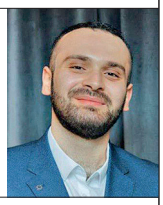
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Investment Mechