with automatic process control system at the local control level; • control of normal operating conditions of control and measuring devices; • control of automatic regulation and control systems serviceability; • simplification of connected equipment and applied data exchange standards; • increase of control accuracy due to the use of SCADA databases; • control of the efficiency of preventive maintenance, service and repair of systems
Searching for pipeline faults	<ul style="list-style-type: none"> • simplification of tracing of surveyed pipeline sections; • simplification of checking the serviceability of water fittings; • diagnostics of hard-to-reach areas; • alternative to correlation and acoustic leak detectors; • refinement of pipeline cleaning methods; • alternative to television diagnostics

of building doubles containing mainly geometry with doubles of engineering systems synthesized with PdM hardware and software. A digital twin of an engineering system may be a simpler and more accessible step than a building twin. Such a twin will be able to model the operational states, processes and life cycle of an asset and allows the generation of any amount of data that is difficult to obtain in reality¹³.

In the future, we can assume the creation of digital doubles of equipment or systems by their manufacturer, providing them to designers so that they can put the necessary parameters into design solutions, and then to the operating organization as diagnostic systems. But predictive operation is our tomorrow. The nearest step in this direction is the development of the market of sensors and laying software supporting their operation. Let's consider what prospects have these PACs applied in WSS systems today.

HARDWARE AND SOFTWARE COMPLEXES IN BUILDING WSS SYSTEMS

Sensors, as a hardware part of PAC, are primary converters and elements of measuring, signaling, regulating or controlling element of the system. They convert the monitored quantity into a usable signal. The most popular applications in WSS systems are water leakage sensors and clog sensors. They play an important role in timely detection and prevention of leaks and clogs, which

can lead to accidents and failures, flooding of premises, and property damage.

There are several basic types of sensors available and used today, each with its own advantages, disadvantages and applications. The most common, simple and inexpensive are point contact sensors. Linear cable sensors, are more complex devices, representing an entire contact cable that reacts to water at any point. These variants can be wired and wireless. More complex, expensive and rare are smart flow meters, acoustic and correlation systems. These are used predominantly on complex systems. In addition, pressure sensors are popular for signaling clogs, pump failures or overflow in the drainage part of the system.

The main disadvantages of most such sensors are: short time or lack of autonomous operation, lack of its own moisture protection, lack of notification by sound signal, small area of the sensing element, unreasonably high price [5].

Against this background, the implementation of modern sensors and PACs for leak and clog detection offers enormous benefits: the main ones are saving water and money, preventing damage from the devastating effects of floods and corrosion, improving system operational reliability, reducing response times to breakdowns, reducing the labor and cost of monitoring, maintenance and repair activities, preventing soil contamination, and reducing the risks of infections and allergies.

As an example, here is one of the variants of such sensors. This is an intelligent water detection system by NeoDetect. This system allows monitoring and timely preventing flooding of premises by shutting off the water supply. The linear sensor extends along

¹³ On the development of predictive maintenance using the example of transformer diagnostics. Habr. URL: http://habr.com/ru/companies/etmc_exponenta/articles/744174/

the pipes, which allows you to detect a leak along the entire length of the pipeline, determine the exact location of the leak or clog, and prevent serious flooding. It is a system that can be used to monitor the drying process of water, see the temperature, and the exact location of the affected area [6].

The developers of this intelligent system predict that its development, improvement of its sensors and expansion of the range of software, creation of a common digital environment, will gradually lead to a number of tangible effects at the stage of operation of any buildings as part of the relevant operational measures (Table 2).

From the analysis of effects, it is obvious that the introduction of intelligent systems will not only help to improve the safety of building WSS systems, but will also make maintenance professions more "digital" and attractive to young people. The digital tools themselves, such as chatbots and applications, when implemented in a comprehensive manner, will simplify interaction between building owners or residents, operating or management companies, and resource supply organizations.

REQUIREMENTS TO HARDWARE AND SOFTWARE COMPLEXES IN BUILDING WSS SYSTEMS

The main task of PAC in building WSS systems, as part of the ACS, is to maintain the operable state of the control system in all modes and at all stages of its operation, as well as to organize its efficient use. Hence, the following requirements can be made to all developed complexes:

- support of remote and automated system control;
- maintainability and modularity of design;
- unified in terms of connected equipment and applied data exchange standards;
- protection against unauthorized access to the object control and SCADA databases;
- duplication of control communication for the most critical objects;
- connection of mobile users to SCADA servers of objects.

CONCLUSIONS

Improving the operational reliability of buildings' WSS systems requires a comprehensive approach: from replacing worn-out pipes

to implementing intelligent systems and switching to PdM. Some Russian cities, such as Rossosh, have already started modernizing networks under concession agreements, investing hundreds of millions of rubles. However, success depends not only on technology, but also on legislative support, staff training and awareness of the importance of prevention by all participants in the process — from management companies to residents. The logical subsequent transition to PdM using IoT of all engineering systems of buildings, will become an accepted standard for the majority. And with the development of artificial intelligence technology, its success will increase many times over. This method of maintenance will require careful planning, proper selection of equipment and operating algorithms. There is already a strong need for the development of electronic components, PACs, regulatory and technical requirements, and training of maintenance personnel.

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Пути повышения эксплуатационной надежности систем водоснабжения и водоотведения зданий

Обеспечение эксплуатационной надежности инженерных систем зданий, независимо от их функционала, является одной из важнейших проблем государства, регионов, муниципалитетов и профильного бизнеса. Вместе с тем эксплуатационная надежность является не только технической и технологической категорией, но и экономической и социальной, ведь увеличение сроков безопасной и надежной эксплуатации, сокращение затрат на ремонты эквивалентны эффектам, которые могут быть получены только от строительства новых зданий. Это предполагает необходимость целенаправленного исследования эксплуатационной надежности инженерных систем посредством решения ряда прикладных задач.

Мировая картина потерь питьевой воды и загрязнения окружающей среды стоками весьма печальна. Цифры измеряются миллиардами кубов в год. В России с ее сложным климатом, где значительная часть инженерной инфраструктуры

зданий изношена, а новые здания часто сдаются с соответствующими недоработками, эта проблема стоит особенно остро. Несмотря на многочисленные обсуждения теоретических положений, анализ и систематизацию экспериментальных данных в имеющихся публикациях, данные вопросы остаются на периферии научных интересов специалистов, и показатели эксплуатационной надежности полностью не исследованы. В данной статье рассмотрены ключевые аспекты и современные решения пути формирования и повышения эксплуатационной надежности систем водоснабжения и водоотведения (ВиВ) зданий. Авторы проанализировали нормативно-техническое регулирование этих вопросов, существующие методы определения надежности и пути ее повышения, перспективы и прогнозируемые эффекты от применения новых технологий на этом пути, задачи и возможности перехода на предиктивное обслуживание.

Ключевые слова: эксплуатационная надежность инженерных систем, отказ систем, аварии систем, датчики, предиктивное обслуживание, обслуживание систем, управление системами

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Comprehensive approach to scientific and technical support of unique facilities at all stages of the life cycle

The modern construction industry is moving inexorably forward, constantly increasing the uniqueness of investment and construction projects. Unique objects, whether they are unique high-rise buildings or large-span ones, require a special approach at all stages of the life cycle of construction projects.

Scientific and technical support at all stages of the life cycle plays a key role in ensuring the safety, reliability and efficiency of such facilities.

However, the lack of an integrated approach to the maintenance of such facilities can lead not only to an increase in project implementation time, but also to the risk of abnormal situations during the implementation of projects due to the failure to perform certain types of work within the framework of scientific and technical support.

This paper discusses the formation of an integrated approach to scientific and technical support at each stage of the facility's life cycle in order to minimize risks during the implementation of investment and construction projects.

Aims and Goals. Development and justification of an integrated approach to scientific and technical support of unique facilities at all stages of their life cycle. This paper is aimed at identifying key approaches that ensure effective process management within the framework of scientific and technical support, minimizing risks and improving the safety of unique facilities.

Materials and methods. The paper considers an integrated approach to scientific and technical support of unique facilities, which is based on the analysis of the regulatory framework, practical experience in project implementation, as well as the integration of theoretical and practical methods. The main focus is on the formation of methodology and fundamental principles, in terms of an integrated approach that ensures effective management of facilities at all stages of their life cycle.

Keywords: *scientific and technical support, methodology, construction, architectural and construction design, unique high-rise buildings and structures, buildings of class KC-3, construction and design of unique high-rise buildings and structures*



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INTRODUCTION

Modern trends in the construction industry tacitly lay the foundation for the development of various kinds of work, in particular, on scientific and technical support of unique buildings and structures.

According to GOST 27751–2014, p. 2.1.21: "Scientific and technical support: a set of works of research, methodological, expert, control, information-analytical and organizational-legal nature, performed by specialized research organizations in the process of research, design, erection, operation, reconstruction or dismantling of construction objects to ensure their reliability, safety, functional suitability and durability" [1].

The purpose of the article is to conduct a comprehensive approach to scientific and technical support, both at individual stages of the life cycle of the construction object, and the relationship of scientific and technical support between the stages: engineering surveys, design, construction and further operation of the object.

The peculiarities of the performed works, taking into account the specificity of unique buildings and structures, within the framework of STS survey and design, as well as the peculiarities of design of underground and above-ground components of the object are considered; the interrelation between

the results of STS P and STS C works is determined. Practical examples of realization of scientific and technical support at different stages of the life cycle of the construction object are given.

Unique objects are various buildings and structures that have additional requirements for design and construction, in this regard, one of the ways that affect, first of all, to ensure safety, is the mechanism of scientific and technical support (STS).

Conducting scientific and technical support should be comprehensive, in order to consider the most possible criteria and analyze the occurrence of different scenarios.

At the stage of pre-project work, the development of architectural and urban planning concept, it is necessary to analyze and determine the composition of work on the STS.

These works may include: modelling and "landing" of the building based on the results of the performed SGI, assessment of construction impact, development of recommendations to the programme of engineering-geological surveys, justification of possible deviations from the current regulations in terms of volumes and methods of surveys, analysis of archival materials in terms of engineering surveys, evaluation of the obtained data to ensure safe design [2].

Formation of the final set of works on STS will depend on the received initial data on the object.

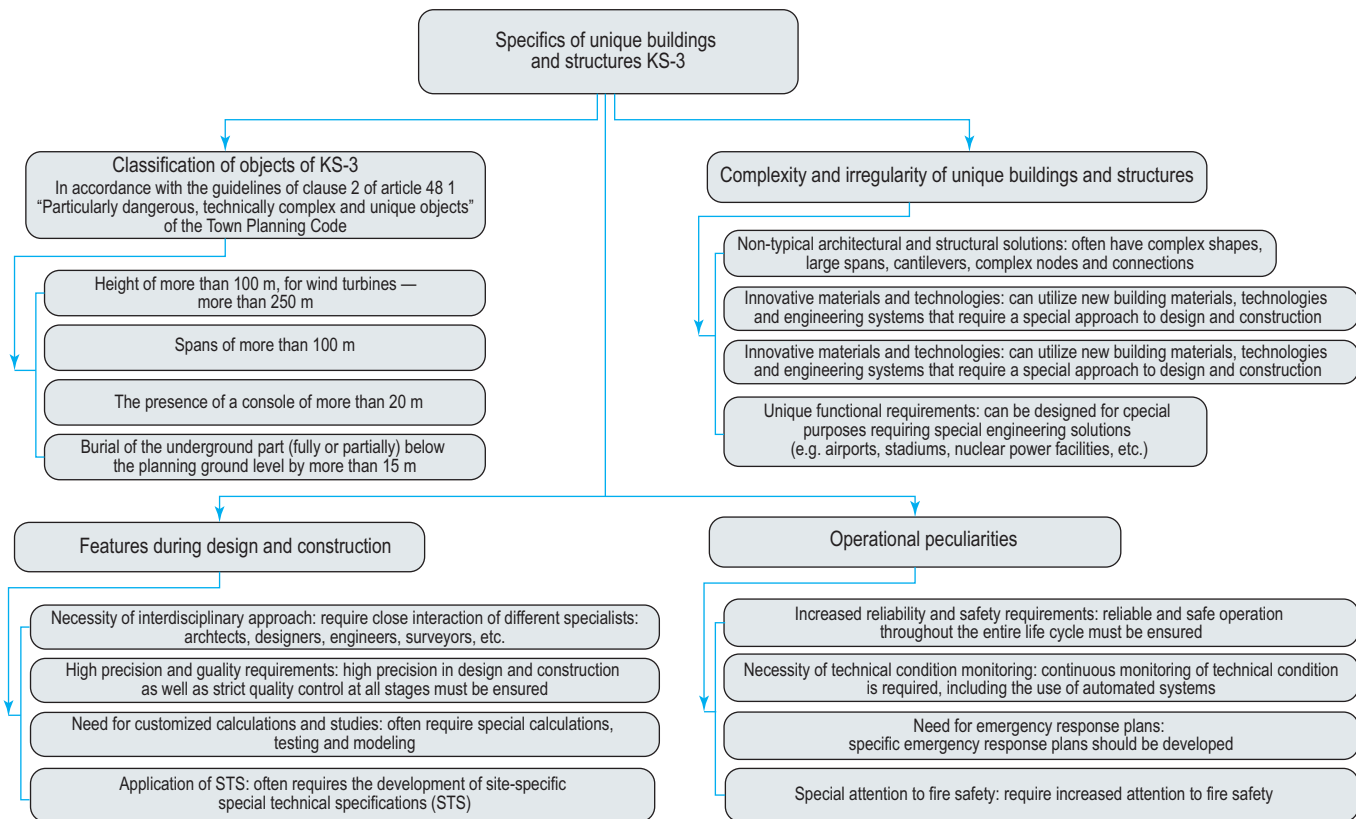


Fig. 1. Specifics of unique buildings and structures

Unique objects are buildings and structures that require a special approach to design and construction, and one of the mechanisms contributing to safety is the mechanism of scientific and technical support (STS) (Fig. 1).

The relevance of the study, in terms of STS, is also due to changes in legislation, in terms of design of buildings and structures, namely, the transition from the development and coordination of special technical conditions and approval of compensatory measures to the development and implementation of scientific and technical support [3].

The scientific and technical support should become comprehensive, in order to consider the most possible criteria and analyze the occurrence of various scenarios.

At the stage of pre-project work, the development of architectural and urban planning concept, it is necessary to analyze and determine the composition of work on STS.

Formation of the composition of works, which would be optimal and sufficient for scientific and technical support, is one of the most important stages, which, for example, may include a variety of works, including:

- development of recommendations to the programme of engineering-geological surveys;
- justification of possible deviations from the current normative documents in terms of volumes and methods of surveys;
- analysis of archive materials and previously performed surveys;
- evaluation of the obtained data to ensure safe design; modelling of geological environment reaction to earthquakes and development of a set of synthesized accelerograms for calculation studies of earthquake resistance of buildings and structures;
- development of additional requirements for the calculation

and design of buildings and structures of the facility taking into account the high seismic activity of the construction site and other dangerous natural processes, with the performance of verification calculations and quality control of the facility design [4].

Scientific-technical support during the construction phase is essential to improve efficiency, specifically, to reduce the amount of time required for the work. However, the regulatory documents partially reflect organizational and technical measures that can affect the efficiency of construction.

It is crucial not only to develop a methodology for providing scientific-technical support at various stages of the life cycle of an investment and construction project's life cycle, but also to conduct a comprehensive assessment to ensure the correct formation of the composition of the work performed [5].

A list of areas for analysis and further organization of scientific and technical support work.

1. Conducting a comprehensive assessment of the surrounding site development.

During the stages of conceptual design and the initial phase of project development, an integral part is the analysis of the immediate construction site and the surrounding area to identify and locate capital construction sites, cultural heritage sites, underground networks, and structures that cannot be dismantled, as well as other underground utilities that may affect the future progress of the project. This includes conducting various types of engineering surveys, as well as providing scientific and technical support for design and foundation engineering.

The analysis also involves verifying the accuracy of calculated soil models and calculating methods, performing foundation calculations when structures and foundations are working together, and



Fig. 2. Analysis of surrounding development

checking the bearing capacity and stability against the ascent of foundations of the stylobate section (Fig. 2, 3).

2. Carrying out STS works at the stage of engineering surveys (geological risk assessment, SIA)

The volume of construction of high-rise buildings is constantly increasing. In this regard, before the start of design and survey works, it is important to determine the necessary and sufficient list of both types of works and the composition of works directly on the engineering survey works.

In addition to the correct definition of the composition of scientific and technical support, within the framework of engineering surveys, there is a possibility of carrying out other works, depending on the conditions of the construction site or after the analysis of data obtained during the survey, for example, such works can be modelling the response of the geological environment to earthquakes, the development of a set of synthesized accelerograms to perform computational studies of earthquake resistance of unique buildings and structures, the development of additional requirements for calculation.

In this regard, the development of a comprehensive approach and the formation of a methodology for scientific and technical support of unique buildings and structures is an urgent problem that requires elaboration [6, 7].

3. Carrying out STS work at the design stage.

In the design of unique buildings and structures, several parts of the facility can be distinguished, viz:

1. Design of excavation enclosure structures.

2. Design of foundations and bases of unique buildings and structures.

3. Design of underground and above-ground parts of unique buildings and structures.

When constructing excavation enclosure structures for high-rise buildings, there are a number of peculiarities that need to be taken into account in the design.

High-rise buildings, as a rule, have an underground part made under the protection of the enclosing structure. The excavation enclosure structure (wall in the ground, sheet pile, etc.) located close to the foundation slab and buried below the bottom of the excavation can create (if one or more edges of the foundation of a high-rise building are located next to the excavation enclosure) an inhomogeneous (asymmetric) stress state in the foundation base, which changes the shape of the foundation slab deformation and causes additional building roll [8].

This impact of the excavation fence depends on:

- depth of the excavation, material;
- the depth of the excavation and the method of excavation fencing;
- dimensions of the excavation in plan;
- soil conditions;
- loads acting on the foundation from the building and other factors.

Given the high sensitivity of high-rise buildings to uneven settlement, the normative literature recommends that the high-rise building should be located in the center of the excavation.

In case of impossibility, its influence should be taken into account in the design by joint calculation of the foundation soil, excavation enclosure and building structures, including the foundation.

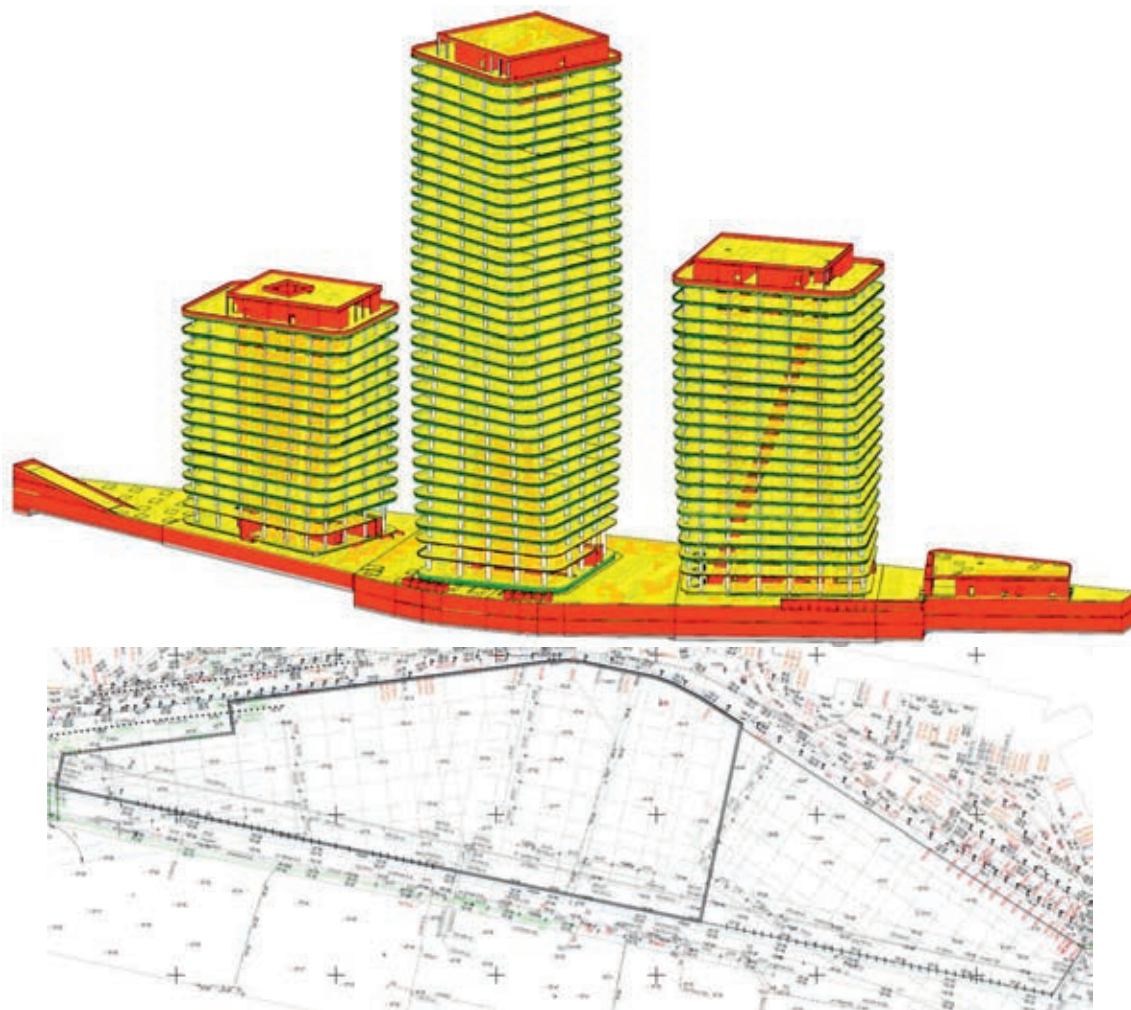


Fig. 3. Planting of the complex. Fencing structures of the excavation

When calculating the foundation, the method of construction of the enclosing structure is important.

Fig. 3 shows, as an example, the planting of a complex, which consists of multi-height buildings, next to the excavation enclosure.

In the construction of foundations of high-rise buildings there are a number of peculiarities that must be taken into account in the design, as well as in the scientific and technical support, within the framework of the design and working documentation, with subsequent recommendations for the work [9, 10]:

1. Due to the fact that the pressure along the foundation footings of high-rise buildings can be many times greater than for buildings up to 75 m high, this requires special survey work, as laboratory and field surveys.
2. The existing norms apply to the calculation of the bearing capacity of a pile up to 35 m long (resistance at the lower end of the pile) and up to 40 m long (resistance at the lateral surface). Since modern projects are characterized by significant height, this may not be sufficient for foundations of high-rise buildings, as the length of piles can reach 70 m.
3. Under significant loads (1–2 MPa) transferred to the substrate, it is necessary to take into account both the strength and deformation characteristics of rocky and non-rocky soils with

$E > 100 \text{ MPa}$, which are considered in accordance with current regulations (CP 22.13330.2011)¹, as incompressible, as well as an increased stress distribution zone in the ground, both in plan and depth, which can lead to an increase in soil layers that absorb the load from the foundation. This can have a particularly strong effect if the layers are uneven.

4. An increase in the depth and width of the compressible layer in the soil leads to a longer time for soil consolidation to complete and a longer duration of the precipitation process.
5. If the foundation is built on soils with different coefficients of consolidation, both primary and secondary, it is important to consider the possibility that due to the uneven stress-strain state of the soil at the intermediate stage of consolidation, the consolidation of different types of soil may occur at the same time. This could lead to the building tilting beyond the limit values.
6. An increase in the size of the deformable area of the foundation can have a greater impact on surrounding buildings and structures, including water-carrying communications. This must be taken into account when calculating and carrying out work.

¹ SP 22.13330.2011. Soil bases of buildings and structures. Date of introduction 2011.05.20.

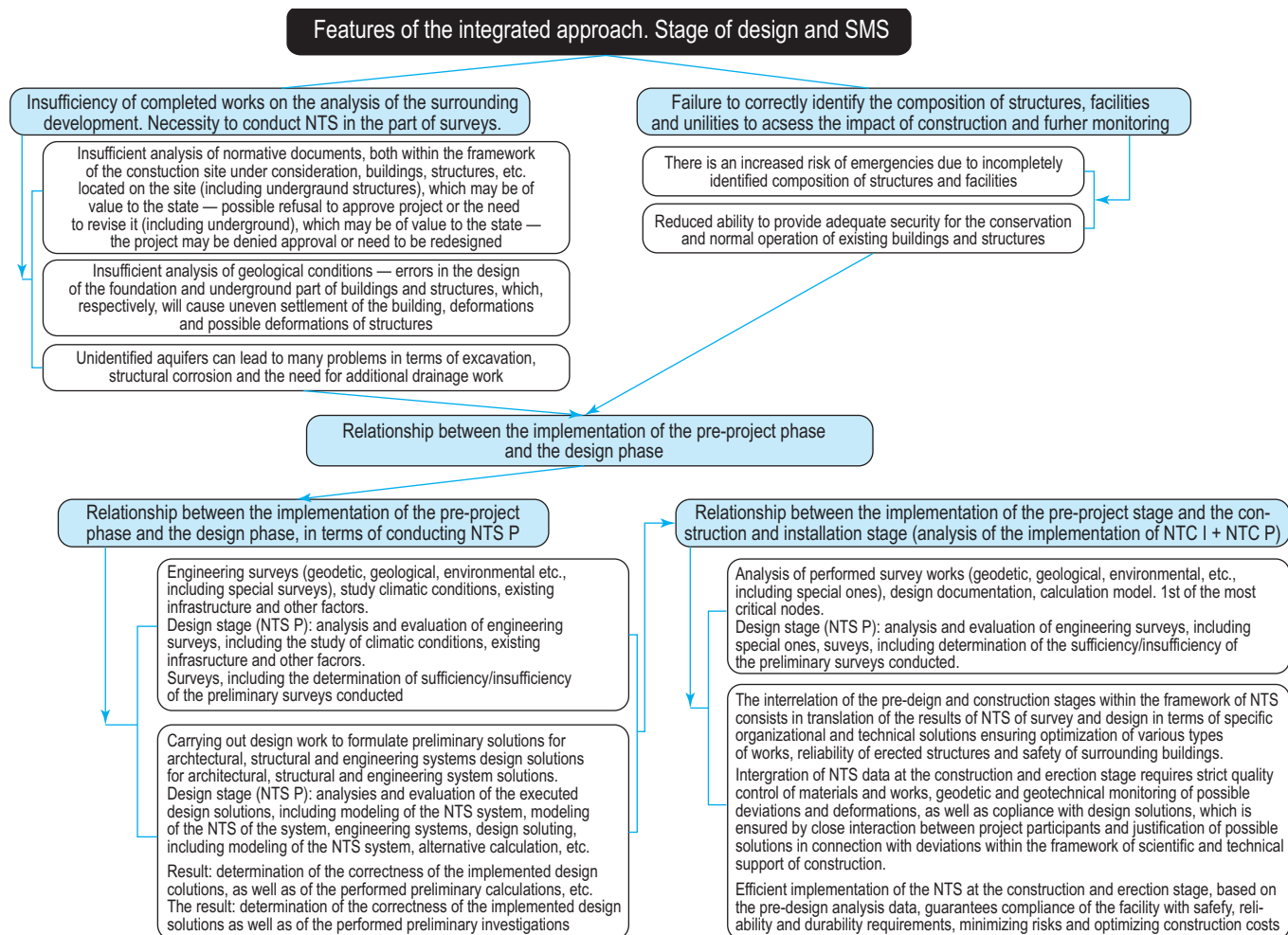


Fig. 4. Peculiarities of the integrated approach to conducting STS

During the construction of structures of the underground and aboveground parts of high-rise buildings a number of features arise that must be taken into account when designing [11].

1. Wind loads and aerodynamics:

- high-rise buildings are subject to significant wind loads, which can cause fluctuations and vibrations.

As part of the design and scientific and technical support, complex aerodynamic modelling is carried out, the aim of which is to provide recommendations on the assignment of aerodynamic coefficients for wind loads used in the calculation of load-bearing structures and enclosing facade systems of tall buildings of the facility. Additionally, the assessment of the level of relative wind comfort in pedestrian areas is conducted.

2. Vertical and horizontal deformations:

- shrinkage and creep of concrete: the need to take into account long-term deformations;
- temperature deformations: due to temperature fluctuations, stresses occur in structures;
- tilt and differential settlement: it is important to ensure an even distribution of loads on the foundation.

3. Fire Safety and Evacuation:

- fire resistance of structures;
- smoke protection, smoke-free stairs, and individual elements of buildings and structures;
- safety zones and elevators (including for evacuation purposes).

4. Architectural planning and energy efficiency solutions.

Carrying out scientific-technical support work at the construction stage

The main organizational and technical solutions, in terms of scientific and technical support during the construction phase, are [12, 13]:

- the formation of a work plan for the implementation of scientific-technical support for construction;
- development of recommendations for quality control of materials, joints, and fasteners;
- conducting control tests on materials, joints, and fasteners. Quality control of installed structures, including using instrumental methods, if necessary. Determining the scope of control within the scientific-technical support programme;
- providing scientific and technical support in solving technical issues arising during the construction of the building;
- quality control of construction and installation works (CIW) at all stages of the construction process, in accordance with the scientific and technical support programme or schedule, which forms an integral part of the scientific and technical support contract;
- control over compliance with the project for the construction of the building's structures, and, if necessary, development of proposals to strengthen or modify the structures;
- analysis of structural health monitoring data for a building under construction;

- assessment of compliance and performance of structures built with design deviations;
- development of recommendations to address identified structural deficiencies.

The programme of scientific and technical support during the CIW stage is formulated at the design phase, and it may involve an analysis of the solutions developed in the working documentation.

The implementation of scientific and technical support is primarily based on the provisions of GOST 27751–2014 [1] and SP 539.1325800.2024 [2].

To summarize, it can be said that providing scientific-technical support during the design phase of unique high-rise buildings is crucial, considering the complex and often individual characteristics of both the underground and above-ground components of such unique structures.

In order to ensure not only the necessary safety during the operation of unique buildings and structures, but also to optimize design solutions, it is important, within the framework of scientific and technical support of engineering surveys, to determine the necessary composition of organizational and technological solutions, thanks to which the stage of design and survey works will be the most effective at the stage of further operation, as well as — optimal for all project participants at the stage of direct design and survey works [14].

Scientific and technical support ensures that all factors affecting the correct implementation of projects of unique high-rise buildings are taken into account, which allows developing more effective design solutions. This contributes to minimizing risks, optimizing costs and improving the safety of the object at all stages of its life cycle (Fig. 4) [15, 16].

Thus, the relationship between the composition and results of scientific and technical support (STS) at the stages of survey, design and construction has been established.

This means that the results of STS at each stage (survey, design, construction) are interrelated and form a single system that ensures the continuity and consistency of solutions.

It is reasonable to perform scientific and technical support at all stages as a single set of works, including involvement of specialists who participated in the STS of survey and design in the STS of construction.

This is due to the fact that the features of the object identified at the stage of STS design (including forecast values, reserves and stocks) allow making more reasonable conclusions about the reliability and safety of the object at the stage of STS construction.

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Комплексный подход в рамках научно-технического сопровождения уникальных объектов на всех этапах жизненного цикла

Современная строительная отрасль неумолимо движется вперед, постоянно повышая уникальность инвестиционно-строительных проектов. Такие объекты, будь то высотные здания или большепролетные, требуют особого подхода на всех этапах жизненного цикла объектов строительства.

Поэтому научно-техническое сопровождение на всех этапах играет ключевую роль в обеспечении безопасности, надежности и эффективности таких объектов.

Однако отсутствие комплексного подхода к сопровождению таких объектов может привести не только к увеличению сроков их реализации, но и к риску возникновения нештатных ситуаций в ходе исполнения проектов в связи с невыполнением отдельных видов работ в рамках научно-технического сопровождения. В данной статье рассматривается формирование комплексного подхода к научно-техническому сопровождению на каждом этапе жизненного цикла объекта.

Цель. Разработка и обоснование комплексного подхода в части выполнения научно-технического сопровождения уникальных объектов на всех этапах их жизненного цикла. Данная статья направлена на выявление ключевых подходов, обеспечивающих эффективное управление процессами, в рамках проведения научно-технического сопровождения, минимизацию рисков и повышение безопасности уникальных объектов.

Материалы и методы. В статье рассматривается комплексный подход к научно-техническому сопровождению уникальных объектов, который базируется на анализе нормативно-правовой базы, практическом опыте реализации проектов, а также интеграции теоретических и практических методов. Основное внимание уделяется формированию методики и основополагающих принципов в части комплексного подхода, обеспечивающего эффективное управление объектами на всех этапах их жизненного цикла.

Ключевые слова: научно-техническое сопровождение, методология, строительство, архитектурно-строительное проектирование, уникальные высотные здания и сооружения, здания класса КС-3

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Shopping centres under the integrated development of territories concept

The paper discusses non-commercial issues of shopping centres development, its role for creating comfortable environment according to the Integrated development of territories (IDT). The IDT concept suggests creating comfortable living areas with smart planning of social, public and business places. The main role in creating comfortable urban environment play attraction centres — apparently, Neighborhood and Community centres can perform such a function for both new and developed areas. Statistical data presented in the paper confirms popularity of Community shopping centres construction in new residential areas in various cities of Russia. The author points out the new elements, which carry out social function, attract visitors, meet the demand of the inhabitants of the neighborhood. Recommendations of the IDT Standard for shopping facilities, regarding the low-rise, middle-rise and central models have been pointed out for the new areas of construction. New outside elements are suggested to be included by developers at the concept and new district planning stage, regarding parking and landscaping. As an example of the existing residential areas development a project in Moscow is studied. A development company transforms movie-theaters of the soviet period into Community Centres and focuses on a close interaction with local community and loyalty program. Based on the optimal tenants mix their concept allows to increase the shopping centre attendance, events and discounts also stimulate new visits. The article allows to estimate how much IDT concept converges business and society interests and describes instruments and factors which affect.

Keywords: *Standard for integrated development of territories, comfortable urban environment, new elements of neighborhood shopping centres, walking distance, attendance, public places, social function of shopping centre, central model, community shopping center*

Commercial estate in Russia has transformed gradually from clothing markets to modern shopping malls. At each stage of its development shopping real estate reflected the current demand tendencies [1]. In 2020 the Federal Law No. 494 "Amendments to City Plan Code of the Russian Federation and some legislative acts in order to provide integrated development of territories" [2] was passed and later some other amendments for better functioning of IDT mechanisms. The changes logically confirmed the vector towards auxiliary needs of visitors, which has been shaping during the past years. According to article 64 p. 1 of the City Plan Code of RF 5 main goals of IDT include: providing proper conditions for development of transport, social and engineering infrastructure, settlements territories' amenity and landscaping, better access to such infrastructure, efficient use of settlements' territories, also for creating comfortable city environment, service and employment points. Achieving those goals is impossible without, first of all, neighborhood and convenience shopping centres [3] with thoroughly considered concept [4].

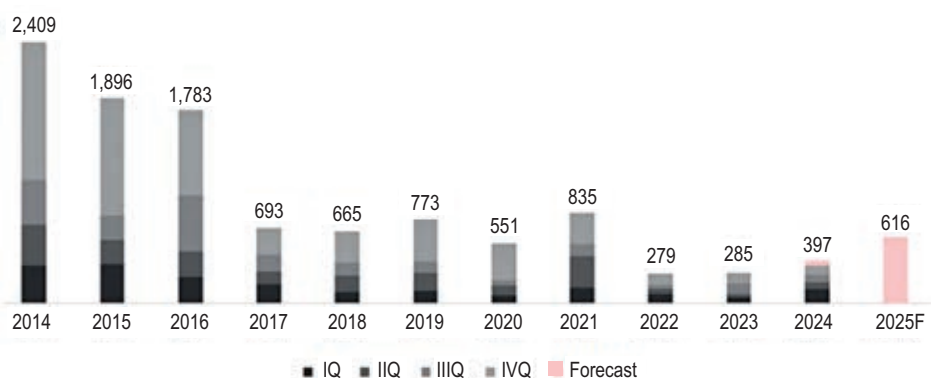
The Standard for integrated development of territories was worked out by the Construction Ministry (Minstroy), DOM.RF and CB Strelka (Construction Bureau), the Standard was initiated in the Government Chairman for IDT adaptation [5]. The recommended percent of social and business infrastructure for low-rise, mid-rise and high-rise residential development is correspondingly 10–20, 20–30 и 30 % and more [6]. The standard implies division into coverage sub-areas in case of a large territory of residential complex, as the standard model is for land plots of 14ha, which is the most comfortable for walking accessibility. Social and business area

consists of street-retail and single-standing buildings of a specialized purpose. The standard recommends [7]: "In the case of low functional variety of the territory it is recommended to include a magnet-unit (a leisure centre, for example, which attracts visitors from other city districts and creates additional traffic for other elements of shopping, services and leisure infrastructure". Thus, it is the **neighborhood shopping** centres that can enrich and improve residential complex's infrastructure, as it is the place where interest of retail and customers meet: large indoor spaces allow to form the most convenient tenant mix (shops, services, entertainment) at one place and create a favourable leisure atmosphere [8].

By the end of 2024 (Fig. 1) 397,000 sq. m of shopping centres have been built. The main share is presented by regions — 68 %, including 13 % Moscow region. Moscow share is 32 % [9].

During the first 3 months of 2025 five malls have been opened in Moscow: BOTANICA, a part of transporting connection point at st. Botanicheskaya (GLA: 28.5 thous. sq. m), meeting point VITYAZJ from ADG Group (GLA: 11.0 thous. sq. m), AFI GALLERY (GLA: 8.1 thous. sq. m), ZYORNISHKO/CORN (GLA: 6.4 thous. sq. m), ZILART universal store (GLA: 16.7 thous. sq. m). Total GLA of the malls appeared January-March 2025 is 69 thous. sq. m (+102 % y/y). Till the end of 2025 about more than 20 malls are expected, which, provided on-time commissioning, can even lead to record-breaking figures for the period of 2017–2025.

There was no opening of shopping centres in 2023–2024 in St. Petersburg, whereas in the 1st quarter of 2025 a gradual opening of Park Mall (GLA: 30 thous. sq. m) at London Park has started.



Source: IBC Real Estate

Fig. 1. Volume of construction of new shopping centres 2014–2025, thous. sq. m

Also 5 more malls have been announced to be open in 2025: HOLLYWOOD (GLA: 60 thous. sq. m), SKY (GLA: 25.7 thous. sq. m), second phase of Eco Park Murino (GBA: 12 thous. sq. m) and two projects from Kronung Group — at Novogorelovo (GLA: 11.8 thous. sq. m) and at the residential complex Sun City (GLA: 3.8 thous. sq. m). Total amount of the expected malls is 136.6 thous. sq. m.

January–March 2025 nine malls opened in regions of Russia, with total square almost 80 thous. sq. m: Grand City Kemerovo (GLA: 30.0 thous. sq. m), DEPO in Voronezh (GLA: 12.5 thous. sq. m), Esfera Centre in Nalchik (GLA: 12.0 thous. sq. m), Moskovskii in Velikii Novgorod (GLA: 6.9 thous. sq. m), Soldatov in Perm (GLA: 6.5 thous. sq. m), Melnitsa in Tula (GLA: 5.0 thous. sq. m), Ilj in Iljinskoye (GLA: 3.3 thous. sq. m), Arsenal in Perm (GLA: 2.5 thous. sq. m) Danish Quarter in Mitishchi (GLA: 1.3 thous. sq. m).

Till the end of this year 200 thous. sq. m of malls is expected, which is 9 % less than in 2024. Regional market shows the tendency for smaller average square of shopping centres: in 2000–2014 it was 30.8 thous. sq. m, in 2015–2025 it reduced by 25 % — till 23.2 thous. sq. m.

Construction of qualitative shopping centres continues in Russia, comprising mostly neighborhood ones. GLA of 75 % shopping centres built since the beginning of 2024 is about 15,000 sq. m. The trend for neighborhood shopping centres is a result of decentralized development of city areas. Since cities grow via new residential areas, the demand for better infrastructure and shops with walking distance grows as well. Retail has to transform to remain up to date and attractive. The transforming buyer's behaviour defines development vector of retail market, stimulating participant to catch up. As shopping centres have to adopt to the increasing segment e-commerce [10] new formats and attraction points prove to be extremely useful.

Since 2000's food court, entertainment and kids' zones [11] became essential part of shopping malls. During the last 5 years new social and business tenant appeared, such as "My documents", MOEK and other organizations. Rates are very low for such tenants, but they attract huge traffic (rate issues are not a subject to this paper).

Social function also continues to develop and progress. Besides basic segments new ones are appearing and taking root reflecting social function, they don't make much profit, but are very convenient and attractive for visitors.

The main new element is children's fests and celebration activities of the main holidays or just seasonal. Interesting to mention:

all parties benefit from it: parent get free entertainment just by their home, tenants act as sponsors and advertise their products, visitors attend their and neighboring shops, food places, supermarket. Gradually a loyal attitude to the shopping mall appears, especially if the even was successful [12]. Many families, leaving nearby can come together or get acquainted, which cultivates positive climate in the neighborhood.

Almost all shopping centres already have kids' zones with free sensor screens for children with drawing or puzzle games.

A similar effect has exhibitions and master-classes for grown-ups. A shopping centre can support local artists, painters, musicians or invite from the city.

Current generation is very environment-oriented, sharing ideas of reasonable economy, things re-use, waste sorting and recycling. Shopping centres also don't stay away from the green movement: there are separate waste bins at the floors, special boxes for batteries, lamps, clothes and other things. People know, that in their neighborhood there is a place where they can apply their care about the planet and the idea is shared [13].

Parking place comes at hand as during the last 5–7 years electro scooters and electro bicycles, not to mention bicycles have become extremely popular and the malls' parking is a very convenient place to rent or to leave this kind of transport.

Charging zones for smart phones and other devices, free wi-fi, info via applications is also for mutual use.

It's becoming popular to place express health-check points at shopping centres: just pressure and temperature scanners or small cabinets with specialists.

Local residents now can meet a technological innovation, such as robot-administrator, helping with navigation or other issues at their own neighborhood centres, without going to central regional malls.

Original museums, reading corners or book-exchange points are also a part of shopping centres' concept now.

There is news about shopping centre exterior space as well. Leisure territory makes a mall more popular and successful. Hodinskoe Pole Park is a good example of such symbiose: sport facilities, green landscaping, children's playgrounds and one of the most popular in Moscow shopping centres "Aviapark".

Based on the Standard developer has an opportunity at the area planning stage incorporate in the malls' concept not only revenue interest, but also IDT improvements, for example: to place a shopping centre (or even several, depending on the territory size) at



Fig. 2. A variant of effective tenant mix for a Neighborhood center



Fig. 3. Loyalty programme of a shopping center

the most convenient places, to calculate optimum size, to plan social and public elements, necessary for the neighborhood, to do landscaping considering parking and vehicles, playgrounds, to combine quest and residential parking (especially for "free of cars" courtyard concept), to add an extra bus stop.

Functional neighborhood shopping centres' concept at the new construction areas is preferable, and that is exactly what developer company ADG suggested even before the IDT law: the company worked out a net of new Neighborhood/Convenience shopping centres for existing residential areas. The main idea is to compensate the lack of local attraction points after complete redevelopment of soviet period movie-theaters into leisure and shopping centres.

According to the ADG the effective tenant mix of everyday goods and services, coffee places, restaurants, movies, activities and entertainment (Fig. 2) provides high traffic during the whole day [14].

The individual approach of Customer loyalty programme creates close long-term relationship with local habitants offering them extra occasions for visits. Individual communication system allows to target the offer to those really interested, which is reflected at Fig. 3. The constructive open plan effect combines with confidential relationship with residents and online resources.

There are also insights about residents for better range of products, online full range, centralized network of pick-up points that allow to reach the maximum income per square meter.

Developers are interested in taking into consideration IDT concept for designing shopping centres as the last 10 years have confirmed the benefit of enlarging social function and including entertainment and public zones [15]. The more comfortable and interesting a shopping centre is the more traffic of loyal visitors it has and the longer they stay at the centre the higher is the bill. And the city and its residents get effective infrastructure and a possibility to satisfy needs without inconvenient long trips as well as additional working places. The IDT concept gives developers convenient instruments, such as the Standard, practical recommendations, which promote complex approach at the stage of planning new areas or developing the existing ones. As a result, neighborhood shopping centre becomes a place that residents love, are proud of and consider to be a part of their life.

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Девелопмент торговых центров в рамках концепции комплексного развития территорий

В статье предлагается рассмотреть не коммерческую составляющую девелопмента ТЦ, а его роль в создании комфортной среды при реализации комплексного развития территорий (КРТ). Появившаяся концепция предполагает создание удобных районов для жизни с продуманным размещением социальных, общественно-деловых объектов. Важная роль в создании комфортной городской среды отводится центрам притяжения в новых или существующих районах, такую функцию во многом могут реализовать районные или окружные ТЦ. Приведена статистика ввода торговых площадей, которая подтверждает популярность строитель-

ва новых районных ТЦ в различных городах России. Автором выделены новые элементы, выполняющие социальную функцию, привлекающие посетителей и удовлетворяющие потребности живущих по соседству горожан. Исследуются рекомендации в Стандарте КРТ в отношении недвижимости торгового назначения для малоэтажной, среднеэтажной и центральной моделей при новой застройке. Для девелоперов предложены варианты организации внешней среды, которые нужно предусмотреть при разработке концепции микрорайона и выборе местоположения для ТЦ, связанные с парковкой, благоустройством. В качестве примера развития уже существующих районов рассмотрен проект создания соседских центров в результате редевелопмента советских кинотеатров одной из девелоперских компаний Москвы. При разработке концепции основное внимание уделяется взаимодействию с жителями района, поддержанию

программы лояльности. Благодаря созданию оптимального набора арендаторов увеличивается посещение ТЦ в различное время, развлекательные мероприятия или скидки становятся поводом для дополнительных визитов. Статья помогает оценить, насколько концепция КРТ помогает сблизить интересы бизнеса и общества, какие инструменты и факторы этому способствуют.

Ключевые слова: стандарт комплексного развития территорий, комфортная городская среда, новые элементы районного торгового центра, пешеходная доступность, проходимость, общественные места, социальная функция ТЦ, центральная модель, окружной торговый центр

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Improvement of the methodology for creating an architectural digital information model of a residential building using a modular approach

The aim of the study is to analyze the application of a modular approach based on a library of standardized building blocks and Building Information Modelling technologies (BIM technologies) in the design of typical residential buildings.

Research hypothesis: creation of BIM models of typical residential buildings using a modular approach and a library of TIM components reduces the time required to complete design work, reduces cost and improves the quality of design work. Research methods: analysis, synthesis and modeling.

The methodology for creating digital information models of typical residential buildings, described in principle in previous works, was considered in relation to all possible special cases. Based on the projects of the Atomstroykompleks company, fundamentally possible variants of typical residential buildings were determined — these are three groups: point, sectional and corner buildings with different floor areas, divided into subgroups by the number of elevators. Staircase and elevator unit modules were created for each subgroup. At the next stage, the parameters of the number of storeys and floor area for the BIM models in each of the subgroups of residential buildings were changed, and the changes occurring in the library modules were determined. As a result, the actions that need to be taken to library modules for their adaptation for use in apartment buildings with different numbers of storeys and floor areas were described.

As a result, the following was determined:

- possible variants of architectural forms of plans of residential buildings;
- changes that library modules may undergo due to changes in the area of a residential building during the design;
- measures that should be taken to adapt library modules to allow for changes in the area of sections of residential buildings.

Keywords: *building Information Modeling (BIM), digital information model, methodology for creating digital information models of typical residential buildings, BIM module library, residential construction, library for design work, mass housing construction.*

INTRODUCTION

Full implementation of BIM technologies^{1,2} into the business processes of an enterprise³ leads to the development of solutions to increase the efficiency of their use [1]. In the case of a large volume of similar construction projects, such a solution may be unification, which, in turn, helps to speed up the implementation of stages of the life cycle of typical residential buildings from the pre-investment stage to the construction stage. This article covers the design stage of the life cycle.

For example, the Atomstroykompleks corporation designs and builds a wide range of facilities, such as schools, kindergartens, medical institutions, public buildings, sports facilities, restored cultural heritage sites and standard facilities — mass residential housing. Mass residential housing is typical because in this type of objects it is possible to

identify elements of the building, premises and zones that can be repeated from project to project after standardization. After analyzing completed projects, unification was conducted with the aim of moving to modular design. Modularity is the division of a residential building into elements — modules, which are the volumetric-planning parts of the building. Which building elements were chosen as modules and how they were standardized is described in previous articles [2–4]. Modularity involves the repeated use of modules from project to project, while a building can consist of modules either 100 % or partially with local individual design.

As a result of the project analysis, the following module classification was created:

- modules of the first level, representing the rooms of apartments (bathrooms, loggias and balconies);
- modules of the second level, representing apartment modules and modules of staircase and elevator unit modules, including an elevator hall, a stairwell and an inter-apartment corridor.

For the selected building elements, the company created standard albums containing a list of possible volumetric planning solutions for each element. These albums became the basis for the creation of BIM module library. Taking into account the regulatory framework a BIM module library was created,

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³ Atomstroykompleks has started designing residential buildings in BIM. URL: <https://atomsk.ru/company/press/news/atomstroykompleks-nachal-proektirovat-zhilye-doma-v-bim/> (date of access: 20.09.2024). (rus.).

which so far includes only staircase and elevator unit modules and modules of the first level. The library elements are digital information models created in accordance with the Employer Information Requirements (EIR) of the company.

The library is owned by the customer, who should benefit from the implementation of modular design. One of the areas of application of modular design is to accelerate and reduce the cost of the design process of the main type of company facilities — typical residential buildings. This is justified by the fact that a designer, receiving a ready-to-use BIM module library as part of a design assignment, can create a typical residential building from a typical floor to the roof entirely or almost entirely from the components of this library. The contractor will not create a completely unique building (with the exception of the ground floor and basement), therefore, the involvement of highly qualified specialists and a large number of man-hours is not required. The use of library components with the LOD 400 (Level of Development) will allow us to come to the conclusion that the BIM models at the stages of project and working documentation will differ only in the design of the project sheets. It should be noted that verification of structural calculation, hydraulic calculation, insulation calculation and others inherent in classical design remains necessary. In addition, using library components, the designer is limited in the use of materials and technical solutions that deviate from the standard of the company. If a company has its own contractors, the use of standard components and materials will improve the quality of construction and installation work and, accordingly, the operational characteristics of the facilities.

Some foreign researchers are engaged in the implementation of a modular approach in the design and construction of typical residential buildings [5, 6]. There are authors who also suggest using the module library in the design process and describe the mechanism for changing layouts [7–9]. Other authors are taking steps to create a system for automatically filling the library with modules based on previously created projects, as well as automatically checking potential modules for compliance with the requirements [10–12].

CREATING A TYPICAL FLOOR PLAN

In previous studies, an initial set of elements of the BIM module library for the design of typical residential buildings was created, which included:

- staircase and elevator unit modules;
- modules of the first level.

Methodological recommendations have been developed for creating a digital information model using a BIM module library. The conducted timing measurements of the creating of a typical floor of the architectural section showed that the use of a BIM module library accelerates the process of creating an information model by almost 40 %. The previous article [2] contains an algorithm for creating a model of an architectural section.

Fig. 1 and 2 show the floor plan of a typical residential building assembled from library elements. The green color indicates the staircase and elevator unit module, the green-blue color indicates apartment modules, the blue color indicates bathroom modules, and the brown color indicates loggia modules. You can see that the bathroom and loggia modules are part of the apartment modules.

IMPROVING THE LIBRARY OF STAIRCASE AND ELEVATOR UNIT MODULES

In the process of testing the methodology for constructing a typical floor of an architectural section, it was discovered that the staircase and elevator unit modules need to be improved. Their disadvantage is that in the existing configuration the blocks are designed for a certain floor area, and therefore a certain number of apartments. At the same time, from an architectural point of view, the shapes of sections of residential buildings in the plan can be point, corridor and corner.

In point buildings (Fig. 3), the inter-apartment corridor is located around the core with elevators and is its border on three sides. The increase in the floor area of point buildings does not have a significant impact on the architectural section, since it occurs in most cases due to the increase in the area of apartments, while the dimensions of the inter-apartment corridor do not change. Even if the number of apartments increases, the configuration of the staircase and elevator unit module does not change; it is only necessary to provide for the possibility of installing additional water supply, heating and electricity supply systems.

In corner and corridor buildings (Fig. 4, 5, respectively), the inter-apartment corridor adjoins the core with elevators and is its border on only one side. When increasing the area of the section, either due to the area of the apartments or due to an increase in the number of apartments, the length of the corridor may change.

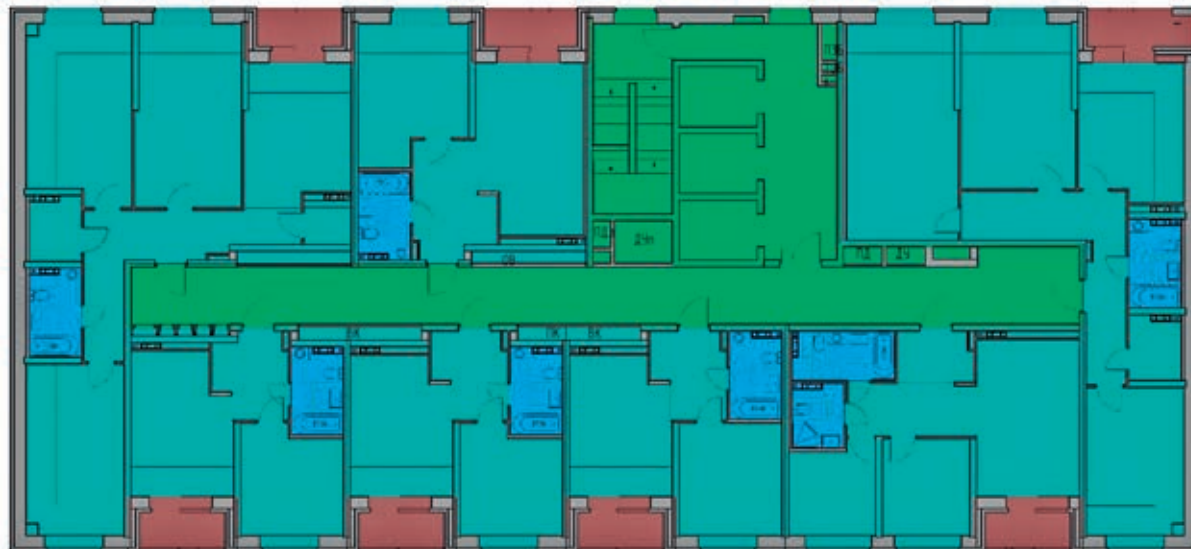


Fig. 1. A typical floor plan consisting of elements from the BIM module library

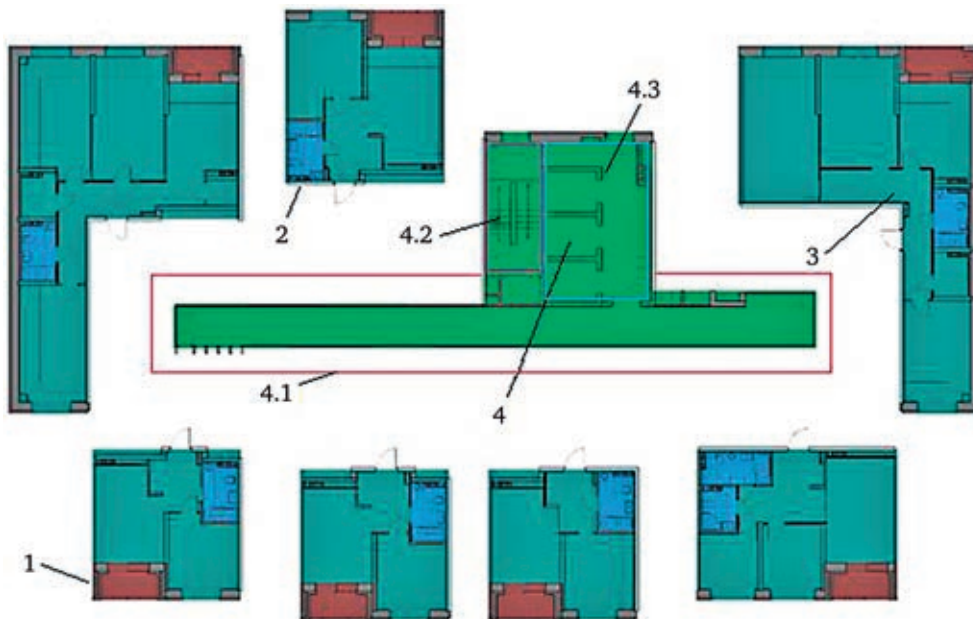


Fig. 2. Elements of the BIM module library that make up a typical floor plan: 1 — loggia module; 2 — bathroom module; 3 — apartment module; 4 — staircase and elevator unit module; 4.1 — inter-apartment corridor as part of staircase and elevator unit module; 4.2 — stairwell as part of staircase and elevator unit module; 4.3 — elevator hall with elevator shafts as part of staircase and elevator unit module

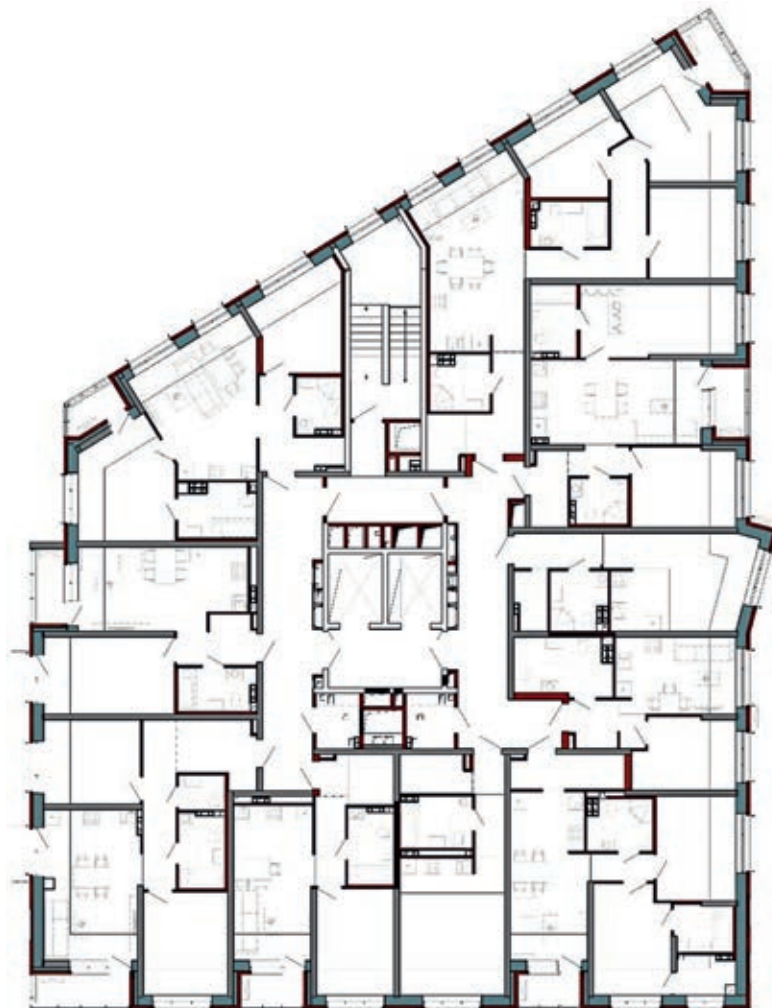


Fig. 3. Example of a point section



Fig. 4. Example of a corner section

The change in the length of the corridor and, consequently, the area of the section is limited by the length of the escape route from the apartment to the entrance to the stairwell.

In the corridor and corner sections, niches for utility networks are located directly in the inter-apartment corridor. An increase in the floor area, both due to a change in the area of apartments and due to a change in the number of apartments, changes the configuration of the inter-apartment corridor in terms of the location of the entrance doors to the apartments. The relocation of entrance doors to apartments in turn entails the relocation of niches for utility networks in the space of the inter-apartment corridor and/or the installation of additional water supply, heating and electricity supply systems. As in the case of point sections, as well as in the case of corridor and corner sections, it is necessary to standardize the dimensions of niches for engineering systems in order to increase or move them in the corridor space and seamlessly increase the number of systems.

The possibility of changing the configuration of the staircase and elevator unit module of the architectural section entails changes in the staircase and elevator unit modules of the engineering

sections. Engineering systems should be modified so that they can be placed in standardized niches to seamlessly change their location in the plan or increase the number of systems.

ADDITION OF THE METHODOLOGY FOR CREATING A TYPICAL FLOOR

The developed methodological recommendations provide the following composition of the architectural module of the stair-elevator unit:

- staircase unit;
- vertical load-bearing structures;
- non-load-bearing walls and partitions;
- trays for electrical networks;
- ventilation ducts;
- premises and basic finishing of premises.

However, in the process of testing the methodology for creating an architectural typical floor, it became necessary to refine the staircase and elevator unit modules. It was established that staircase and elevator unit modules can be of three types: point, corridor and corner.

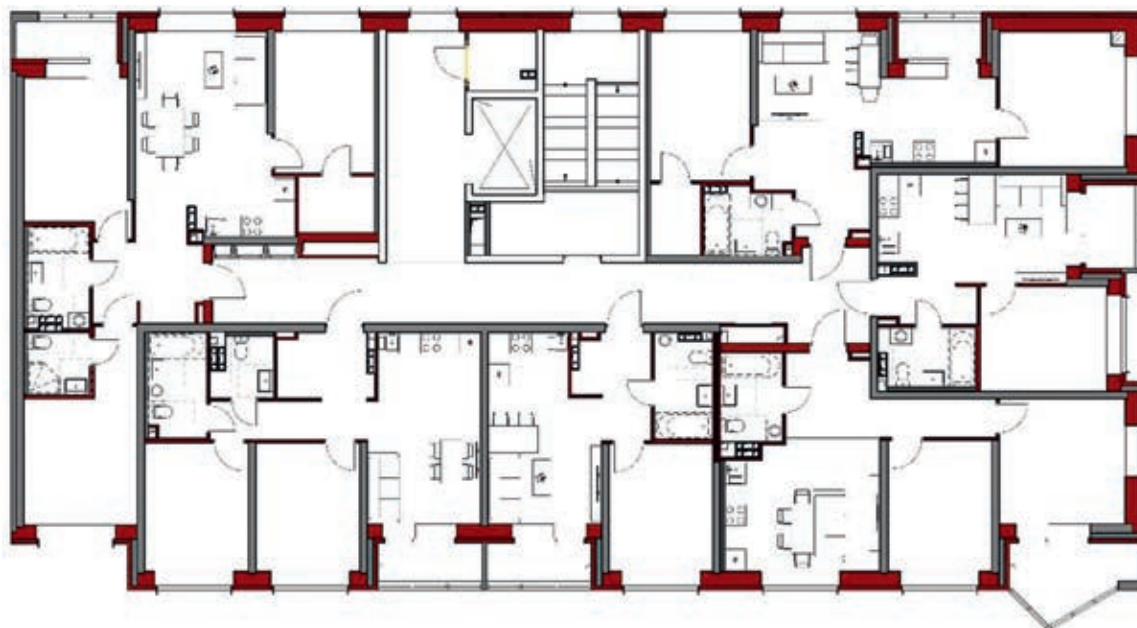


Fig. 5. Example of a corridor section

The principle of constructing the model was initially based on the construction of point building models. However, in the previous section it was established that it is necessary to decompose the staircase and elevator unit modules into 3 types. In connection with the described features of the staircase and elevator unit module types, the composition of the staircase and elevator unit modules and the procedure for working with them must be changed.

For point modules, the composition does not change, the dimensions of the inter-apartment corridor remain unchanged, it is only possible to increase the number of niches and trays for placing electrical networks in them. After placing the staircase and elevator unit module, it is necessary to add a check of the number of niches for the placement of engineering systems.

The composition of point and corner modules can be divided into two categories. The first category is permanent elements, which include the stairwell, elevators and elevator hall with the structures that limit them. The second category is variable elements, which are the inter-apartment corridor and the structures that limit it. The procedure for working with these types of staircase and elevator unit modules should include a process for checking the number of niches for placing engineering systems. The process of creating a typical floor plan must be supplemented by the process of linking the location of niches for engineering systems with apartment layouts. After creating a typical floor plan, a process must be added to check the compliance of the length of the inter-apartment corridor with the requirements of SP 1.13130.2020⁴ and bring the length into compliance with the standards by editing the floor plan.

CONCLUSION

In the process of researching the methodology for applying a modular approach to constructing architectural digital information models of residential buildings, shortcomings were discovered that arose due to the expansion of the range of modules of staircase and elevator unit modules. The disadvantage is the lack of adaptation of modules to a possible increase in the floor area or an increase

in the number of apartments on the floor, which consists in the inability of modules to change the number of engineering systems or change their location in common areas.

To eliminate this deficiency, the following measures were taken:

1. The nomenclature of staircase and elevator unit module was classified into modules for point sections, modules for corridor sections and modules for corner sections.

2. For each type of staircase and elevator unit modules, it was determined which elements and how would be subject to change when the area of the section floor changes.

3. The methodology for constructing a digital information model was adjusted, operations were added for each type of staircase and elevator unit module, taking into account the possibility of changing the area of the section floor.

In the future, it is necessary to test an improved method for constructing digital information models using improved modules of staircase and elevator unit modules.

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⁴ SP 1.13130.2020. Code of Practice. Fire protection systems. Evacuation routes and exits. (rus).

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Совершенствование методологии создания архитектурной цифровой информационной модели жилого здания с применением модульного подхода

Предметом исследования является процесс проектирования типовых многоквартирных домов. Цель исследования — анализ применения модульного подхода, основанного на библиотеке типовых модулей зданий и технологиях информационного моделирования (ТИМ), в проектировании типовых многоквартирных домов.

Гипотеза исследования: создание цифровых информационных моделей типовых многоквартирных домов с применением модульного подхода и библиотеки ТИМ-компонентов снижает стоимость, повышает качество и сокращает сроки выполнения проектных работ. Методы исследования: анализ, синтез и моделирование.

Методология создания цифровых информационных моделей типовых многоквартирных зданий, принципиально описанная в предыдущих работах, была рассмотрена применительно ко всем возможным частным случаям. На основе проектов компании Атомстройкомплекс были определены принципиально возможные варианты типовых многоквартирных домов — это три группы: точечные, секционные и угловые дома с различной площадью этажа, разбитые на подгруппы по количеству лифтов. Для каждой подгруппы были созданы модули лестнично-лифтовых узлов. На следующем этапе изменялись параметры этажности и площади этажа для ЦИМ в каждой из подгрупп многоквартирных домов, определялись происходящие изменения в модулях библиотеки. В итоге были описаны действия, которые необходимо предпринять в отношении модулей библиотеки для их адаптации к применению в многоквартирных домах с различной этажностью и площадью этажа.

В результате определены:

- возможные варианты архитектурных форм планов жилых домов;
- изменения, которым могут подвергнуться модули библиотеки из-за изменения площади жилого дома в процессе выполнения проектных работ;
- указаны мероприятия, которые следует предпринять для адаптации модулей библиотеки для возможности изменения площади секций жилых домов.

Ключевые слова: технологии информационного моделирования (ТИМ), цифровая информационная модель, методология создания цифровых информационных моделей типовых жилых зданий, библиотека ТИМ-компонентов, жилое строительство, библиотека для проектирования, массовое жилое строительство

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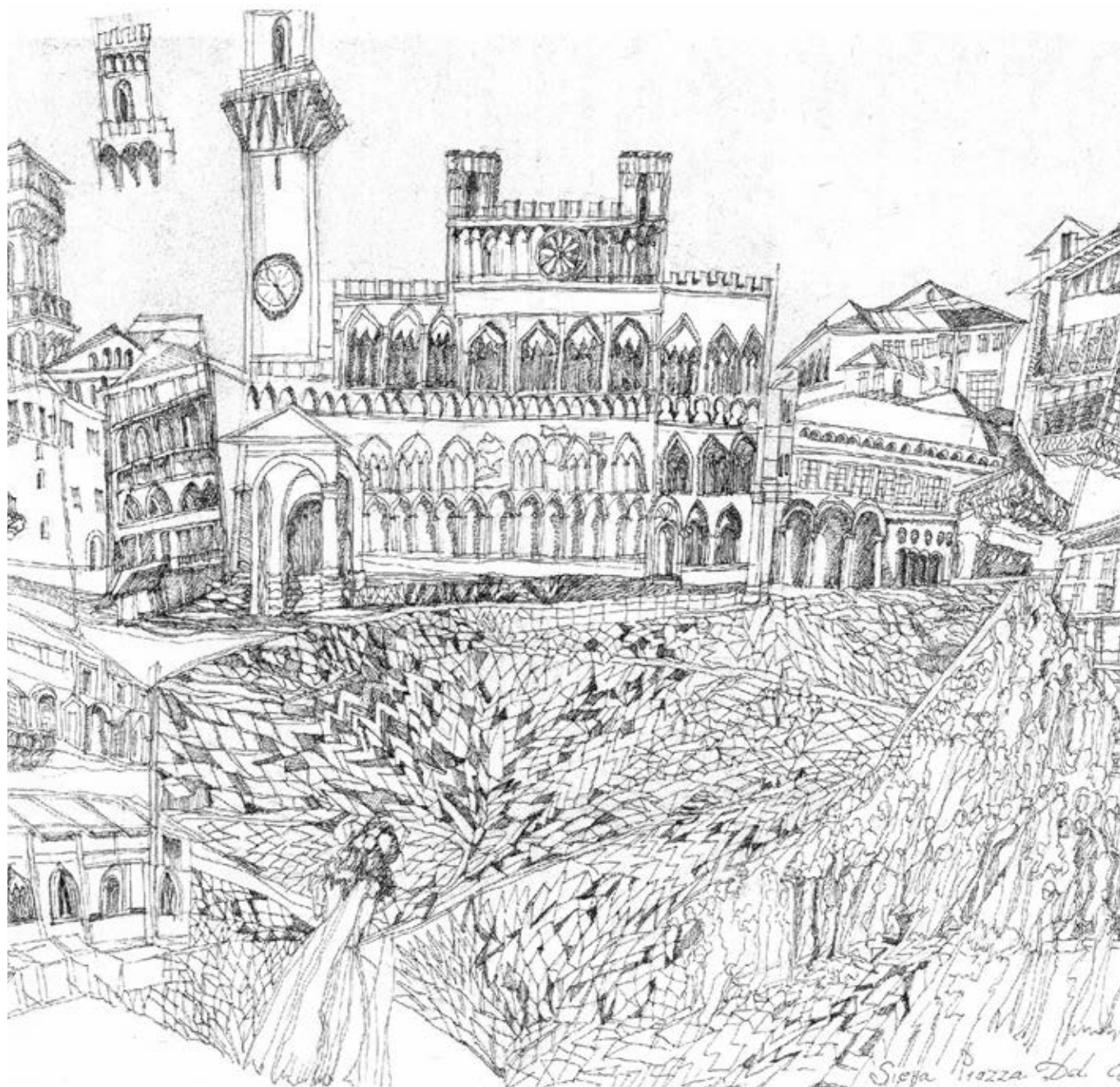
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Сиена. Площадь Дель Кампо

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The role of functional requirements for university campus facilities in their design and operation

This article is a continuation of a series of publications on the further development of the network of university campuses as innovative educational spaces in our country. At the moment, the Russian economy is facing great challenges in the field of technological development. And the integration of education, science and technology on the basis of modern educational spaces plays a new role as a fundamental element in the implementation of national projects and the solution of many global problems. In previous publications, within the framework of this direction, the author disclosed the results of his research, determining the possibility and effectiveness of implementation and application of a number of multifunctional tools, such as "Educational-technological conditions", "Educational-technological task", "Combinatorial matrices" within the development of innovative educational spaces. The ways of integration of "Educational-technological task" with information models of capital construction objects within campuses were described. The peculiarities of life cycle management of various objects of university campuses were analyzed.

This article is devoted to the identification of the determining role of functional requirements and their prevalence in the modern educational environment over architectural, constructive, technical and other requirements. After all, they determine the properties of the created and developed material and spatial environment of the university, which in turn contributes to the prestige and competitiveness of higher education. The article touches upon the interdisciplinary approach to the stages of design, operation, repair, modernization of campus facilities, determined by the need to solve a variety of tasks in them, involving in their functioning students, teachers, scientists, entrepreneurs of different ages, with different interests. It is the interdisciplinary approach that can ensure density and intensity of communications, quality of space, flexibility, ability to rebuild and experiment, diversity of non-academic functions, formation of effective economic and management models.

Keywords: *scientific and technological development, innovative methods, material and spatial environment, technological companies, requirements, interdisciplinary approach, environment parameters*

INTRODUCTION

In the next 10–15 years, according to the Strategy for Scientific and Technological Development of the Russian Federation, the priorities of scientific and technological development of Russia will be those areas that will allow to obtain advanced scientific and scientific-technical results, to form breakthrough technologies that are the basis for innovative development of the domestic market of products and services, sustainable position of the country in the foreign market. They will enable the transition to advanced digital, intelligent production systems, creation and application of high-tech products [1].

Accordingly, systemic changes in approaches to scientific and technological development of the country are required to achieve technological sovereignty in the field of critical and cross-cutting technologies. And on this path, it is necessary to consolidate the efforts of federal public authorities, public authorities of the subjects of the Russian Federation, scientific, educational and business community, civil society institutions to create favorable conditions for the development and application of science and technology in the interests of socio-economic development of Russia [2].

In order to ensure leadership in traditional and new markets of technologies, products and services, to build an integrated national innovation system, it is necessary to concentrate resources in order to obtain new scientific results necessary for

the country's transition to the next technological modes. It is necessary to implement a set of organizational, legal and other measures aimed at a significant increase in the efficiency of expenditures on research and development, increasing the return on investment in the relevant areas of the economy for the development of national research and development centers. The creation of effective partnerships with domestic and foreign research centers, the emergence and development of private companies capable of becoming leaders in technological markets can play an important role in this direction.

This is what the Standard of Innovative Educational Environment (campuses) [3] is largely aimed at with its requirements and provisions, such as:

- creation of campuses as centers of new opportunities, points of migration, technological and investment attraction;
- end-to-end implementation of digital twin technologies;
- necessity and possibility of creating innovative products, modern technologies, patents on the basis of research infrastructure;
- maximum involvement of students of all levels in project, research activities, technological entrepreneurship, and sports life of the university;
- creation and continuous increase in the number of high-performance jobs;
- formation of flexible ecosystems of techno-

logical entrepreneurship with support from industrial partners, development institutions;

- provision of elements of related business infrastructure and continuous improvement of user satisfaction.

The campus that provides these conditions will be transformed into a center of innovative production and implementation of new technologies, attract the most highly productive and creative workforce due to the availability of innovative infrastructure and high standard of living on its territory [4]. This is the target image of new-type campuses. But for this, it will be necessary to revise the approaches and ensure a variety of factors in the design and organization of the material and spatial environment.

PRINCIPLES AND FACTORS OF SCIENTIFIC AND TECHNOLOGICAL DEVELOPMENT

In the current situation and under the conditions of providing complex functional requirements, the subjects of scientific and technological development in our country can become:

- associations (technological holdings, etc.), including educational, research, design and production base, pilot production, which can be formed around technical universities or technological companies on the basis of an integrated approach [5];
- research consortia, capable of implementing large-scale technological projects up to the development of prototypes ready for commercialization, the main functionality of which will be aimed at the operational solution of scientific and educational tasks by building effective interaction between the consortium members by combining their own and external resources, redistribution of these tasks between them and optimization of costs for research, development and technological work [2].

In the activities of such entities, it is possible to identify the most significant principles of scientific and technological development and group them by directions: financing, opportunities, support (Table 1).

The described principles, in the conditions of state policy in the field of scientific and technological development of the Russian Federation, suggest the availability of opportunities and prospects

Table 1. Principles of scientific and technological development

Directions	Principles	Significance of the principles
Financing	Integrity of the innovation cycle	Ensuring "seamlessness" and provision of support measures at all stages of technology creation and implementation from research and development to implementation in the real economy within the framework of the technological development ecosystem
	Concentration of resources	Focusing intellectual, financial, organizational and infrastructural resources to support research and development, creation of products and services
Opportunities	Freedom of scientific and technical creativity	Providing opportunities for scientific teams and organizations, other participants of research and development to choose and combine directions, forms of interaction, methods of solving research, technological problems while increasing their responsibility for the effectiveness of their activities and the significance of the results obtained for the development of the national economy and society [6]
	Openness	Effective interaction of scientific organizations, participants of research and development with representatives of the business community, society and the state, as well as based on national interests with the international community
	Recognizing the right to risk	Possibility of failure to achieve the planned results of technological works, including research and development works
Support	Systemic support	Ensuring a full cycle of obtaining new knowledge, developing qualitatively new technologies, creating innovative, breakthrough products and services, forming new markets, and taking a sustainable position in them
	Rational balance	State support for research and development aimed at solving both significant tasks within the framework of the priorities of scientific and technological development of the Russian Federation and tasks initiated by researchers and conditioned by the internal logic of science development, state and public support for fundamental research as a tool for long-term development of the country
	Fair competition	Use of public mechanisms to provide access to public infrastructural, financial and non-financial resources to the most productive research teams, other subjects of scientific, scientific-technical and innovative activity regardless of their organizational and legal form and form of ownership

for the use of innovative methods, new technologies in the transformation of education and science, and the integration of education, science and business.

But such global changes in the organization of scientific, technical and innovation activities lead to the emergence of new significant internal factors for the scientific and technological development of the country, which also need to be taken into account in the analysis of ways to address the goals and objectives [1].

Such factors include:

- compression of the innovation cycle: the time for obtaining new knowledge and creating new technologies, products and services and bringing them to market has been significantly reduced;
- blurring of disciplinary and industry boundaries in research and development;
- a sharp increase in the volume of scientific and technological information and the emergence of fundamentally new ways of working with it;
- changes in the forms of organization, hardware and software tools for research and development;
- growing requirements to the qualification of researchers, international competition for talented highly qualified workers and their involvement in science, engineering, technological entrepreneurship;
- increasing role of international standards;
- the emergence of a limited group of countries dominating in research and development and the formation of a scientific and technological periphery that is losing its scientific identity.

THE ROLE OF FUNCTIONAL REQUIREMENTS

The basic requirements for the functioning of the campus listed in the introduction should be ensured by an appropriate material and spatial environment. For example, in order for the campus to become a platform for joint development of researchers and businesses, incubators and startups, it is necessary to provide a number of multifunctional spaces for joint projects of the university and companies, which will be aimed at the creation and testing of new

▶ technologies. In the necessary volume for the future development and corresponding to a number of functional requirements for the possibility of transformation. Today, in the architectural and urban planning understanding, a modern scientific and educational complex is a cluster system, which includes various types of objects: educational centers, workshops, research laboratories, as well as public recreational and residential facilities [7].

In order to keep the campus oriented towards practice-orientedness, to increase students' responsibility for the results of learning, to form programs of cognitive development of personality, to participate in modular learning, to individualize the educational process, it is necessary to provide the campus infrastructure with appropriate spaces, educational and technological equipment, networks and equipment for building individual educational trajectories or educational trajectories for small groups. And to integrate the campus into the city structure with a balance of functions for convenient life, study and work, it is necessary to adapt its infrastructure, material-spatial environment and management models to the new joint demands of the university, business, municipal authorities, local residents, etc. using parameterization mechanisms. The output should provide the necessary degree of dispersion, i.e. the counter availability of urban infrastructure necessary to ensure the activities of the campus [8].

At the same time, functional requirements to campus facilities by their specificity can have functional-organizational, functional-technological, functional-infrastructure or functional-operational properties. And refer primarily not to architectural and structural or volume-planning solutions, but to the possibility of transformation and adaptation of spaces, the possibility of using different combinations of educational, technological, research equipment, the availability of technological networks and structures, the ability to change temperature and humidity conditions, the ability to change the magnitude and nature of the load on building structures, the presence and operation of digital systems that create a unified digital campus environment, the availability of integration digital platforms. By their properties, functional requirements can be included and interconnected in the Educational and technological task as a document containing the initial data for design [9]. And the overall functionality of the campus should correspond to the target model of the HEI defined in the program of its development.

The standard of innovative educational environment (campuses) [3] establishes an extensive set of basic requirements for the functioning of the campus in terms of its basic functionality and scientific and educational infrastructure, necessary to ensure at the stages of design and operation of campus facilities. In their main directions, these requirements provide the following capabilities:

- realization of activities within the framework of national and federal projects;
- conducting research and development, creating results of intellectual activity and high-tech products;

- creation of structural subdivisions of universities together with external partners;
- implementation of practice-oriented educational programs together with industrial partners, network programs;
- organization of industry events, including those for city residents, etc.

It is these basic functional requirements that determine the possibility of achieving the socio-economic effects of the campus program at the national level, at the entity level, at the institutional level [10]. In turn, most of the basic requirements consist of groups of detailed requirements that determine the possibility of their clear formulation, control and confirmation.

If we analyze the functional-oriented requirements of the Standard and systematize them by scope of application, we can get a clear picture of what the campus program focuses on (Table 2).

The comparison shows that the main part of the requirements is focused on creating a favorable, efficient, safe environment for education, science and business. And from the significant difference between the number of basic and detailed requirements, we can conclude about the necessary flexibility and transformability of this environment. Thus, we can conclude that in accordance with the Standard, it is supposed to create not only a convenient and compliant infrastructure, but also an educational and material-spatial environment in which it will be possible to realize the stated goals and objectives of innovative development.

Speaking about the lists of requirements defined by the Standard, it would be rational to propose to form a corresponding register of them for more convenient and efficient work with them at the stages of design and operation. The Strategy for the development of the construction industry and housing and communal services of the Russian Federation for the period up to 2030 with a forecast up to 2035 defines that the "register principle of development of technical requirements" is the principle of development of technical requirements, which implies the possibility of their practical implementation (including on a mandatory basis) only after the inclusion of such requirements in the relevant register [11].

In addition, it is obvious to assume that requirements, even those included in the relevant register, cannot be equivalent. In connection with the entry into force of SP 555.1325800.2025, it is possible to define that a requirement is a provision (normative document) containing quantitative and (or) qualitative criteria that must be met to divide the requirements into groups [12]. At the same time, key requirements can be singled out as requirements, the fulfillment of which during the entire life cycle of a building or structure (including the implementation of such requirements in the process of construction, reconstruction, capital repair, as well as maintenance of parameters and characteristics of buildings and structures at the level set by these requirements in the process of operation) directly ensures the fulfillment of the relevant tasks, i.e. ensuring the functional characteristics of the capital construction object.

Table 2. Systematization of functional requirements for campus facilities

Types of requirements	Number of basic requirements	Number of detailed requirements
Functional-technological (including requirements for the level of digital services and technological entrepreneurship ecosystem)	25	74
Functional and organizational (including service and openness requirements)	12	18
Functional and infrastructural (including requirements for material and technical equipment)	27	68
Functional and operational (including requirements provided at the design stage)	14	43

CHALLENGES TO IMPROVE THE FUNCTIONALITY OF CAMPUSES

In the conditions of rapid economic development it is important to provide not only opportunities for advanced education, but also for advanced architectural and construction design of higher education institutions.

It is necessary to use the results of modern ergonomic research (anatomical, physiological and psychological changes that a person undergoes during work) not only in the organization of workplaces and within the framework of industrial design [13], but also in the organization of "educational" places and the design of the necessary material and spatial environment of innovative campuses. Only in this case there is an opportunity to increase the productivity of the participants of the educational and research process. At the same time, it is especially difficult, but also important, to ensure the communication between educational, research and innovation centers on the basis of spaces suitable for conducting joint projects.

In particular, by providing pre-determined and justified requirements and parameters for the material-spatial environment that enhance its functionality, it is possible to:

- close the needs of students, faculty and staff in a comfortable environment for living, learning and working;
- avoid the deficit of teaching and laboratory spaces, places in dormitories and sports and recreational infrastructure [6];
- to recalculate the standards of space per 1 student, which at the moment do not correspond to the realities and foreign analogs;
- expand options for conducting relevant scientific research and engaging in innovative activities;
- close the demand for the use of end-to-end technologies in the educational process, for example, technologies for storing and analyzing big data, virtual and augmented reality technologies, quantum computing, etc.;
- provide conditions for the implementation of joint projects with business, ordering research and R&D from the university.

It is important to note that the weakest point in the prospects of the campus program is the organization and management of interaction between universities and the real sector of the economy and industry business [14]. The discontinuity of the innovation cycle leads to the fact that public investments in human capital actually ensure the growth of competitiveness of other economies, as a result of which, the ability to retain the most effective scientists, engineers, entrepreneurs who create breakthrough products is significantly reduced in comparison with the countries leading in innovation. Against this backdrop, there is a perception that increasing the functionality of existing and emerging campus facilities will offer participants the environment necessary to realize innovative ideas and quickly bring new products to market, increase the general interest in the implementation of joint projects, entail investments in infrastructure, and benefit companies from such partnerships.

Considering the campus program at the state level, one cannot but note that in order to ensure the independence and competitiveness of our country through the creation of an effective system for building up and making the fullest use of the intellectual potential of the nation, it is necessary to solve a number of complex and still open tasks. Among them:

- creation and development of mechanisms for identifying talented young people and building a successful career in science, technology and innovation;

- creation of a system of conditions for conducting research and development, corresponding to modern principles of organization of scientific, scientific-technical, innovative activity with the best Russian and world partners;
- formation of an effective system of communication in the field of science, technology and innovations, providing increased receptivity of the economy and society to innovations, as well as conditions for the development of knowledge-intensive business;
- formation of an effective modern end-to-end management system in the field of science, technology and innovation;
- promoting the formation and development of models of international scientific and technological cooperation and international integration in the field of research and technological development.

CONCLUSIONS

Today there is a need to consolidate around the program of university campuses researchers in the field of construction, design, pedagogy, psychology in order to study the impact of the functional characteristics of the material and spatial environment of universities on the effectiveness of the educational and scientific process, integration with business and industry, and design options in accordance with the requirements of tomorrow. Only such consolidation will allow to ensure the possibility of an effective response to technological challenges, taking into account the increasing relevance of synthetic knowledge and technologies created at the junctions of multiple disciplines. And the campus begins to represent an optimal form of organization of complex forms of activity between permanent residents-participants of the project campuses, partner network and external consumer environment, which cannot occur separately [15]. In this case, the object of management in the campus becomes the creation of conditions for the emergence of joint activities and the appropriate selection of tools.

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Роль функциональных требований к объектам университетских кампусов при их проектировании и эксплуатации

Данная статья является продолжением серии публикаций, посвященных дальнейшему развитию в нашей стране сети университетских кампусов как инновационных образовательных пространств. В настоящий момент перед российской экономикой стоят большие вызовы в области технологического развития. А интеграция образования, науки и технологий на базе современных образовательных пространств играет новую роль как основополагающий элемент реализации национальных проектов и решения многих глобальных проблем. В предыдущих публикациях в рамках данного направления автор раскрывал результаты своих исследований, определяющих возможность и эффективность внедрения и применения в рамках развития инновационных образовательных пространств ряда многофункциональных инструментов, таких как «Образовательно-технологические условия», «Образовательно-технологическое задание», «Комбинаторные матрицы». Были описаны пути интеграции «Образовательно-технологического задания» с информационными моделями объектов капитального строительства в составе кампусов. Проанализированы особенности управления жизненным циклом разнообразных объектов университетских кампусов.

Настоящая статья посвящается выявлению определяющей роли функциональных требований и их превалирования в современной образовательной среде над архитектурными, конструктивными, техническими и другими требованиями. Ведь именно они определяют свойства создаваемой и развиваемой материально-пространственной среды университета, которая, в свою очередь, способствует повышению престижа и конкурентоспособности высшего образования. В статье затронут междисциплинарный подход к этапам проектирования, эксплуатации, ремонта, модернизации кампусных объектов, определяемых необходимостью решения в них разнообразных задач, вовлечения в их функционирование студентов, преподавателей, ученых, предпринимателей разных возрастов с различными интересами. Именно междисциплинарный подход может обеспечить плотность и интенсивность коммуникаций, качество пространства, гибкость, способность перестраивать и экспериментировать, разнообразие неакадемических функций, формирование эффективных экономических и управленческих моделей.

Ключевые слова: научно-технологическое развитие, инновационные методы, материально-пространственная среда, технологические компании, требования, междисциплинарный подход, параметры среды

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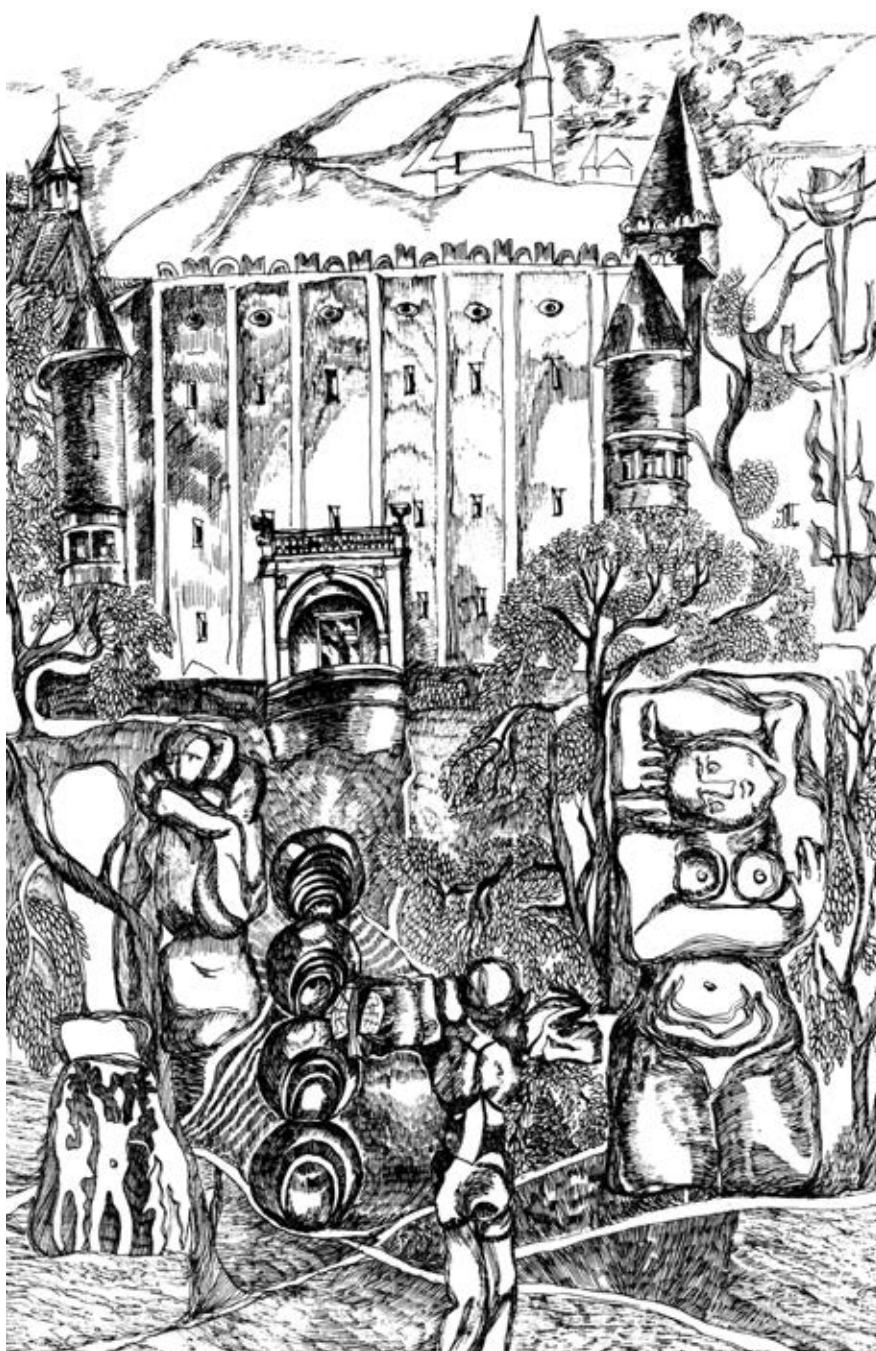
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Digital Platform for Life Support Management: Topological Concept

In modern digital control platforms, reliability is achieved through the ability to reroute flows in the event of breakdowns and failures. To achieve this, it is possible to use a topological approach that considers the interrelations of elements in various systems, including life support. An overview of existing flow routing algorithms is given; their advantages and disadvantages are given. The paper presents a concept of flow management based on topological tables. Formal concepts of rank (node–edge–face–cell hierarchy) are introduced. For each pair of ranks, a topological contact relation is introduced, and the resulting matrix of sixteen topological tables T_{km} records the incidence of elements without using metric information. Such a structure forms a compact, stable connectivity storage, simplifying network updating and analysis. Then, we consider how, based on these concepts, it is possible to organize the storage of connectivity information (topological tables) and use them to reroute data flows in the event of node or channel failures, increasing network reliability. A description of the flow rerouting algorithm is given. After a node or link failure is detected, the corresponding records in the tables are marked as inactive, then the affected sessions are automatically identified, and the shortest bypass route is selected for each.

The sequence of operations includes:

1. Prompt table updating.
2. Classification of the affected flows.
3. Search for an alternative path or selection of a previously saved backup.
4. Instant switching to an alternative route without inter-node exchange of service messages.

If backup routes are available, the downtime is limited by the event detection delay; otherwise, the path is calculated using the updated graph with linear complexity.

Keywords: digital control platforms, redirection of information flows, maintaining operability during failures, topological tables, topological contact, network reliability, neighbourhood

INTRODUCTION

The importance of detecting faults in low-current, fire-fighting, etc. systems

In today's world, the safety and reliability of engineering systems play a key role in both the private and industrial sectors. Low-current systems, fire-fighting systems, and communication systems represent complex technological solutions that ensure the uninterrupted operation of critical facilities, the safety of people, and the preservation of property. However, even a minor malfunction in these systems can lead to serious consequences, including disruptions in production processes, material losses, and — most critically — a threat to life and health.

Detecting faults at early stages not only minimizes risks but also significantly reduces repair and maintenance costs. For the effective functioning of all these systems, it is necessary to implement methods for diagnosis, monitoring, and prevention of potential problems. Modern technologies such as automated control systems, intelligent data analysis algorithms, and specialized equipment help to increase the accuracy and timeliness of fault detection.

One of the promising directions for improving diagnostic systems is the development of a new method for effective resource redistribution based on a topological approach. This method allows one to take into account the structure and interrelations of system elements, which contributes to a more rational distribution of loads, a reduction in the risk of failures, and an increase in overall infrastructure reliability. The application of the topological approach

enables the identification of potential bottlenecks, the prediction of possible faults, and the optimization of resource usage to enhance system efficiency.

This article examines the importance of timely fault detection in low-current systems, fire-fighting systems, and communication systems, and proposes an innovative approach to resource redistribution based on topology. Special attention is paid to the main causes of problems, methods for their elimination, and practical techniques that help to improve the reliability and efficiency of these systems.

OVERVIEW OF EXISTING ALGORITHMS

Currently, there are many algorithms aimed at the effective redistribution of resources in low-current systems, fire-fighting systems, and communication systems in emergency situations. Among the most common methods are:

Dynamic Resource Redistribution Algorithms: these methods are based on real-time monitoring of system status and decision-making based on changing parameters. They are widely used in automatic control systems, allowing for rapid response to emergencies [1, 2]. A disadvantage of this approach is the high computational load and the need for constant data collection and processing, which may lead to delays unacceptable in emergency situations.

Graph Routing Algorithms: used in network and communication systems for finding optimal paths for data transmission and load redistribution [3, 4]. Examples include Dijkstra's algorithm, Bellman-Ford [5], and their modifications [6–8]. Their

disadvantages, similar to those of dynamic resource redistribution, are the high computational complexity when scaling the network and limited adaptability to sudden failures.

Optimization Methods Based on Queueing Theory: these methods regulate data flows and allocate the bandwidth of communication systems [9, 10]. They minimize delays and data losses in emergency situations. However, they are dependent on input parameters and are complex to adapt to dynamically changing conditions.

Artificial Intelligence and Machine Learning Methods: algorithms using neural networks and deep learning are capable of predicting potential faults and redistributing resources in advance to minimize damage. Their explosive increase in efficiency is associated with the development of electronics and parallel computing [11–14]. However, these methods require large amounts of training data, produce decisions that can be difficult to interpret, and involve lengthy training processes.

Hybrid Algorithms: these combine several approaches, allowing for the consideration of various risk factors and adaptation to specific conditions [15–17]. Such algorithms are used in complex engineering systems where a high degree of autonomy and precision is required. However, the combination of different approaches also brings together the disadvantages of each method, such as complexity of implementation, high computational load, and the need for fine tuning.

The application of efficient resource redistribution algorithms plays an important role in ensuring the uninterrupted operation of low-current systems, fire-fighting systems, and communication systems. However, most existing approaches have certain drawbacks related to high computational complexity, low adaptability, and dependence on external parameters. Using a topological approach helps to eliminate these problems, increase system predictability, optimize data routing, and improve overall resource distribution, ultimately enhancing network reliability [18]. The main outcome of its use is the ability to predict and preempt bottlenecks, which reduces the load on the computational system and speeds up the system's response. While each group of methods has its individual advantages, the topological approach can be used with graph algorithms for predicting and reserving critical nodes; in the analysis of optimization methods based on queueing theory, the proposed approach allows for dynamic load transfer and identification of backup routes; and for artificial intelligence and machine learning methods, topological information becomes available as additional features for more accurate prediction. Simplification of the structural organization of algorithms through the use of topological data for more logical routing and resource distribution becomes possible when employing a topological approach for hybrid algorithms.

Despite the fact that the application of the topological approach can eliminate most of the shortcomings of the considered methods, the aim of this work is to develop a new, "inherently" topological algorithm.

MATERIALS AND METHODS

Statement of the problem

The goal of this work is to develop a new algorithm based on topological tables [19, 20] that is free from the disadvantages of the aforementioned methods. In the proposed method, the authors aim to move away from describing topology by traditional programming methods — which represent the relationships between

elements and objects using real numbers — and towards a purely topological method. This is motivated by the fact that processing and interpreting real numbers on a computer always lead to inaccuracies.

Hierarchy of Components

To formalize the network, we introduce a hierarchy of topological elements by rank (dimension):

- **Node (Vertex):** a zero-rank (0-dimensional) element. It denotes a basic object (for example, a device, a node computer, or a switch). The set of all nodes is denoted by N ;
- **Edge (Link):** a first-rank (1-dimensional) element. It represents the connection between two nodes through which flows can pass (for example, a cable or a communication channel). Formally, an edge e connects a pair of nodes (n_1, n_2) , with $(n_1, n_2) \in N$. The collection of all edges is denoted by E ;
- **Face (Surface):** a second-rank (2-dimensional) element. In the context of networks, this may correspond to a closed cycle of links forming an alternative route. A face is defined as a closed sequence of edges that form a loop. For example, if the nodes and links of a network form a ring, the faces represent such ring topologies. The set of faces is denoted by F ;
- **Cell (Volume):** a third-rank (3-dimensional) element. This usually corresponds to a closed volume bounded by faces. In network models, cells occur less frequently but may describe, for instance, autonomous subnets or isolated segments completely surrounded by links. The set of cells is denoted by C .

Definition 1: The *rank* of a topological element is the dimension of the corresponding object: nodes have rank 0, edges rank 1, faces rank 2, and cells rank 3. This hierarchical model corresponds to representing the network as a cellular complex, where nodes are 0-dimensional vertices, edges are 1-dimensional arcs, faces are 2-dimensional polygons (cycles), and cells are 3-dimensional regions. This hierarchy allows for a formal description of the network structure and the interrelations between its elements at different levels.

Geometric Contact

Geometric contact: two elements, whose boundaries have common points, but which do not have any other common point, are in geometric contact. Fig. 1 shows examples of geometric contact of a T-shaped face f_1 and a rectangular face f_2 .

In the centre diagram of Fig. 1, nodes n_1, n_2 and edge e_1 are subdomains(subset) of face f_1 but not of face f_2 . The points of nodes n_1, n_2 and edge e_1 are interior points of edge e_2 of face f_2 . Faces f_1 and f_2 are in geometric contact, but not in topological contact. The boundaries of the two domains do not contain a common domain.

In the right diagram of Fig. 1, node n_3 and the red line segment are not domains of the boundary of face f_1 . Node n_3 and the red line segment are not domains of the boundary of face f_2 . The boundaries of the two faces do not have a common domain. Faces f_1 and f_2 are in geometric contact, because their boundaries have common points, but the faces do not touch topologically.

Topological Contact and Adjacency of Elements

A key concept in the structural description is topological contact — the incidence relationship between elements of different ranks. An element of a lower rank is said to be in topological

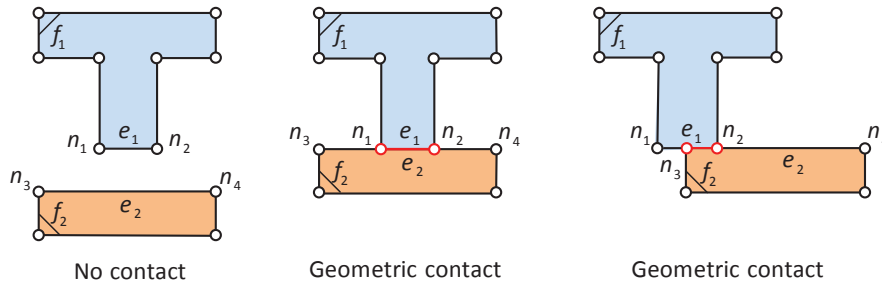


Fig. 1. Geometric contact between faces f_1 and f_2

contact with an element of a higher rank if it is part of its composition (i.e., it forms part of its boundary):

- a node is in topological contact with an edge if the node is one of the endpoints (vertices) of that edge. In other words, node n is incident to edge e , if $n \in e$;
- an edge is in topological contact with a face if the edge is part of the cycle forming that face. Formally, edge e is incident to face f , if $e \in f$ (the edge lies on the boundary of the face);
- a face is in contact with a cell if the face is part of the boundary of that cell (the face forms part of the surface enclosing the cell).

Thus, topological contact defines a “part – whole” relation: a node is included in an edge, an edge is part of a face, and a face bounds a cell. This relation is bidirectional: for example, if node n is in contact with edge e (node n — endpoint of e), then edge e is also in contact with node n .

In addition to the incidence of different ranks, one can introduce the notion of adjacency among elements of the same rank based on contact: two elements of the same type are considered adjacent if they share a common element of a lower rank. For instance, two edges are considered adjacent if they share a common node; two faces are adjacent if they share at least one edge; and so on. For example, if edges $e_1 = (n_1, n_2)$ and $e_2 = (n_2, n_3)$ share node n_2 , then they are topologically adjacent via node n_2 .

Definition 2: topological contact is the relation $\Gamma, \Gamma(\mathbf{X}, \mathbf{Y})$ between elements of different ranks, for which $\Gamma, \Gamma(\mathbf{X}, \mathbf{Y})$ is true if element \mathbf{X} is included in (or forms part of the boundary of) element \mathbf{Y} . In practice, the most important contacts are those between nodes and edges (node – edge) and between edges and faces (edge – face), as they describe network connections and cycles, respectively.

The presence of an extensive structure of contacts means that the network possesses alternative connections: for example, if two nodes are connected by several different edges through various intermediate nodes (i.e., there exists a cycle/face linking them), then if one of the nodes or edges fails, the network can remain connected through other elements. It is precisely the use of topological contacts (incidences) that allows one to identify such backup routes.

Topological Tables for Flow Management

For effective management of data flows in a network and their redirection in case of failures, it is necessary to have a data structure that stores complete information about the network’s topology — who is connected to whom and via which cycles. A topological table is a collection of data about the topological contacts throughout the network, organized in a convenient form (for example, as adjacency lists or incidence matrices).

Essentially, a topological table contains a map of the network: for each node, all incident edges (and the neighboring nodes connected via those edges) are specified; for each edge, its terminal nodes and possibly the cycles it belongs to are recorded; and so on. In its simplest form, a topological table can be implemented as a dictionary or adjacency table: each node is mapped to a list of neighboring nodes (directly connected via an edge). Additional information about cycles may also be stored — for instance, identifiers of the cycles (faces) in which each edge participates, which allows for the detection of alternative bypass routes.

Example of topological table’s structure: consider a network with nodes $N = \{n_1, n_2, n_3, n_4\}$ and edges $E = \{\{n_1, n_2\}, \{n_2, n_3\}, \{n_3, n_4\}, \{n_4, n_1\}\}$, forming a cycle $f_1 = n_1 - n_2 - n_3 - n_4 - n_1$ (face f_1).

A topological adjacency table

Node	Neighboring Nodes (via an Edge)
n_1	n_2, n_4
n_2	n_1, n_3
n_3	n_2, n_4
n_4	n_1, n_3

Here, for example, the row for node n_1 shows that n_1 is in topological contact with nodes n_2 and n_4 (via edges $\{n_1, n_2\}$, and $\{n_4, n_1\}$, respectively). Similarly, the table lists the direct connections for each node. Such a table is essentially equivalent to storing the node – edge incidence lists, but in a human-readable form that displays the entire connectivity structure.

Another way to represent a topological table is to list all known routes in the network, indicating both the primary and backup paths. For any destination node, one can store not only the optimal route but also one or several alternate routes. This concept is used in some routing protocols. For instance, the EIGRP protocol builds a topological table at each router, in which both the best (primary) route to each network destination and alternative routes are stored [21]. Under normal operation, traffic follows the primary route, but if the primary path becomes unavailable, the protocol immediately switches to the backup route from the topological table without additional computations or message exchanges with neighbors. This mechanism significantly reduces the time required to restore network connectivity in the event of failures.

Definition 3: a topological table is a data structure containing complete information about the network topology (the topological contacts between nodes, edges, faces, etc.) used for determining the routes for data flows. Formally, a topological table can be represented as a set of mapping: $\tau_0: N \rightarrow 2^E$ (one that maps each node to the set of incident edges), $\tau_1: E \rightarrow 2^N$ (maps each edge to the pair of terminal nodes), $\tau_2: E \rightarrow 2^F$ (maps an edge to the set of faces it

T_{km}		Rank m , component type			
		1 node	2 edge	3 face	4 cell
Rank k , component type	1 node	T_{11}	T_{12}	T_{13}	T_{14}
	2 edge	T_{21}	T_{22}	T_{23}	T_{24}
	3 face	T_{31}	T_{32}	T_{33}	T_{34}
	4 cell	T_{41}	T_{42}	T_{43}	T_{44}

Face – edge – table						
Face	Edges of the face					
1	1	2	3	4	–	–
2	1	31	7	25	–	–
5	4	49	23	24	5	26
6	7	9	10	8	6	5
7	6	25	22	24	–	–
12	7	32	58	27	–	–
13	58	35	55	30	–	–

Fig. 2. Matrix of the topological tables for linear complexes

belongs to), and so on. Based on this data, one can derive the list of neighbors for each node and identify the presence of alternative paths (cycles) between nodes.

Thus, the topological table serves as the basis for flow management algorithms. With such a table, the system can solve the routing problem: choosing optimal paths for flows based on the current network state and switching flows to alternative paths when the state changes (for example, upon failures). Unlike local routing tables (which store only the next hop for a destination), the topological table contains a global view of the network’s connectivity, enabling flexible route reconfiguration and the discovery of bypass solutions. The following sections describe algorithms for redirecting flows in case of failures based on topological tables.

The matrix in Fig. 2 shows the 16 types of topological tables that can be constructed for a linear complex with node, edge, face and cell elements. The symbol T_{km} denotes a table, whose pivot elements have rank k and whose contact elements have rank m . For example, table T_{32} in Fig. 2 is the topological face–edge–table. Table T_{23} is the topological edge–face–table. The diagonal elements of the matrix in Fig. 2 are tables whose pivot and contact element are of equal rank.

RESULTS

Algorithm for Flow Redirection in the Event of a Node Failure

A node failure is a situation in which a particular network node suddenly stops functioning (for example, due to a device power-off or a node software fault). Formally, when node $X \in N$ ceases to function, all edges $e \in E$ incident to X (i.e. for which $X \in e$) also cease to operate. As a result, the removal of X disrupts all flows that passed through it. The task of flow management is to promptly restore these flows by redirecting them along alternative routes, if available in the topology.

The redirection algorithm can be divided into several stages:

1. **Updating the Topological Table:** immediately after detecting the failure of node X , the system updates the topological table by marking node X as non-operational and excluding all edges incident to X . This leads to changes in the neighbor lists: all nodes that were previously neighbors to X lose their connection with it. Formally, this corresponds to removing vertex X and all its incident edges from the network graph $G = (N, E)$, resulting in a new graph $G' = (N \setminus X, E \setminus e: X \in e)$.

2. **Identifying Affected Flows:** the flows whose routes included the failed node X are identified. Typically, these are flows where X served as an intermediate node (a router) rather than being the sender or receiver. Based on the topological table, one can find

pairs of nodes whose connection passed through X . If the topological table already contains both primary and alternative routes for each destination, then at this stage it is simply determined which primary routes passed through X , and the corresponding backup routes are retrieved from the table.

Flow Redirection: for each affected flow, a new route that bypasses node X is calculated. There are two approaches:

- **Precomputed Routes:** if the topological table already stored alternative paths (backup routes) for the given directions, the system immediately switches to them. In this case, the restoration delay is minimal — it is sufficient to update the local routing tables on the neighbors of X , replacing X with the next node from the backup route;
- **Dynamic Route Recalculation:** if alternatives were not precomputed, the system initiates a path-finding algorithm on the updated graph G' . Typically, a shortest path algorithm (for example, Dijkstra’s algorithm or breadth-first search) is used based on the updated topological table. Since the table contains complete connectivity information, the source node or a designated network controller can establish a new route from the sender to the receiver that bypasses the failed node X . The newly found alternative path is then distributed to the corresponding nodes as the new route for that flow.

4. **Restoration of Transmission:** the updated routes take effect, and data is redirected along the new paths. The flow is restored — packets reach their destination by bypassing the segment affected by the failure.

It is important to note that the feasibility of step 3 (the existence of an alternative path) directly depends on the original topology. If the failed node was an articulation point of the network (i.e., its removal splits the graph into several disconnected components), then no alternative route exists within G' . Formally, node X is an articulation point if, upon its removal, the graph G' breaks into two or more connected components. In such a case, some nodes become completely isolated, and the flows to them cannot be restored (until the physical problem is resolved). A topology is considered robust if it lacks such articulation points (i.e., the graph is biconnected by vertices) — in that case, the network withstands the failure of any single node without losing connectivity. Similarly, the absence of bridges (edges whose removal would disconnect the graph) signifies resilience to individual link failures. The design of a reliable communication system must ensure the required degree of connectivity (for example, biconnectivity of the network graph), and flow management must efficiently utilize this connectivity for routing.

With the presence of backup connections, the topological approach ensures high reliability: flows automatically “bypass” the failed node via other routes embedded in the network structure.

► The recovery time is limited either to the immediate switch to a precomputed backup route or the time needed to compute a new path. Because the topological table stores global network information, the search for alternatives is performed locally (within a controller or router) without the need to query remote nodes for their status — thereby accelerating the system's reaction to a failure. For example, in self-healing networks based on graphs, route state converges faster if each node is already aware of the existence of bypass paths [21]. Reducing the downtime of flow increases the overall fault tolerance of the communication system.

Example: Restoring a Flow After a Node Failure

Consider a specific example illustrating the application of a topological table for redirecting a flow in the event of a node failure. Suppose there is a network of four nodes (A, B, C, D) connected in a ring (each node is connected to two neighbors): A–B, B–C, C–D, D–A. Initially, traffic between nodes follows the shortest paths. Assume that node B is designated as the intermediate router for the data flow from A to C (i.e., data from A is routed through B to C). Under normal conditions, node D remains idle for this flow, even though it is physically part of the ring.

Now, suppose node B fails (for example, due to a sudden power outage or software error). Node B and both its incident channels (A–B and B–C) cease to function. From a topological standpoint, B becomes unavailable, and the ring opens up into a chain A–D–C. Nodes A and C lose their direct connection with B but remain connected to each other via node D. The data flow from A to C, interrupted at the moment of B's failure, can be restored through the alternative path.

In the presented example (Fig. 3, 4), the failure affects only one flow (between A and C). After rerouting through D, data continues to be delivered. The flow's downtime is determined solely by the time required to detect the failure of B and select an alternative route. If the network did not have the redundant link to D (for instance, if the topology were simply a chain A–B–C without node D), then the failure of B would make communication between A and C impossible — illustrating the importance of planning a topology without articulation points.

Initial Topology: Primary path A→B→C highlighted

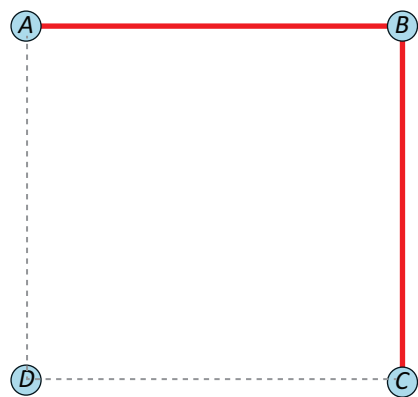


Fig. 3. The primary network topology of the four-node ring (A, B, C, D) with the main flow from A to C (highlighted in red via node B). The grey dashed lines indicate the network's backup links (in this case, the alternative A–D–C path) which are not used during normal operation. At this stage, the topological table contains the primary route A→B→C for the A→C flow along with information about the existence of an alternative cycle A–D–C

Initial route A→D→C after failure of node B

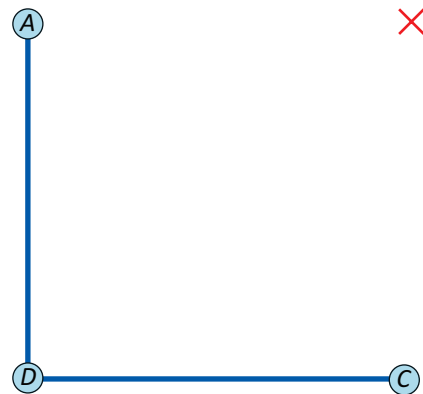


Fig. 4. The network after the failure of node B. Node B (located in the upper right) is marked with a red cross to indicate its failure. The links A–B and B–C are broken. However, thanks to the ring topology, nodes A and C remain connected through D (the route A→D→C is highlighted in blue). Immediately after the failure, the topological table is updated: node B is removed from the neighbor lists. The new neighbor lists become: A: {D}, C: {D}, D: {A, C}. Based on these data, the system detects that a path between A and C still exists (via D). The route A→D→C is either retrieved from the topological table (if it was precomputed as a backup) or computed anew, and the flow from A to C is redirected through node D, bypassing the failed B

DISCUSSION

The considered ring topology exhibits redundancy — each node has a degree of 2 (two links), and the graph is biconnected. The removal of any single node still leaves the graph connected. Therefore, the probability of maintaining connectivity between any pair of nodes is higher than in a linear topology. In such a network, topological tables store alternative routes (for example, a direct route through one neighbor and a bypass route through the opposite node), which enhances the network's self-healing capability. In real networks, connections can also be interrupted for other reasons (link failure, node overload, software error), but the principle remains the same: the more alternative paths that are provided for and reflected in the topological tables, the higher the network's resilience. Flow management based on topological tables allows for the automatic selection of these routes, maintaining service even in the face of partial infrastructure failures.

CONCLUSION

Flow management methods based on topological tables demonstrate effectiveness under conditions of node and channel failures. The formal representation of the network through the hierarchy "node – edge – face – cell" and the concept of topological contact provide a rigorous foundation for routing algorithms. Topological tables serve as the central element linking theory and practice: they store the structural information about the network necessary for rapid flow redirection. The inclusion of backup routes in topological tables enables the system to react instantly to failures, switching to alternative paths without lengthy route recalculation. Even if alternatives are not precomputed, the availability of the complete topology accelerates the search for a new route. Thus, the topological approach to flow management enhances the reliability of the communication system — the failure of individual

components does not lead to catastrophic network breakdowns, as issues are localized and bypassed. This is especially critical for low-current systems and automated diagnostic platforms where continuous and timely data transmission is essential.

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Цифровая платформа управления жизнеобеспечением: топологическая концепция

В современных цифровых системах управления надежность обеспечивается способностью перенаправлять потоки при сбоях и отказах. Для этого можно применять топологический подход, учитывающий взаимосвязи элементов в различных системах, включая системы жизнеобеспечения. Представлен обзор существующих алгоритмов маршрутизации потоков, отмечены их достоинства и недостатки.

В работе предлагается концепция управления потоками на основе топологических таблиц. Вводятся формальные понятия рангов (иерархия «узел – ребро – грань – ячейка»). Для каждой пары рангов задается топологическое отношение контакта, и результирующая матрица из шестнадцати топологических таблиц Ткм фиксирует инцидентность элементов без использования метрической информации. Такая структура образует компактное устойчивое хранилище связности, упрощая обновление и анализ сети.

Далее рассматривается, как с помощью этих понятий можно организовать хранение информации о связности и применять ее для перенаправления потоков данных при отказах

узлов или каналов, повышая надежность сети. Описан алгоритм перенаправления: после обнаружения отказа соответствующие записи в таблицах помечаются как неактивные, затем автоматически идентифицируются затронутые сеансы и для каждого выбирается кратчайший обходной маршрут. Последовательность операций включает:

1. Оперативное обновление таблиц.
2. Классификацию затронутых потоков.
3. Поиск альтернативного пути или выбор ранее сохраненного резервного.
4. Мгновенное переключение на альтернативный маршрут без межузлового обмена служебными сообщениями.

При наличии резервных маршрутов длительность простоя ограничивается задержкой обнаружения события; при их отсутствии путь вычисляется по обновленному графу с линейной сложностью.

Ключевые слова: цифровые платформы управления, перенаправление информационных потоков, поддержание работоспособности при отказах, топологические таблицы, топологический контакт, надежность сети, соседство

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Application of the critical chain method as a way to reduce the time of construction project implementation

The paper considers the problems of modern development companies in a complex and unstable economic environment. In the current conditions, the question arises about the stability of the functioning of construction enterprises, which are forced to look for new methods, approaches and tools in the conditions of competition, complex economic and market conditions to maintain the efficiency of operational processes, as well as to maintain the relevance and economic efficiency of construction projects. In the paradigm of these conditions, traditional ways of working on projects for developers require modernization and updating, taking into account modern methods of management, control, and the system of internal and external interaction between organizations. At the same time, attention is focused not on the approach of changing and applying new tools or introducing digital or AI tools, but on the basis of changing the internal fundamental methods of the organization. To clearly formulate the problem, the concept of a project, the features of construction projects were given, the methods of planning along the critical path and along the critical chain were analyzed. The study proposes a modification of project planning and control based on the critical chain method. The critical chain method, in comparison with the traditional critical path method, takes the safety time to buffers located at the end of the critical chain and the ends of the feeder chains. Based on this, the study proposes a modification of the method adapted to domestic realities, which assumes an increased total reserve of time in buffers, and proposes the introduction of a contract buffer for the performance of fixed volumes of contract work. For the viability of the modified method, it is proposed to use contracts with "reward" instruments for early completion of work. At the same time, the described method has flexibility in the framework of time estimates in the performance of tasks for its adaptation to specific conditions contained in various construction projects.

Keywords: construction, construction project, project management methods, project execution control, critical chain

INTRODUCTION

Project management is a mechanism that has existed and developed for quite a long time, since 1917. In spite of more than 100 years of history, there have not been many milestones in this field. The main milestones starting with the invention of the Gantt chart can be considered the development of the critical path planning method in 1957 and the invention of the network planning schedule in 1958.

After that new approaches and methodologies to operational management were developed, but globally the planning and project management processes did not change from the methodological point of view.

All projects are based on three main factors: timing, budget and quality. In the current situation of high key rates and widespread use of project financing in construction projects, the decisive factor affecting the success of the project is the timing of project implementation. Each month of the project with the use of project financing is very expensive and has a huge impact on the budget and, as a consequence, on the level of profit.

Two factors also have a significant impact: changes in preferential mortgage lending programs in terms of expiration¹; the national project "Housing and Urban Environment", which aims to annually increase the volume of housing construction up to

120 million square meters. by 2030, and this is without taking into account the construction of necessary infrastructure². All this complicates the situation in the real estate market, in which developers have increased risks. Not only the usual approaches to the implementation and internal component of construction projects [1, 2], but also the sustainability of enterprises in the construction sector may be under threat.

In such conditions, the success of the project largely depends on the timely completion of the project without loss of quality. The key influence on the success of the project and organizations is definitely the correctness of management. Digitalization, artificial intelligence and other modern technological capabilities are only tools, not a panacea in the implementation and management of projects.

A construction project is a multifactor stochastic system. That is, planning predicts a certain set of activities that are necessary to achieve the final goal, and these activities can be disrupted by the influence of uncertainty factors generated by the multifactor environment. This applies to all works of the investment stage of the project: preparatory, design and construction.

In the current economic situation, the author sees the main way to increase the liquidity of the project as a minimum in compliance with the set

¹ House of the Russian Federation. The Preferential Mortgage Programme ended on July 1, 2024. URL: <https://xn--h1alcedd.xn--d1aqf.xn--p1ai/catalog/gotnaya-ipoteka/> (Accessed: 06.03.2025).

² National goals and strategic objectives for the development of the Russian Federation for the period up to 2024 : Decree of the President of the Russian Federation of May 7, 2018 No. 204.

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Factors limiting the production activity of construction organizations

Factors/Period	IV quarter 2019, %	II quarter 2020, %	IV quarter 2023, %	II quarter 2024, %
High level of taxes	41	36	33	31
Lack of work orders	25	29	20	17
High cost of materials, structures and fabrications	29	28	45	46
Insolvency of customers	22	23	15	13
Competition	26	22	20	21
Lack of funding	24	21	13	12
Lack of skilled workers	17	15	24	31
High rate of interest on commercial loans	16	14	14	15
Weather conditions	13	12	11	12

deadlines for implementation (as the failure to meet the deadlines is a ubiquitous factor in most construction projects) fixed in the financial model of the project, and as a maximum their reduction. This is justified by the fact that the transformation in the methods of project management as a way to meet or reduce the required deadlines practically does not require additional financial costs.

THEORY AND METHODS

According to the data of the Federal State Statistics Service, construction companies emphasize the most significant factors limiting production activities, mainly those related to finance^{3,4}. The results of the specimen survey with the distribution of responses of construction companies in percent are shown in Table.

In the course of the work we analyzed the postponement of scheduled delivery dates of apartment building construction projects. The analysis is based on the project data of more than four hundred developers⁵. This indicates that large companies have a large resource and financial reserve to create capacity reserves for all necessary supply lines, such as: project team, special

equipment, workers and crews, construction materials and products. The relationship between construction volumes and average carryover is shown in Fig. 1.

Thus, the average value of postponement is 5.98 quarters, which is 17.94 months or one and a half years. There is also a clear increase in the postponement of deadlines with a decrease in the number of realized objects, i.e. in essence the scale of organizations. In such a case, the most effective method of improving construction efficiency is methodical changes in project management approaches and principles.

At the moment, the vast majority of organizations use the critical path method for planning and management. The author suggests using the critical chain method as an alternative. Within the framework of the research the sequence of work when using each of the methods is not described in detail, there is a lot of scientific literature on this topic [3–6].

Within the framework of analyzing both methods, the main differences between them were identified, they are as follows:

- mandatory resource leveling and elimination of multitasking;
- estimation of the duration of works with 50 % probability;
- supplementing the critical chain (critical path) and the work sequences included in it with buffers — time reserve for work execution.

The first point within the construction project refers more to the planning of design works, because in this case the resources are directly people — architects, designers, engineers, etc. In the framework of the research, the main focus is on the works of

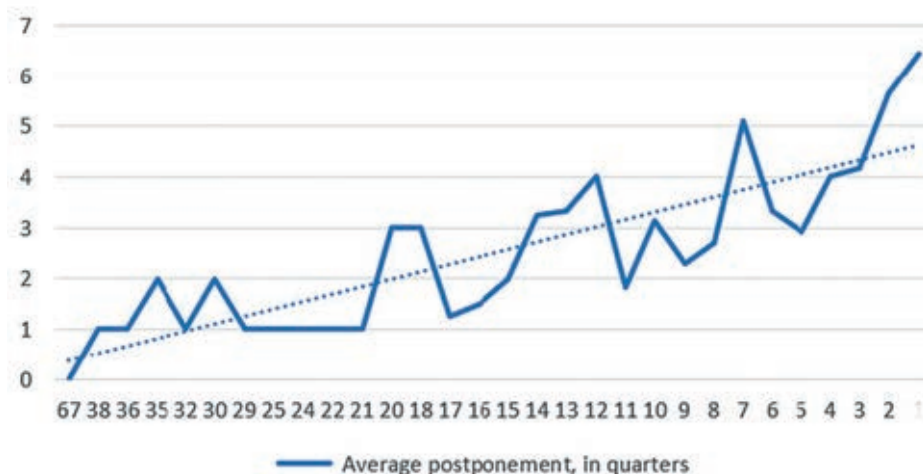


Fig. 1. Dependence of average postponement of delivery date and number of objects

³ Factors limiting the production activities of construction companies in 2019–2020. URL: https://rosstat.gov.ru/storage/mediabank/TASKTSKO/Stroitelstvo_2020.pdf (Accessed: 25.03.2025).

⁴ Factors limiting the production activities of construction companies in 2023–2024. URL: https://rosstat.gov.ru/storage/mediabank/Stroit_2024.pdf (Accessed: 25.03.2025).

⁵ The average delay in the construction of residential complexes of construction and development companies in Moscow and the Moscow region. URL: <https://msk.stroykontrol.info/companies> (Accessed: 21.03.2025).

the construction phase of the project, where the resources are mainly contracting organizations. This stage includes differences numbered 2 and 3.

In considering these differences and the theoretical basis of the critical chain method, it is necessary to take into account the duality inherent in the contracting organization in the performance of work. On the one hand for the project it is a separate independent resource, on the other hand the units performing the work are individual people. The latter fact substantiates the effectiveness and validity of this method within the framework of estimating the duration of work with 50 % probability, since this part is based mainly on psychological traps described in the method [5]. In the framework of the research, project planning and management is considered from the side of ACA organizations, management company or general contracting organization, which do not directly control the performers of works within subcontracting organizations.

The effectiveness of applying the critical chain method to construction projects is confirmed by the following sources [7–9]. In practice, taking into account the above-described features of work on construction sites mainly by contracting organizations, the problem of reducing deadlines is revealed. Within the framework of tender procedures for the performance of certain types of work, potential organizations of performers offer their commercial proposals, which contain the terms and cost of work. These conditions are in fact already minimal for them, because each contractor interested in the execution of works forms in the commercial offer the most balanced conditions for itself taking into account the following parameters: maximum profit — minimum term — minimum risks. Taking this into account, a half reduction of the planned terms initiated by the customer is not favorable conditions for the contractor. This problem makes it impossible to apply the critical chain method in its original form.

As a tool of adaptation to the realities of the construction industry and contracting procedures established in the domestic construction market, the author proposes the synthesis of the critical chain method with motivation tools within the contractual relations of the parties. This will make it possible to cover potential risks on the part of the contractor from the reduction of terms, and at the same time really increase his interest and motivation to conclude a contract with a shortened period of realization.

Taking into account that the share of apartment building projects with the use of project financing according to the Central Bank's data for the 3rd quarter of 2024 exceeded 97 %⁶, and the weighted average rate on loan agreements throughout the Russian Federation is 9.89 % according to the Bank of Russia as of February 1, 2025⁷. It should be taken into account that the data of the Bank of Russia are based on all project finance projects currently being implemented. Most of these projects started when the key rate was much lower. Currently, the rates on project finance contracts are about 27–31 % (the key rate is 21 + 6–10 %). On this basis, an increase in the cost of work contracts as an incentive for contractors is reasonable. It is economically efficient from the project's point of view to contract works that are on the critical chain, as their delay will lead to the failure of the intermediate and

final deadlines of the project, which will entail additional costs to cover the project financing debt. The motivation tools used for each individual project should be selected through local expert assessments, taking into account the reliability of the contracted contractor, the existing relationships, the importance of working within the schedule, etc. Such methods are described in the following sources [10–13].

This adaptation of the application of the critical chain method in synergy with motivational tools in contracting requires additional methodological transformations in the theoretical foundations of the method. First, this approach should be communicated to the contractor (in this case the person or persons on the contractor's side who are responsible for carrying out and handing over the work under the contract) at the stage of preliminary agreement, so that everyone will operate with the same data and clearly understand the control structure. It also obliges the person on the client's side to ensure that the required scope of work is delivered in a timely manner. Secondly, the approach to calculating the project buffer should be changed.

MAIN RESULTS

In the original method, buffers are placed at the end of the critical chain and in the places where parallel non-critical chains of works (feeding) merge with the critical chain. Due to the fact that the critical chain consists of several types of works performed by different organizations, or by different subdivisions of the same organization, with which contracts are signed for the performance of specific volumes, a new way of calculating and placing buffers in the work schedule is proposed as an adaptation. There are many ways to calculate project buffers: the fifty percent method, simple and modified mean square error methods, the method of adapted procedures, and the method of fuzzy numbers⁸. For adaptation we use the most common method of RMS error, it takes into account the difference in the potential complexity of the work performed and allows us to adjust the size of the buffer with the help of expert judgment. The basic formula for calculating the design buffer is as follows:

$$2\sigma = 2\sqrt{\left(\frac{\omega_1 - a_1}{2}\right)^2 + \left(\frac{\omega_2 - a_2}{2}\right)^2 + \dots + \left(\frac{\omega_n - a_n}{2}\right)^2}, \quad (1)$$

where σ — project buffer size (buffer per critical chain);

ω_n — the worst estimated duration of the work, in our case the volume under one contract with a particular contractor.

The maximum estimate, i.e. the worst case, is proposed as 90 % of the work duration;

a_n — average duration of work, also from the volume per contract. Proposed as 50 % of the duration.

In this formula ω_n and a_n are taken from the original estimated duration of the works with the safety net time embedded inside the works.

The essence of the proposed calculation method is to allocate a part of the total project buffer to intermediate — contractual buffers for individual works. It is necessary to distribute the time of safety net from the buffer to the works in progress, and at the same time to preserve the project buffer in order to secure the total project completion time. In the original formula, when using in all works a maximum worst case estimate of 90 % and an expected average

⁶ Project financing of housing construction in the third quarter of 2024. Bank of Russia. URL: https://www.cbr.ru/Collection/Collection/File/54851/pf_2024_Q3.pdf (Accessed: 06.03.2025).

⁷ Information on project financing: concluding loan agreements with developers using escrow accounts for settlements under equity participation agreements, and opening escrow accounts for settlements under equity participation agreements. URL: https://www.cbr.ru/banking_sector/statistics/?cf.date.time=Any&cf.tagid=167 (Accessed: 06.03.2025).

⁸ Behzad Montazeri, Comparing Critical Chain Project Management with Critical Path Method: A Case Study. Western Kentucky University, Master Thesis. URL: https://digitalcommons.wku.edu/cgi/viewcontent.cgi?params=/context/theses/article/2939/&path_info=montazeri__behzad_800980779_thesis.pdf (Accessed: 06.03.2025).

▶ duration of 50 %, the average size of the buffer results in an average of 23 % of the time margin from the reduced to 50 % completion time. In the author's opinion this is not sufficient, since the contractor's estimated duration of the work is already optimistic.

Thus, the following formula is proposed for calculating contractual buffers:

$$\sigma_n = 2\sqrt{((\omega_n - a_n)/2)^2} \quad (2)$$

and to calculate the project buffer:

$$\varphi = \sqrt{((\sigma_1/2)/k_1)^2 + ((\sigma_2/2)/k_2)^2 + \dots + ((\sigma_n/2)/k_n)^2}, \quad (3)$$

where σ_n — project buffer size (buffer per critical chain);

ω_n — the worst estimated duration of the work, in our case the volume under one contract with a particular contractor.

The maximum estimate, i.e. the worst case, is proposed as 90 % of the work duration;

a_n — average duration of work, also from the volume per contract. Proposed as 50 % of the duration;

φ — project buffer size;

k_n — a coefficient showing the weight of a job, i.e. the ratio of the duration of a particular job to the duration of the critical chain.

The k_n coefficient is calculated using the following formula:

$$k_n = v_1 / \sum v_i, \quad (4)$$

where k_n — a coefficient showing the weight of a job, i.e. the ratio of the duration of a particular job to the duration of the critical chain;

v_1 — critical chain operating time;

$\sum v_i$ — total duration of all critical chain operations.

Thus, the proposed calculation method incorporates the flexibility to estimate the probability of average and worst-case duration of the work through expert judgment, taking into account the unique factors for each project, while providing sufficient buffer time for both the work within the critical circuit and for the entire project.

The buffer calculation for feeder circuits should be performed using the method of RMS error given in (1) or the fifty percent method, where half of the total time of the work sequence is used as the buffer.

With the Critical Chain Method, managers have a transparent way to monitor progress through buffers. The important thing is that it is preventive. In the traditional format with the application of the critical path method, the assessment of work progress does not imply the possibility of applying preventive actions to prevent tardiness, because the time margin is built into each specific work of the schedule and the fact of tardiness is fixed too late to prevent it.

The present method proposes to control the progress of work execution by measuring the buffer consumption. Since a buffer is included in the schedule, overdue tasks do not start shifting all the following tasks in the schedule to the right. The overdue work only starts eating up the days put into the buffer by the contract, or in the worst case by the project. And it is the degree of buffer consumption that determines the status of work execution. An example of the diagram is shown in Fig. 2.

As soon as the buffer flow rate leaves the white zone upwards (as in Fig. 2), it means that it is time to take decisive actions to accelerate the completion of current tasks, reinforce the preparation of work fronts, technical and resource support, etc.

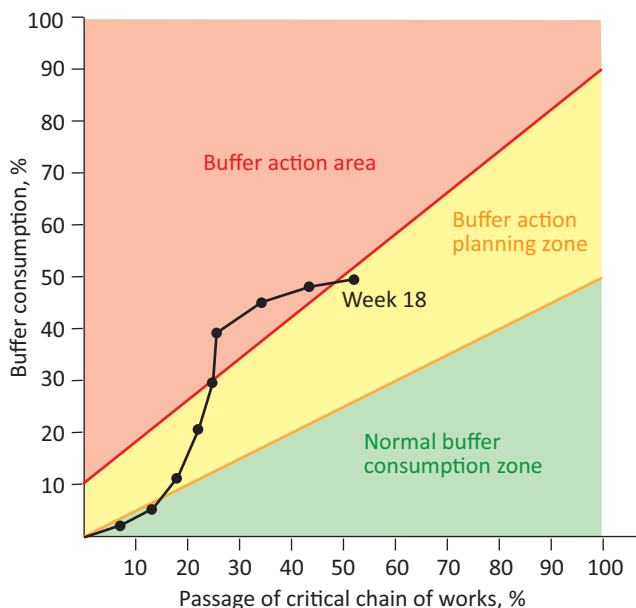


Fig. 2. Example of buffer consumption diagram for a project

CONCLUSIONS

The paper analyzes the current economic situation and its impact on the construction industry. A modification of project planning and control based on the critical chain method is proposed as a way to increase the probability of timely completion of the project, or to reduce the time of project execution. The stated method assumes a larger aggregate time reserve in buffers than in the original, proposes the introduction of a contract buffer for the fulfillment of fixed volumes of contractor work. As a way of motivation for contractors it is supposed to use contracts with "reward" instruments for early completion of works. At the same time, the outlined method has flexibility within the framework of time estimates in the performance of tasks for its adaptation for specific conditions contained in various construction projects. This approach will allow to increase competitiveness, to manage uncertainty more flexibly within the framework of multifactor stochastic system of the construction project, to build direct trustful relations with contractors and to control the progress of the project with the possibility of applying preventive measures to prevent failure of the project terms.

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Применение метода критической цепи как способ сокращения сроков реализации строительного проекта

В статье рассмотрены проблемы современных девелоперских компаний в условиях сложной и нестабильной экономической обстановки. В нынешних условиях ставится вопрос о стабильности функционирования строительных предприятий, которые вынуждены в условиях конкуренции, сложных экономических и рыночных условий искать новые методы, подходы и инструменты для сохранения эффективности операционных процессов, а также для поддержания актуальности и экономической эффективности строительных проектов. В парадигме этих условий традиционные уклады работы над проектами для застройщиков требуют модернизации и актуализации с учетом современных методов ведения, управления, контроля, системы внутреннего и внешнего взаимодействия между организациями. При этом заостряется внимание не на подходе изменения и применения новых инструментов или внедрения цифровых или ИИ инструментов, а на основе изменения внутренних фундаментальных методов работы организации. Для четкой постановки проблемы было дано понятие проекта, особенности строительных проектов, проанализированы методы планирования по критическому пути и по критической цепи. В рамках исследования предложена модификация планирования и контроля проекта на основе метода критической цепи. Метод критической цепи, в сравнении с традиционным методом критического пути, выносит время подстраховки в буферы, расположенные в конце критической цепи и концах питающих цепей. На основе этого в исследовании предлагается адаптированная под отечественные реалии модификация метода, которая предполагает увеличенный совокупный запас по времени в буферах, и предлагает введение контрактного буфера на выполнение фиксированных объемов подрядных работ. Для жизнеспособности модифицированного метода предлагается использование контрактов с инструментами «вознаграждения» за досрочное завершение работ. При этом изложенный метод обладает гибкостью в рамках временных оценок в выполнении задач для его адаптации для конкретных условий, содержащихся в различных строительных проектах.

Ключевые слова: строительство, строительный проект, методы управления проектами, контроль выполнения проектов, критическая цепь

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Москва. Церковь Антипапа на Колымажном дворе. Рисунок, тушь перо

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Analysis of current areas of project activity of development companies in the context of adaptation to crisis phenomena

In conditions of a high key interest rate and, as a result, reduced demand for real estate, the issue of ensuring the commercial effectiveness of development projects is relevant. Based on the analysis of the activities of large development companies in the current crisis conditions, key areas of optimization of project activities in the current negative macroeconomic context have been identified. They can be systematized both on the basis of a hierarchy: the level of the project portfolio and the project level, and according to individual significant criteria. In order to substantiate and illustrate the identified trends and patterns, the article presents the processed statistical data of the ERZ.RF portal for the FSK Group of companies. As a result of the analysis, it is concluded that when choosing a specific direction of adaptation and development, it is necessary to take into account many diverse factors, including target effects, industry specifics of development, current stages of ongoing projects, the need for costs for implementing adaptation and optimization measures, the duration of the planning horizon, the degree of impact of events on the reputation of the development company in the business environment and others. A comprehensive assessment of the effectiveness of the decisions currently being taken will be possible at least in the coming 1–3 years, however, it can already be noted that the market as a whole has adapted to the current conditions and remains in a state of relative stability with a general downward trend in business activity and medium-term stagnation.

Keywords: *anti-crisis measures, portfolio of development projects, portfolio diversification, development project, project efficiency, real estate market in conditions of a Central Bank's highkeyrate and, as a result, reduced demand for real estate, the issue of ensuring the commercial effectiveness of development projects is relevant. In this regard, there is an increased interest in approaches and methods for improving performance indicators*

In conditions of a Central Bank's highkeyrate and, as a result, reduced demand for real estate, the issue of ensuring the commercial effectiveness of development projects is relevant. In this regard, there is an increased interest in approaches and methods for improving performance indicators.

In summary, the effectiveness of a project is determined by the ratio of the effects achieved to the integral costs. According to the researchers, the main reasons for the decline in commercial efficiency in the current conditions are the following factors [1, 2]:

- *Central Bank's high key rate.* The key interest rate affects many components of the effectiveness of a development project. Since most of the funds in the budget of construction projects are borrowed, a high loan rate significantly increases costs, obliging developers to increase the price of their products by the appropriate amount, which, in turn, negatively affects the purchasing power of consumers. On the other hand, an increase in the mortgage rate due to an increase in the key rate increases the cost of monthly payments, which also reduces the purchasing power of the population and leads to a cooling of the real estate market. In turn, reduced demand reduces project revenues in the short term, as well as increases the cost of paying off interest on a housing loan, as apartment sales dynamics affect the loan rate;
- *Partial cancellation of preferential mortgage programs.* The increase in mortgage rates

due to the cancellation of benefits that previously helped stimulate demand in the residential real estate market acts similarly to the previous paragraph in terms of the impact on buyers;

- *Sanctions on the supply of foreign equipment, supplies, and software.* Restrictions force developers to import unavailable goods or import them through third countries, which increases the cost of purchasing them.

Based on the analysis of the activities of large development companies in the current conditions, the directions of optimizing project activities in the context of crisis conditions can be identified. They can be systematized based on the following hierarchy: project portfolio level and project level.

Within the framework of the conducted research, a classification was carried out according to individual criteria. In most of the methods, the processed statistical data of the ERZ.RF portal is provided as a visual illustration of the patterns for the FSK group of companies. The following is a detailed description of the identified approaches.

1. Diversification. Economic diversification generally refers to the distribution of resources, investments, and activities between different fields of activity, industries, types of goods, and others. In the field of development, first of all, it implies the diversification of the project portfolio, the overall effect of which is expressed in reducing the risks associated, respectively, with the state of the economy of a particular region, the state of a particular industry and the solvency of a certain group of the population [3].

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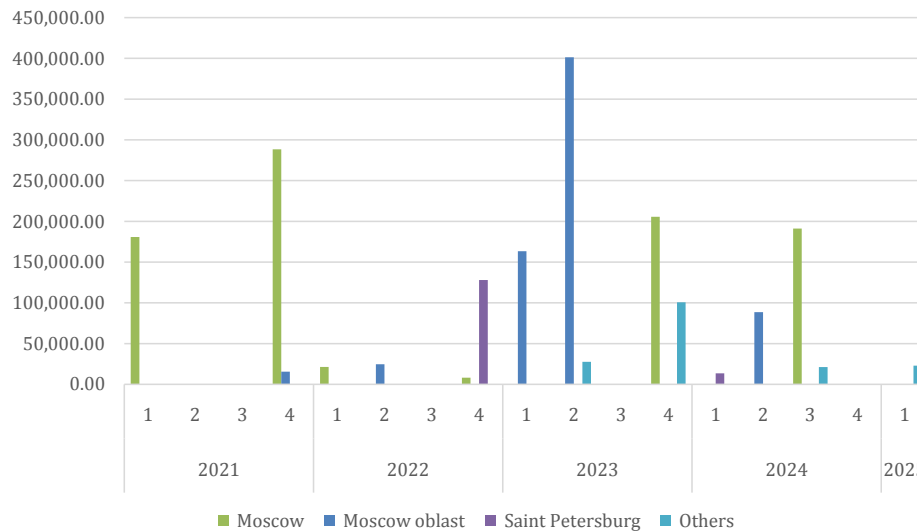


Fig. 1. Area of initiated FSK projects in the regions, sq. m

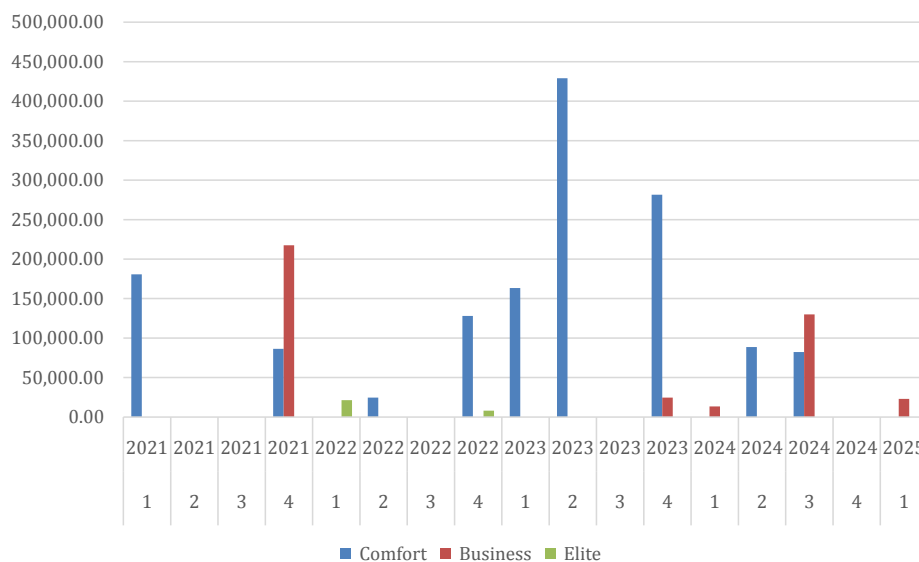


Fig. 2. Area of the initiated FSK projects in the context of real estate classes, sq. m

The main methods of diversifying the portfolio of a development company include the following: diversification by geography, by price categories, by purpose of facilities and by type of client.

1.1. Geographical diversification. This method of diversification involves the territorial distribution of the company's projects across the country. According to ERZ, FSK has been diversifying its construction regions over the past 4 years — the leading region in terms of the area of projects started is changing every year¹. So, in 2021, the vast majority of projects were launched in Moscow, in 2022 70 % of the launched projects were located in St. Petersburg, in 2023 the majority were in the Moscow region — 63 %, besides Moscow, projects were launched in PrimorskyKrai and the Republic of Tatarstan, in 2024 Moscow again became the leader — 61 %. In the first quarter of 2025, one project was launched in the Nizhny Novgorod region. A detailed illustration of the areas of the FSK projects started is shown in Fig. 1.

¹ FSK Group of Companies. URL: <https://erzrf.ru/zastroyschiki/brand/gruppa-kompanij-fsk-755344001?region=vse-regiony®ionKey=0&organizationId=755344001&costType=1> (Date of reference: 04/27/2025).

1.2. Diversification by price categories (real estate classes). The method involves differentiating the company's projects by real estate classes. It can be noted that in the crisis conditions of 2021 and 2024–2025, FGC's share of business class projects is increasing: in 2021, the share of comfort and business class in new projects was 55 and 45 percent, respectively, and in 2024 — 54 and 46 percent, in 2025 the only project started is a business class project¹. The company's policy on this issue may be related to the following pattern: in crisis conditions, expensive real estate segments show greater stability than mass ones. A visualization of the distribution of initiated projects by class and over time is shown in Fig. 2.

1.3. Diversification by functional purpose of facilities. Large development companies capable of attracting specialists from various construction industries can expand their specialization by including projects that are atypical for most of these smaller-scale companies in their portfolio, for example, FSK has recently included non-residential real estate projects in its portfolio. So, in 2022 it was reported that the FSK Group of Companies, together

with the telecom operator FILANKO, will create the LEADER IT Technopark² [5]. At the end of 2024, FSK Group received permission to build the Magistralnaya 12 business center³ FSK also regularly builds ABC-medicine polyclinics, while the location of The clinics are not linked to residential complexes being built by the company (according to the official website of FSK, the network currently includes 18 clinics)⁴. However, when entering a new market, it is necessary to study changes in the level of competition, for example, in 2024, the new supply in the Moscow office real estate market increased by 103 percent compared to 2023 to 567 thousand square meters⁵.

1.4. Customer type diversification. In this case, it means dividing the client into 2 types: private and public. The main clients of development companies are individuals and private legal entities, however, a government customer may act as a potential recipient of development products. This option is available to vertically integrated companies that have design and contracting departments in their structure. In 2024, 126,000 notices of completed construction purchases were published by government customers using the OKPD2 codes 41 (Buildings and construction works), 42 (Civil engineering structures and construction works) and 43 (Specialized construction works). This figure exceeded the level of 2023 by 5 %. The maximum initial contract price for these purchases was 29.8 trillion rubles⁶. An example of working with a government customer is the participation of development companies in renovation projects as a general contractor, for example, MFS, owned by Pik-General Contractor LLC, is a leader in the volume of renovation contracts — the company participates in the construction of 54 residential complexes out of 218⁷.

2. Optimization of project costs. At the moment, there are two key areas for reducing project costs: postponing project launch dates and optimizing the loan rate. Both methods affect the credit component of cost items, the difference is only in the nature of the projects. Shifting the launch dates, assuming that a reduction in the key rate is envisaged in the short term, reduces costs for planned projects, and optimizing the loan rate reduces costs for projects that are being prepared for implementation in the near future.

2.1. Shifting project deadlines. Analyzing data from the Moscow real estate market research, it can be noted that in 2024, in some classes, there was a decrease in the volume of new supply, for example, in the comfort class segment, there was a decrease in the amount of new project space by 13 %. For example, in 2024, FSK reduced the release of projects by more than 2 times, a decrease of 65 % compared to the previous year^{1,8}.

² FSK Group of Companies will create an IT technology park in Moscow. URL: <https://fsk.ru/about/news/1235> (Date of application: 04/27/2025).

³ FSK Group of Companies has received permission to build the Magistralnaya 12 business center. URL: <https://fsk.ru/about/news/gk-fsk-poluchila-razreshenie-na-stroitelstvo-biznes-centra-magistral-naya-12> (Date of request: 04/27/2025).

⁴ FSK Group of Companies. Company structure. URL: <https://fsk.ru/about#today> (Date of reference: 04/27/2025).

⁵ Office real estate. Results 2024. Moscow. URL: <https://nikoliers.ru/upload/iblock/ef7/0zvppq44qvactp8o4du284w9smcgx85.pdf> (Date of request: 04/20/2025).

⁶ EIS Procurement. The official website of the Unified Information System in the field of procurement. URL: <https://zakupki.gov.ru/epz/main/public/home.html> (Accessed: 04/21/2025).

⁷ Who is creating new buildings under the renovation program in Moscow — half of the contracts worth billions were taken by one particular developer. URL: <https://msk1.ru/text/realty/2024/03/29/73357952/> (Date of access: 04/27/2025).

⁸ Residential real estate Classes. Results of 2024. Russia. Moscow. URL: <https://nikoliers.ru/upload/iblock/ddd/zvurk9lk0pvz25v73oz8ixbgkui4btd0.pdf> (Date of issue: 04/13/2025).

2.2. Optimization of the loan rate. As a method of reducing the loan rate, such a measure of state support for the construction industry as the DOM.RF infrastructure bond mechanism can be used, which allows obtaining borrowed funds for the construction of various infrastructure at a discounted rate. The disadvantages of the method include the need to undergo a selection process carried out by DOM.RF and the Government Commission for Regional Development in the Russian Federation, however, the concomitant positive effect is to increase customer confidence in the project. Since the average market value of the profitability of construction projects is 20 %, even minor changes in the amount of costs significantly affect the amount of profit, which determines the relevance of the infrastructure bond mechanism, which is able to make profitable projects that would not be feasible without it.

During the selection process, the project is analyzed according to the following criteria⁹:

- social significance;
- economic efficiency;
- financial stability;
- a guaranteed source of return on investment.

The volume of allocated financing is growing every year, in 2022 it amounted to 27 billion rubles, in 2023 — 72 billion rubles, in 2024 it increased to 99 billion rubles¹⁰. In 2024, the largest amount of funding was allocated for road and engineering infrastructure, 49 and 20 %, respectively. As of 2024, 54 percent of the financing portfolio is accounted for by concession and public-private partnerships, 35 percent for projects outside housing construction and 11 percent for housing construction projects in the amount of 2.7 billion rubles distributed over 5 projects. Analyzing the above information, it can be noted that at the moment the mechanisms most popular in concession and PPP projects (25 projects), while in the field of housing construction the mechanism has not yet found wide application, however, given the global trend towards an increase in financing and bond placement volumes (an increase from 25 billion rubles to 45 billion rubles in the period from 2022 to 2023, a slight decrease of 5 billion rubles in 2024), it can be assumed that in the future more and more developers will turn to this tool to increase the efficiency of projects.

3. Increasing demand. According to DOM.RF data at the moment, the ratio of sales to construction readiness is falling and as of March 2025, it stands at 74 %¹¹. The intensification of competition for a buyer, due to a decrease in demand caused by a high key interest rate and the partial cancellation of preferential mortgage programs, forces developers to apply various mechanisms to increase demand. At the moment, two key methods can be distinguished: the use of financial mechanisms to increase demand and the erosion of class requirements.

3.1. Financial mechanisms for increasing demand. Among the methods that are gaining popularity, we can single out the installment mechanism from the developer. According to Alexander Danilov, head of the Central Bank's regulatory department, at the beginning of 2023, the percentage of installment transactions in housing under construction was 1 %, at the beginning of 2024 there was an increase to 2 %, as of March 2025, the share of installments

⁹ Infrastructure bonds. URL: <https://дом.Russian Federation/investors/infrastructure-obligacii/> (Accessed: 05/04/2025).

¹⁰ Annual reports with information on projects. URL: [https://conf.дом.pdf/about\(05/10/2025\)](https://conf.дом.pdf/about(05/10/2025)).

¹¹ Sales and building readiness. URL: <https://наш.дом.pdf/аналитика/распродажность-стройготовность?repYear=2025&repMonth=3> (Date of appeal: 04/22/2025).

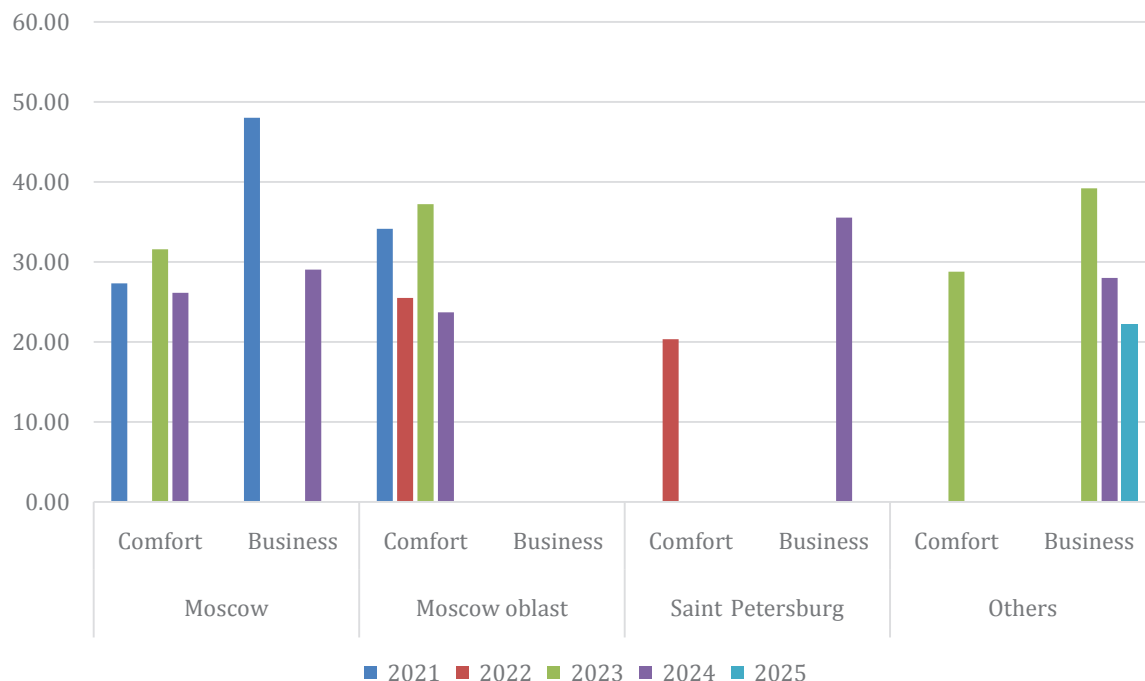


Fig. 3. Weighted average assessment of the initiated FSK projects by regions of Russia and classes
Brief description of the directions of development of project activities by development companies

Level	Approach	Method	Branch of the developer applying the method	Target effect	The stage is the red line for making a decision on the application of the method	Time range of the effect	Impact on reputation
Project portfolio	Diversification	Geographical diversification	All industries	Riskreduction	Conceptual	Medium-term	Positive
		Diversification by price categories					
		Diversification by purpose of facilities					
		Diversification by type of client					
Project	Increasing demand	Blurring of class requirements	Residential and commercial real estate	Increasing the competitiveness of the product	Operation	Short-term	Negative
		Promotions, discounts, installments	Residential and commercial real estate	Increasing the competitiveness of the product	Operation	Short-term	Negative
	Optimizing project costs	Optimizing the loan rate	Residential and commercial real estate	Reducing the cost of lending	Designing	Short-term	Positive
		Postponing the start of new projects	Allindustries	Reducing inefficient costs in the short term, increasing revenue in the future	Designing	Short-term to long-term	Negative

is 13 %¹². The disadvantages of the method include a decrease in the reputation of the company if the costs associated with its use are included in the cost of real estate or a decrease in the profitability of the project if such costs are not included in the cost per square meter [4].

3.2. Blurring of class requirements. At the moment, the requirements for residential real estate classes are not legally fixed, which allows the developer to flexibly interpret the class of objects being built. For example, analyzing the weighted average estimates of the quality of FSK projects, determined on the basis of ERZ

project estimates, we can conclude that the quality of projects has decreased compared to 2021. After territorial and chronological differentiation, it is noticeable that estimates in 2024 are at the lowest level in the last 4 years [4]. Thus, in Moscow, the largest drop in quality is noticeable in the business class segment — a decrease from 48 to 29, in the Moscow region, the comfort class rating increased in 2023, but in 2024 there was a decline again, in projects in other regions of Russia there is a significant decrease in quality, visualization is shown in Fig. 3. A long-term decline in the quality of projects at a stable real cost per square meter can lead to a deterioration of the company's reputation and a decrease in sales.

Table summarizes data on all the approaches described above, as well as additional information: the industry of companies for

¹² The Ministry of Construction and the Central Bank warned about the risks of installments for housing. URL: <https://realty.rbc.ru/news/68021afe9a7947638af1593e> (Date of request: 04/21/2025).

which the method is applicable is described, the extreme stage at which it is possible to start using the method is determined, and the timerange of expected effects from the methods is described.

As a result of the analysis, it is concluded that when choosing a specific direction of adaptation and development, it is necessary to take into account many diverse factors, including target effects, industry specifics of development, current stages of on going projects, the need for costs for implementing adaptation and optimization measures, the duration of the planning horizon, the degree of impact of events on the reputation of the development company in the business environment and others. A comprehensive assessment of the effectiveness of the decisions currently being taken will be possible at least in the coming 1–3 years, however, it can already be noted that the market as a whole has adapted to the current conditions and remains in a state of relative stability with a general downward trend in business activity and medium-term stagnation.

Анализ актуальных направлений развития проектной деятельности девелоперских компаний в контексте адаптации к кризисным явлениям

В условиях высокой ключевой ставки и, как следствие, сниженного спроса на недвижимость актуальным является вопрос обеспечения коммерческой эффективности девелоперских проектов. На основе проведенного анализа деятельности крупных девелоперских компаний в текущих кризисных условиях выявлены ключевые направления оптимизации проектной деятельности в актуальном негативном макроэкономическом контексте. Они могут быть систематизированы как на основе иерархии: уровень портфеля проектов и уровень проекта, так и по отдельным значимым критериям. В целях обоснования и иллюстрации выявленных тенденций и закономерностей в статье приведены обработанные статистические данные портала ЕРЗ.РФ по группе компаний ФСК. В результате анализа сделан вывод, что при выборе конкретного направления адаптации и развития необходимо учитывать множество разнородных факторов, в том числе целевые эффекты, отраслевую специфику девелопмента, текущие стадии реализуемых проектов, необходимость затрат на реализацию адаптационных и оптимизационных мероприятий, продолжительность горизонта планирования, степень влияния мероприятий на репутацию девелоперской компании в бизнес-среде и другое. Проведение всесторонней оценки результативности принимаемых в настоящее время решений будет возможно, как минимум, в перспективе 1–3 года, однако уже сейчас можно отметить, что рынок в целом адаптировался к текущим условиям и пребывает в состоянии относительной устойчивости при общей тенденции к снижению показателей деловой активности и среднесрочной стагнации.

Ключевые слова: антикризисные меры, портфель девелоперских проектов, диверсификация портфеля, девелоперский проект, эффективность проекта, рынок недвижимости

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Technical and regulatory aspects of establishing signs of emergency of apartment buildings within the framework of forensic construction and technical expertise

In the practice of experts working in the framework of judicial construction and technical expertise, questions of-ten arise related to the identification of signs of technical and regulatory nature of the accident rate of apartment buildings. This is due to the fact that the number of such houses, according to Rosstat, is steadily increasing. As the analysis of expert opinions carried out in various state forensic expert institutions has shown, there is currently no single approach to this kind of research. In this regard, this article is of particular interest, since issues related to emergency housing are relevant. In research conducted by experts on these issues, there is often a semantic unification of the concepts of "dilapidated building condition" and emergency technical condition. The purpose of this work is to develop a universal research algorithm for judicial construction and technical examinations aimed at resolving issues about the accident rate of residential multi-apartment buildings, which, among other things, will eliminate contradictions between the conclusions of interdepartmental commissions and the actual technical condition of buildings. The article provides specific examples of damages and accidents (collapses) of apartment buildings, their causes. The regulatory, legal and technical aspects of the problem are considered. It is noted that all the described accidents are not related to man-made or emergency situations (earthquakes, explosions, fires, terrorist attacks), but are the result of weakening of critically important load-bearing structures.

Keywords: forensic construction and technical expertise, emergency housing stock, technical and regulatory signs of emergency, dilapidated condition of the building, emergency technical condition of the building

INTRODUCTION

According to Rosstat [1], despite the current state programme for the resettlement of the population in the country, the emergency housing stock in the Russian Federation increased in real terms from 15,188 thousand m² to 22,059 thousand m² in 2015–2021 alone, which is an increase of 45.2 %. By 2030, an increase is projected compared to 2020 by 1.5 times [2]. In some regions, there is a situation where housing is not recognized as emergency "due to the fact that this fact entails an increase in resettlement obligations, and there is not enough funding for these tasks".

According to data presented on open Internet resources¹, at the beginning of 2024, more than 70 thousand buildings with over 1 million people living in them were declared emergency. It is noted that the recognition of an apartment building (AB) as an emergency and subject to demolition or reconstruction belongs to the exclusive competence of interdepartmental commissions². However, due to various circumstances, it is not uncommon for the last AB to be unreasonably not recognized as emergency and subject to demolition or reconstruction, but rather the wording "major repairs are required" is indicated. Within the framework of this article, the existing problem is considered in detail. At the same time, the number of complaints about these issues of substandard housing is steadily increasing. In total, the Forensic Expert Centre (FEC)

of the Investigative Committee of the Russian Federation (IC RF) for housing of inadequate quality, dilapidated houses carried out 185 forensic construction and technical examinations in 2022, 339 in 2023, and 609 in 2024, which amounted to 53.7 % of the total number of construction and technical expertise and research carried out in the FEC of the IC of Russia.

As the analysis of expert opinions carried out in various state forensic expert institutions has shown, there is currently no single approach to this kind of research. Experts often try to link the concepts of "dilapidated condition of a building", based on indicators of physical wear and tear, established in accordance with the standards of VSN 53-86(r) [3] or methods [4, 5], with the concept of "emergency technical condition". In particular, appendix 6 of the document [6] notes that "dilapidated condition of a building" is a condition in which the structure of the building and the building as a whole are worn out: for stone houses — over 70 %, wooden houses with walls made of local materials, as well as attics — over 65 %. At the same time, the main load-bearing structures retain strength sufficient to ensure the stability of the building, however, the building ceases to meet the specified operational requirements. As noted in the article [8], although dilapidated housing is characterized by a fairly high degree of wear and tear, there is no formal danger of collapse, unlike emergency housing. Even if the deterioration of the structure is more than 70 %, this is not a guarantee that the dilapidated housing will be resettled [8].

The article [9] presents an approach for determining the category of technical condition of

¹ URL: <https://tass.ru/ntdvizhizmost/20626935> (date of request 29.08.2024).

² Paragraph 47 of the Decree of the Government of the Russian Federation dated 28.01.2006 No. 47 [7].



Fig. 1. General view of an apartment building in Kuibyshev Street in Perm before and after the collapse

buildings by physical wear, however, due to the introduction in 2019 of uniform criteria for assessing the emergency and limited-functioning technical condition of residential buildings, this approach cannot be used in the production of forensic construction and technical examinations, which require the resolution of questions about AB accident rate.

The main purpose of this work is to develop a universal research algorithm for forensic construction and technical examinations aimed at resolving issues about the accident rate of residential buildings, which, among other things, will eliminate contradictions between the findings of interdepartmental commissions and the actual technical condition of buildings. For this purpose, a number of accidents that have occurred in long-term residential buildings over the past 10 years have been considered, as well as relevant technical and regulatory aspects of legislation regulating the recognition of residential buildings as emergency and subject to demolition or reconstruction. When conducting the study, it is proposed to rely solely on the technical signs of the emergency condition of structures made of various structural materials [10–12], with instrumental control of the parameters of defects and damages according to the criteria specified in tables 5.2–5.26 of the Code of Practice [13].

DAMAGE, ACCIDENTS OF AB AND THEIR CAUSES

On 11.07.2015, the corner part of a 5-storey residential building on Kuibyshev Street in Perm collapsed (Fig. 1). The house was built in 1957. It was established that before the collapse, the reconstruction and redevelopment of the basement premises was carried out. During the reconstruction, instead of the loading hatch of the store, an entrance group to the basement was made, for which the sill section of the window opening was dismantled and a recess for the installation of an external staircase was filled in, as well as a new opening in the inner load-bearing wall, which was not provided for by the project.

After the reconstruction, force damage was observed in the newly formed basement pillar in the form of cracks separating the integrity of the masonry section, chipping of bricks in peripheral sections of the pillar, and a network of cracks under the lintel support crossing more than four rows of masonry. These damages occurred as a result of the redistribution of loads from the overlying structures after making changes to the vertical supporting structures of the basement part of the building (Fig. 2). Vertical cracks



Fig. 2. View of the pillar of the non-designed opening in the basement, which was the source for activating the process of destruction of the building (the state of the pillar, recorded before the collapse of the corner of the building)

formed on the exterior walls, which subsequently separated the collapsed fragment, as a result of cyclic freezing of the soil base in a deepened hole under the exterior staircase.

On 29.08.2017, the middle section collapsed within one span of a 4-storey residential building in the city of Orel along the Dubrovinsky Embankment (Fig. 3, a). The house was built in 1955 with brick walls and wooden floors, located in close proximity to the Oka River.

Shortly before the collapse, damage was recorded in the piers of the first floor: vertical cracks along the entire height of the piers with an opening width of more than 1 cm, layering of the masonry into thin flexible columns and bulging of the outer wythe (Fig. 3, b). This state of brickwork corresponds to the 3–4 stage of destruction, which is the final stage of masonry destruction, when through cracks do not stabilize, but continue to develop and increase without increasing the load [14].



a



b

Fig. 3. General view of an apartment building along the Dubrovinsky Embankment in the city of Orel after the collapse: a — emergency condition of the first-floor walls; b — recorded before the collapse

The reasons for this weakening of the masonry were the regular soaking of the structures of foundations, walls and pillars by groundwater and floodwaters, leaks from engineering communications, inadequate horizontal waterproofing of walls, uneven degradation of the strength and deformation properties of the masonry solution within the seam. Concomitant unfavorable factors, due to which additional uneven deformations appeared — precipitation of foundations, were the construction work during the construction of the Oka River embankment in 2015 using heavy machinery, and possible vibrational decompression of the foundation soils.

On 12.08.2022, the end part of a 5-storey building in XX Partysyezda Street in Omsk collapsed (Fig. 4). In 2024, a secondary collapse occurred in a resettled but not demolished building, as a result of which the floors from 1st to 5th collapsed adjacent to the previously destroyed site. 1st floor and a full-height longitudinal exterior wall.

The house was built in 1966 with brick walls and prefabricated reinforced concrete floors. The cause of the collapse was the loss of the bearing capacity of the brickwork (made of clay bricks) of the basement of the building at the intersection of the end and longitudinal exterior walls. The collapse was preceded by systematic

leaks from engineering communications in the basement. The brickwork at the basement and ground floor levels, where the wet rooms are located, was systematically saturated with capillary moisture, and on the street side it was subjected to repeated freezing/thawing. Subsequently, this caused a significant decrease in the bearing capacity of the masonry — buckling deformations of the outer wythe appeared according to the 3–4 stage of destruction scheme [14] and further avalanche progression of damage deep into the section under load.

On 16.11.2023, the third and fourth entrances of a five-story apartment building in the Leninsky district at 1a Vokzalnaya Square in Astrakhan collapsed (Fig. 5). The house was built in 1962 with brick walls and prefabricated reinforced concrete floors (3 walls). The foundation is ribbon; the building is basement-free. The supporting structure of the ceiling was wooden, with beams supported on brick pillars on the ground. Partially, the floors at the indicated mark were made of concrete on the ground (under the bathrooms). To maintain communications and maintain them in proper condition in such a building, it was necessary to open the floors and ceiling structures in the apartments on the first floor. The actual



Fig. 4. General view of an apartment building in XX Partsezda St. in Omsk before and after the collapse (the arrow shows the progressive destruction of the corner section of the outer wall a few seconds before the collapse of the end part of the building)

implementation of horizontal waterproofing and its current condition did not allow for the capillary suction of moisture into the outer wall structure from the saturated soil in contact with the wall and led to weathering of the masonry (degradation of strength and deformation characteristics).

Immediately before the collapse, on the section of the outer wall that subsequently collapsed, the presence of oblique cracks crossing the sections of brickwork under the window openings from the first to the fifth floor was recorded in the level of residential floors. The deformations of the brickwork, uneven in length, which were accompanied by a skew in the geometry of the window openings, the window cover burst fullness, a characteristic crack was heard. As a result, the cause of the collapse, as well as in the previous case, was the weakening of the strength and deformation characteristics of the masonry at the basement and ground floor levels due to environmental influences as a result of systematic leaks from engineering communications. Moreover, the physical wear calculated according to the method [3] on the date preceding the collapse was 51 %.

All the accidents mentioned above are not related to emergencies, such as gas-air mixture explosions and terrorist attacks, but they have a general picture of the mechanism of destruction. The accidents discussed in the article are related to the weakening

(man-made and/or environmental — corrosion) of critically important load-bearing structures during operation, both during reconstruction and redevelopment, and as a result of accelerated physical wear due to improper condition of engineering communications, waterproofing, and building structure elements.

REGULATORY AND LEGAL ASPECTS

The following issues can be resolved without going beyond the competence of an expert in the conduct of forensic examinations. The first group of issues is related to the study of the technical condition of AB (building as a whole), including when the decision of the interdepartmental commission needs to be challenged in court³:

- did the interdepartmental commission⁴ have any technical grounds for deciding that there were no grounds for

³ If there are relevant documents, for example, technical reports made by specialized organizations authorized by the SRO in the field of engineering research for construction, the study can be conducted on the basis of these documents as of the date of the engineering survey.

⁴ The study is conducted using regulatory legal acts in force on the date of issuance of the interdepartmental commission's Opinion (if there is a technical opinion from a specialized organization on the relevant date).



Fig. 5. General view of a destroyed apartment building in the Leninsky district on 1a Vokzalnaya Square in the city of Astrakhan

recognizing AB as an accident and subject to demolition or reconstruction?

- are there signs of an emergency condition of AB at the time of the examination?

Are there grounds for recognizing the residential premises of AB as uninhabitable, and the buildings as a whole as emergency and subject to demolition?

The second group of issues is related to the study of the technical condition of individual⁵ load-bearing structures of AB, necessary for making a decision on the expediency of conducting a technical inspection of AB as part of a preliminary investigation:

Are there signs of an emergency condition of individual load-bearing structures of AB?

The grounds for the recognition by the interdepartmental commission of AB as unsafe and subject to demolition or reconstruction in accordance with Part 3 of art. 55.26-1 of the Urban Planning Code of the Russian Federation [15] are established by the provisions of Section IV of the Regulation (approved by Decree of the Government of the Russian Federation dated 28.01.2006 No. 47) [7]. The procedure for assessing the conformity of a building (or residential building) with an emergency one, which is subject to reconstruction, repair, demolition, as well as the list of documents necessary for making such a decision, is established in paragraph 44 [7].

Based on the results of the work, the interdepartmental commission must make one of the decisions specified in paragraph 47 [7] on assessing the compliance of premises and apartment buildings with the established requirements.

It should be noted that in the practice of conducting forensic examinations, conclusions of interdepartmental commissions are quite common, which indicate that a decision has been made to recognize AB as subject to capital repairs, however, such a solution is missing in paragraph 47 of the Provision approved by Government Decree No. 47 [7].

Thus, the wording in the Conclusion of the interdepartmental commission should clearly correspond to one of those listed in paragraph 47 [7], which should be reflected in the expert's conclusion within the framework of the study.

The main document for the interdepartmental commission in assessing the suitability (unsuitability) of residential premises for

⁵ Single structure: A load-bearing building structure (part of the structure), which is a repeating element in the totality of all load-bearing building structures of this type (clause 3.1.4 [13]).

living, and the recognition of AB as emergency and subject to demolition, is the conclusion of a specialized organization⁶ on the condition of load-bearing and enclosing structures (technical opinion). If the applicant is a state supervision (control) body, it submits its opinion to the commission, and after its consideration, the commission invites the owner of the premises to submit the documents specified in paragraph 45 [7]. Based on the above, the specified documents for the examination are provided by the investigator, among others, in the materials of the criminal case.

In the absence of a technical opinion from a specialized organization, an interdepartmental commission, and other documents in the materials provided for the study, the expert can only conduct an investigation to identify signs of malfunction of individual load-bearing structures of AB without going beyond the competence.

If the case file contains a technical opinion from a specialized organization, which establishes the emergency technical condition of the building, and there is a decision by local governments and state authorities that the building is recognized as emergency and subject to demolition, but the building is not actually inhabited, then there is a need to appoint forensic construction and technical examinations in relation to such housing for the above-mentioned there are no questions. At the same time, ABs that are not recognized as emergency, but are located in a building with other buildings recognized as emergency in the territory subject to complex development, may be subject to demolition or reconstruction in accordance with paragraph 2, Part 2, art. 65 of the Urban Planning Code of the Russian Federation [15], if the physical wear of the main structural elements exceeds the value defined by the subject of the Russian Federation⁷. Such issues are not considered in the framework of forensic examinations, as they fall within the competence of local self-government bodies.

Summing up the above, in order to resolve the issues of the first group, the investigative body must provide a technical report from

⁶ In the case that, in accordance with the third paragraph of paragraph 44 [7], the provision of such a conclusion is necessary for making a decision on recognizing residential premises as meeting (not meeting) the requirements established in the Regulation [7].

⁷ In accordance with the regulatory legal act of the subject of the Russian Federation, the regional capital repair programme may not include apartment buildings, physical wear of the main structural elements (roof, walls, foundation) which exceed 70 %, and (or) apartment buildings in which the total cost of services and (or) major repairs of structural elements and internal engineering systems that are part of the common property in apartment buildings, per square meter of the total area of residential premises exceeds the cost of, defined by the regulatory legal act of the subject of the Russian Federation (paragraph 1, part 2, art. 168 of the Housing Code of the Russian Federation).

Technical aspects of classifying a structure as an emergency category

CP 454.1325800.2019 [13]	Regulations [7]
More than 5 % of the load-bearing building structures of at least one type of the total number of load-bearing building structures of this type have been identified ⁸ , but not less than three corresponding to the emergency category of technical condition (clause 5.1.5 of the Code of Practice [13])	Paragraph 34 of the regulation [7] describes the procedure for establishing an emergency technical condition of AB, which is determined in accordance with GOST [16], justified by appropriate verification calculations of the bearing capacity of structures and (or) the foundations. For houses with no more than two floors, it is possible to determine the emergency technical condition in accordance with the Code of Practice [13], while more than 50 % of the structures of foundations, load-bearing walls and ceilings are classified as an emergency technical condition
Two types and more load-bearing building structures have been identified (with the exception of the types of structures specified in 4.4–4.6 [13]) with the number of emergency load-bearing building structures exceeding 3 % of the total number of structures in each, but not less than three in total (clause 5.1.7 of the Code of Practice [13])	If the specified volume of emergency structures is not detected during the examination in accordance with the Code of Practice [13], but one of the listed facts is found (see exceptions), then the examination must be carried out in accordance with GOST [16]
<i>Exceptions</i>	
If a residential building has load-bearing building structures for which the Code of Practice [13] does not provide criteria for emergency and limited-functioning technical conditions and in which significant damage was detected during inspection, their assessment is carried out in accordance with GOST 31937 (clause 5.1.4 of the Code of Practice [13])	<ul style="list-style-type: none"> • localization of defects in a separate part of an apartment building, including in one entrance, on one floor; • a single significant defect in a separate load-bearing building structure of an apartment building, which may lead to a threat of collapse of the apartment building
If a sufficient number of emergency load-bearing building structures have not been identified to recognize a residential building as an emergency as a whole, but there is a single significant defect in a separate load-bearing building structure that may lead to a threat of collapse of the residential building, the assessment of the technical category of the residential building is carried out in accordance with GOST 31937 (clause 5.1.6 of the Code of Practice [13])	Presence of an apartment building that has been arbitrarily rebuilt and (or) redeveloped

a specialized organization for examination, as well as organize an inspection of the scene with the participation of an expert and interested persons (representatives of the local administration, the management company and the owner).

TECHNICAL ASPECTS

If there is no conclusion of a specialized organization in the case file, the following approach is used. Currently, a residential building is classified as an emergency technical condition category if (see the Table).

The exceptions provided for by the current regulatory documents make it possible to identify the emergency category of technical condition, and are well combined with the indicators of identification of accidental damage in Table 5.2–5.26 of the Code of Practice [13], observed before AB accidents in the above review, and not with indicators of physical wear, which in the examples of emergency buildings is not exceeded 60 %. In low-rise residential buildings, where wooden floors are most common (wooden flooring on wooden beams, sheeting and plaster on shingles from below) and most often have the greatest damage (hidden defects), the following inspection scheme is proposed. The inspection is carried out in accordance with clause 5.2.14 of the Code of Practice [13], but if necessary (due to the lack of access through technological openings), autopsies⁹ are performed in the places specified in clause 5.3.4.6 of GOST [16], in the presence of residents and with their consent. In accordance with paragraph 5.2.4, According to the rules [13], at least 10 % (but not less than three) of the load-bearing building structures of each type are subject to inspection

⁸ The specified number does not include emergency wooden covering structures, emergency stairway structures and outbuildings (which do not affect the main building), if there are possibilities to strengthen or replace emergency elements without evicting residents (paragraphs 4.4–4.6 [8]).

⁹ In order to carry out autopsies of load-bearing structures, the expert submits a reasoned petition to the investigator.

and measurements of controlled parameters. Damages are recorded in such a way that it is possible to compare with the accident rates in tables 5.2–5.26 of the Code of Practice [13].

If the case file contains an opinion of a specialized organization (technical opinion), which does not establish an emergency technical condition of AB, or there is no technical opinion at all, the inspection of AB is carried out according to the methodology specified in section 5.2 of the Code of Practice [13]. During such an inspection, it is also necessary to ensure that there are no emergency load-bearing structures. When conducting forensic construction and technical examinations on the issues of AB accidents, the damage recorded in the inspection report is examined. It is also compared with the data of a specialized organization and an analysis of the verification calculation, if it is provided.

CONCLUSION

1. A brief overview analysis of the existing approaches for determining the technical condition of AB is given.
2. AB accidents that have occurred over the past 10 years and the causes that caused them are considered, which well illustrate the criteria for the emergency technical condition of a residential building provided for by current regulatory documents.
3. An algorithm (approach) has been developed for the production of forensic structural and technical examinations, in which it is required to resolve questions about the signs of AB accidents.

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Технические и нормативно-правовые аспекты установления признаков аварийности многоквартирных жилых домов в рамках судебных строительно-технических экспертиз

В практике экспертов, работающих в рамках судебных строительно-технических экспертиз, часто возникают вопросы, связанные с выявлением признаков технического и нормативно-правового характера аварийности многоквартирных жилых домов. Это связано с тем, что число таких домов, по данным Росстата, неуклонно возрастает. Как показал анализ заключений экспертов, выполненных в различных государственных судебно-экспертных учреждениях, единого подхода к подобному рода исследованиям в настоящее время не существует. В этом отношении настоящая статья представляет определенный интерес, поскольку вопросы, связанные с аварийным жилым фондом, являются актуальными. При исследованиях, проводимых экспертами по данным вопросам, часто происходит смысловое объединение понятий «ветхое состояние здания» и «аварийное техническое состояние». Целью данной работы является разработка универсального алгоритма исследований для судебных строительно-технических экспертиз, направленного на разрешение вопросов об аварийности жилых многоквартирных домов, который, в том числе, позволит устранять противоречия между выводами межведомственных комиссий и фактическим техническим состоянием зданий. В статье приводятся конкретные примеры повреждений и аварий (обрушений) многоквартирных домов, их причины. Рассмотрены нормативно-правовые и технические аспекты проблемы. Отмечается, что все описанные аварии не связаны с техногенными или чрезвычайными ситуациями (землетрясения, взрывы, пожары, теракты), а являются результатом ослабления критически важных несущих конструкций.

Ключевые слова: судебная строительно-техническая экспертиза, аварийный жилой фонд, технические и нормативно-правовые признаки аварийности, ветхое состояние здания, аварийное техническое состояние здания

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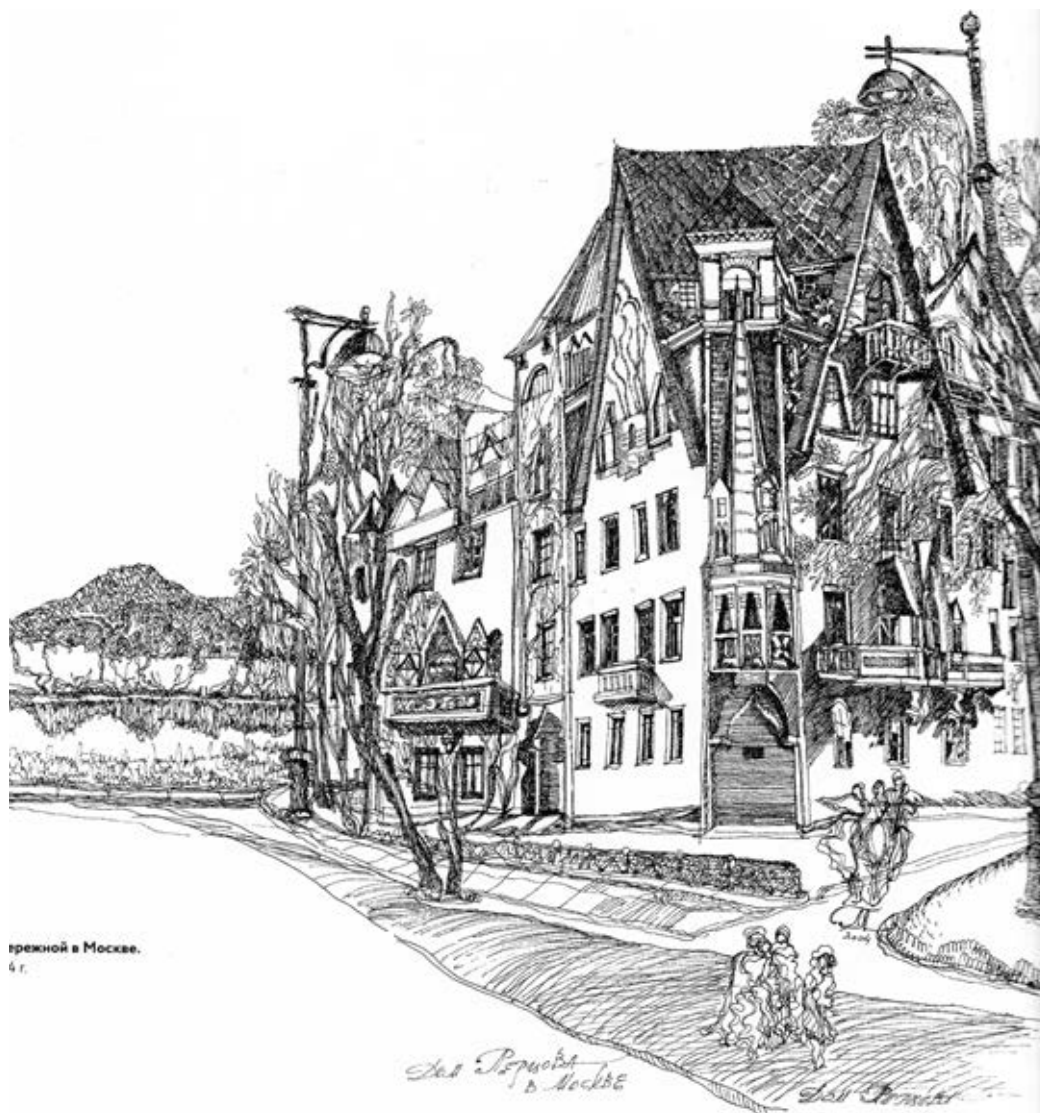
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Москва. Дом П.Перцова на Пречистинской набережной

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Conceptual approach to assessing the economic efficiency of out-of-court settlement of construction disputes

The paper is focused on the potential of conciliation mechanisms as an integral component of investment and construction projects delivering in terms of out-of-court disputes resolution, taking into account their diversity and the presence of a public element. The main goal of mediation approaches is emphasized — to reduce conflict component in both economic activity as a whole and in the construction industry. Concept approach towards cost-effectiveness evaluation of out-of-court disputes resolution is represented revealing the levels of mediation approaches development (legislative enshrinement, regulatory and consulting activity, sphere of education, the structure of contracts) and structuring the costs of litigation: litigation fee, expenses for conducting a construction expertise focusing on economic, technical, financial, value assessment and examination, expenses for the services of a representative (legal assistance) and indirect costs which are mostly related to time period. Furthermore, essential factors which have an impact on cost-effectiveness evaluation are highlighted: the amount of litigation fees, the duration of proceedings, inflationary processes, fee exemptions and refund and type of a contract. An important conclusion is made in the article that even in case of winning, court proceedings without the use of mediation technologies at the early stages (referral to conciliation rooms) is not an effective way to settle disputes. The findings and results can foster constructive partnership while delivering projects and taking preventive measures in order to reduce significantly the level of conflicts in investment and construction sphere. **Keywords:** *conciliation mechanisms, out-of-court disputes resolution, economic efficiency, mediation approaches, litigation fee*

INTRODUCTION

The current priorities of the construction industry development are focused on the implementation of conciliation mechanisms in practice, which make it possible to eliminate contradictions and disagreements in project delivery promptly and at the lowest cost (both direct and indirect).

The above mentioned conciliation mechanisms provide mediation approaches, the main goal of which is to reduce conflict component in both economic activity as a whole and in the construction industry (given that construction disputes are among the most mediative), and, as a result, to create a framework for ensuring a favorable business climate, taking into account certain inequalities between representatives of government agencies and large construction companies, banks and representatives of small businesses. Because of this, the principle of adversarial litigation reinforces the destructive processes of construction projects practical implementation.

The basics of mediation approaches are the constructive nature of interaction among participants in economic activity, the priority of negotiation process, the voluntary nature of certain procedures, cost reduction and resource savings (compared with judicial proceedings), the availability of additional competencies of dispute resolvers, their independence and impartiality [1].

MATERIALS AND METHODS

Concept approach towards cost-effectiveness evaluation involves revealing the levels of mediation approaches development and structuring the costs of litigation.

Structural dynamic analysis of disputes resolution methods has allowed to identify the following essential aspects:

- the greatest difficulty in resolving disputes involving a public element is the lack of conciliation mechanisms and constructive interaction [2];
- the presence of a public element significantly limits the scope of alternative dispute resolution methods, which may be non-arbitrable;
- commercial arbitration is the least preferable way of resolving disputes related to the implementation of construction projects, as it does not allow to cover all disputable points and monitor all stages of project implementation, timely relieving tension and coordinating the interests of all participants (both professional and non-professional) [3];
- project mediation with the participation of construction experts with specialized competencies may be the most promising way to resolve disputes [4];
- the relevant contract clauses should detail dispute resolution procedures and provide a clear concept of dispute resolution with a differentiated approach to managing disputes and disagreements in the project;
- it is also important to consider the option to use alternative dispute resolution after the initiation of litigation;
- in order to develop specialized ways of dispute resolution in the public element, it is necessary to develop not only out-of-court methods (mediation, extrajudicial expertise), but

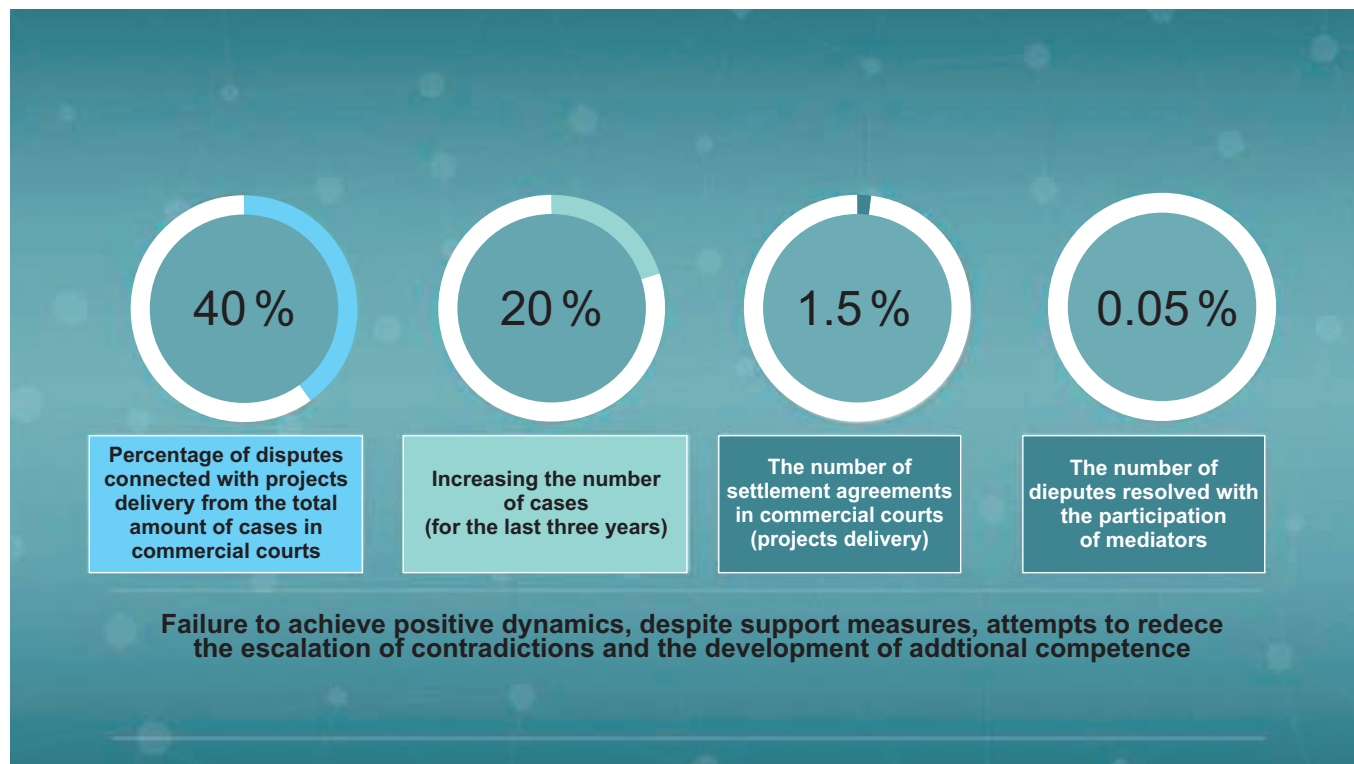


Fig. 1. Statistics characterizing the level of conflict in investment and construction (in the Russian Federation)

also conciliation procedures provided for by the procedural legislation, which can be initiated within the courts (most of them have open and functioning conciliation rooms, the parties can apply to such rooms at any stage of the process) [5].

Moreover, existing approaches to the usage of conciliation mechanisms (in terms of out-of-court dispute resolution) do not take into account the total amount of costs of disputing parties and their subject composition.

It is necessary to emphasize that in practice the amount of damage to one or more parties to a dispute is often the result of not only violations of contractual obligations arising from errors and miscalculations of parties, but also can occur for the reasons not depending on them in investment and construction activities (Fig. 1).

Mediation approaches in the sphere, in which public authorities are involved, require a number of measures that are both directive, organizational and managerial in nature [6].

Let us highlight the levels of implementation of these approaches:

1. Legislative enshrinement: the most preferable way to introduce out-of-court mediation approaches into practice is to fix the procedures in various legislative acts (having both general procedural character and sectoral affiliation). Moreover, such procedures may be mandatory, in which case the disputing parties will have no choice but to apply them. It should be emphasized that the opinions of scholars and practicing mediators are traditionally divided, not all of them are supporters of the mandatory nature of the use of alternative dispute resolution methods, as it can be of a formal nature and only delay the process (if the conflicting parties do not intend to constructively resolve the contradictions) [7].

2. Regulatory activities: establishing standards for interaction with business entities, requirements for relevant procedures,

adoption of legal acts and methodological recommendations as a guideline. Even if it constitutes "soft" regulation" of relations, nevertheless the level of conflict can be significantly reduced.

3. Consulting activities: the use of alternative dispute resolution methods involves the involvement in the processes of dispute prevention and resolution of persons with special competencies in such areas as conflict management, psychology, design and expert activities, information technology, architecture. The participation of such individuals, in turn, determines the development of consulting services market in terms of effective management of disputes and disagreements in the project [8].

4. The field of education: it is obvious that the development of additional competencies takes place at the level of educational programs that provide appropriate training areas within the framework of using alternative dispute resolution methods in relation to project management (for example, project mediation, extrajudicial examination, etc.), taking into account the intersectoral orientation.

5. Contract instruments particularly related to the implementation of projects with the participation of public authorities [9, 10]. An important conclusion can be made that public contracts, concession agreements, agreements on the procedure of monetary compensation to the owners of engineering networks often contain bonded (unfair) conditions. Such conditions may relate to excessive penalties, high amount of payments to in the absence of counterpart provision, unclear obligations of the public party, asymmetry of responsibility, overly burdensome obligations for the construction of social infrastructure, gratuitous transfer of the created objects, etc. In turn, the lack of negotiation process in a number of cases does not allow economic entities to influence the wording of contracts, so it is extremely important that the initial standard forms do not contain knowingly unreasonable conditions (Fig. 2) [11].

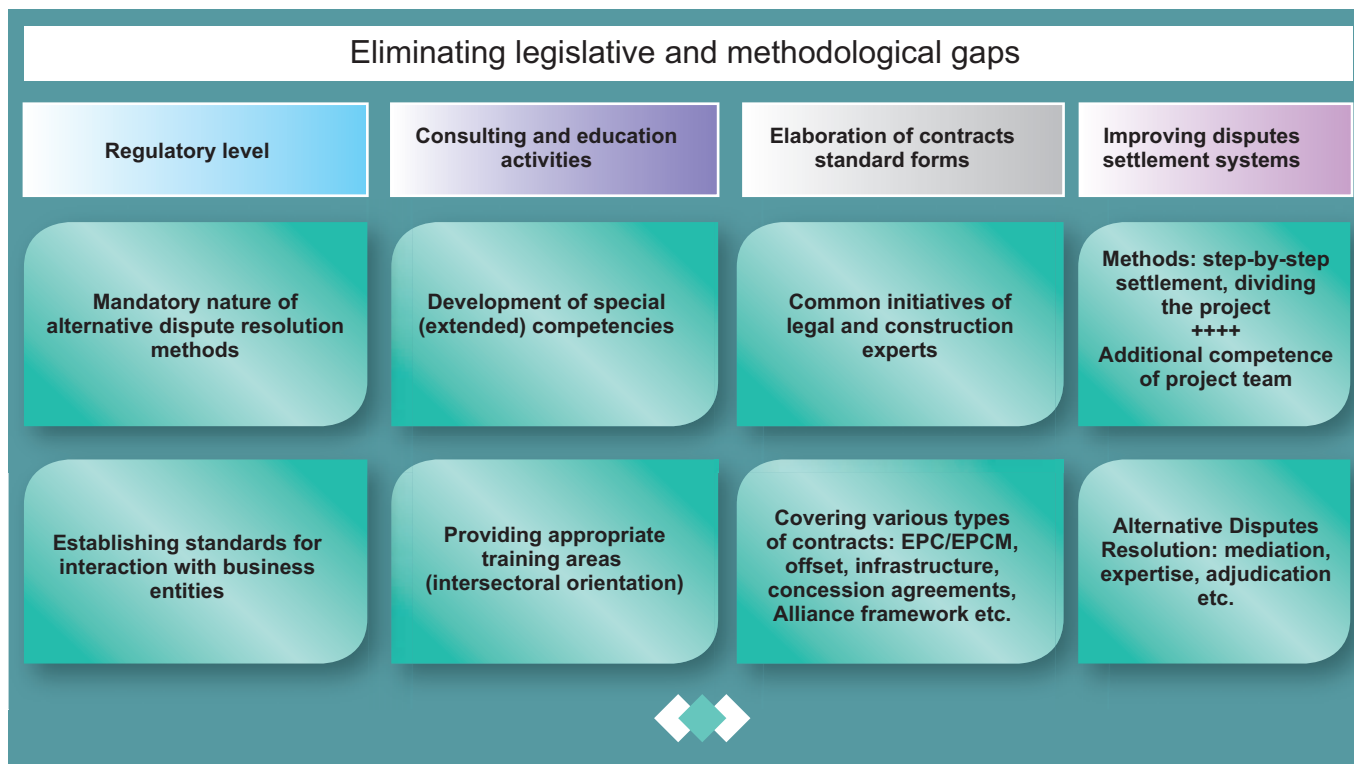


Fig. 2. Levels and directions of efficient approaches development

RESULTS

Adoption of measures at various levels will ensure the effectiveness of mediation approaches in the process of project delivering.

As mentioned above the cost-effectiveness evaluation involves structuring the *costs of litigation* (taking into consideration the amount of the claim, approximately — 9–10 % of this amount):

- litigation fee (which depends on the value of the claim). In accordance with the recent reform in the Russian Federation, the amount of such fees has significantly increased, it creates an important incentive for the parties to use out-of-court settlement;
- expenses for conducting a construction expertise focusing on economic, technical, financial, value assessment and examination;
- expenses for the services of a representative (legal assistance).

Indirect costs are mostly related to time period.

As a practical example, a case on recovery of debt under an agreement on payment of monetary compensation to the owner of engineering networks and structures (compensation for all losses caused by the elimination of gas networks on the land plot) can be considered.

These actions are necessary in the case of construction of facilities on the land plot if there is a need to take measures in relation to engineering networks and structures. The peculiarity of such disputes is the dependence of issuance of a permit for commissioning of the facility on the actions of the owner of the said networks to execute the act of liquidation. In addition, a procedural feature of similar cases is the need (in some cases) to initiate a forensic expert examination to establish the actual cost of the work performed.

Payment for work performed is based on actual costs incurred and the compensation amount specified in the contract is

provisional and cannot be used for final calculation of the cost of work.

In practice, the parties may disagree as to the interpretation of the terms of the agreement concerning the determination of the price of the work: the defendant may believe that the initially determined price is approximate and subject to adjustment in relation to the actual costs incurred in performing the work, while the plaintiff may believe that the price of the work is not subject to adjustment unless the scope of work agreed upon by the parties is changed.

If we consider the ability of such disputes to be mediated, it is clearly present, both in terms of mediation itself, which allows to agree on the value of the work performed, and out-of-court expert examination (which also belongs to alternative dispute resolution methods) in order to determine the actual scope of work performed and its value [12]. Moreover, such disputes often point to inconsistent behavior of a party to the dispute, including requests to take measures to fulfill obligations and readiness to make a final settlement.

In practice the total duration of such disputes may be about two to three years. Even in case of winning the dispute it is necessary to take into account *inflationary processes*, which for three years can amount to — 28 %.

Thus, even in the event of winning the case (although, as noted above, in such disputes the results of the forensic construction expertise are decisive), given the length of the trial, there are substantial losses due to inflationary processes.

As for mediation technologies, disagreements concerning the amount of compensation to the owner of engineering networks and structures (compensation of all losses caused by the liquidation of gas networks on the land plot) can be settled both within the framework of judicial mediation and out of court. In the first case — the plaintiff's savings would amount to 70 % of the litigation fee (in case of conclusion of a settlement agreement (conciliation

agreement) before the decision of the court of first instance, this amount is subject to refund to the plaintiff). And, in addition, time savings would have been achieved (even taking into account the expert examination) [13].

In the second case, the costs could be associated only with the negotiation process with the participation of a mediator and, if necessary, with out-of-court expertise.

Thus the analysis shows that the use of alternative dispute resolution methods is the most preferable way out of a conflict situation, and at the earliest stages. Thus, in practice there are cases of conclusion of amicable agreements after a considerable period of time (for example, almost 2 years) after filing a statement of claim and after the case has passed all the court instances. Undoubtedly, such time costs seem unreasonable in view of the above factors.

CONCLUSION

Current development priorities require a significant revision of approaches to conflict reduction in the construction industry. The use of mediation approaches could have a significant impact on this process [14].

The conceptual approach to assessing the economic efficiency of out-of-court dispute resolution is based on the ratio of the costs of litigation and conciliatory procedures (such as project mediation and out-of-court expertise), taking into account such factors as the amount of litigation fees, the duration of proceedings, inflationary processes, fee exemptions and refund and type of a contract.

Analysis of the cost-effectiveness of dispute resolution using mediation approaches was carried out on the example of a dispute on debt recovery under the agreement on payment of monetary compensation to the owner of engineering networks and structures (compensation for all losses caused by the liquidation of gas networks on the land plot). Thus, litigation costs amounted to more than 9 % of the claim amount. In addition, indirect costs related to the time resource lead to depreciation of the claim amount for the plaintiff (due to inflationary processes). The calculation made (taking into account the average duration of the trial) showed a loss of 30 % and a long stay in the conflict. Thus, even in case of winning, court proceedings without the use of mediation technologies at the early stages (referral to conciliation rooms) is not an effective way to settle disputes.

Despite the obvious potential of mediation approaches, there is currently a clear lack of measures aimed at their development, and therefore levels of adoption are outlined: legislative enshrinement, regulatory and consulting activity, sphere of education, the structure of contracts [15].

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Концептуальный подход к оценке экономической эффективности внесудебного разрешения строительных споров

Статья посвящена потенциалу примирительных механизмов как неотъемлемого компонента реализации инвестиционно-строительных проектов с точки зрения внесудебного разрешения споров, с учетом их разнообразия и наличия публичного элемента. Подчеркивается основная цель медиативных подходов — снижение конфликтной составляющей как в экономической деятельности в целом, так и в строительной отрасли. Представлен концептуальный подход к оценке экономической эффективности внесудебного урегулирования споров, раскрывающий уровни внедрения указанных подходов (за-

конодательное закрепление, консалтинговая деятельность, сфера образования, модификация контрактных конструкций) и структурирующий затраты на судебный процесс: судебные издержки, расходы на проведение строительной экспертизы, направленной на экономическую, техническую, финансовую, стоимостную оценку, расходы на услуги представителя (юридическую помощь) и косвенные расходы, которые в основном связаны с временными издержками. Кроме того, выделены существенные факторы, влияющие на оценку экономической эффективности: размер судебных издержек, длительность разбирательства, инфляционные процессы, освобождение от уплаты и возврат государственной пошлины, а также тип контрактной модели. В статье сделан важный вывод о том, что даже в случае выигрыша спора в суде без использования медиативных технологий на ранних стадиях (направление в комнаты примирения) судебное разбирательство не являет-

ся эффективным способом урегулирования разногласий. 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: согласительные механизмы, внесудебное разрешение споров, экономическая эффективность, медиативные подходы, затраты на судебное разбирательство

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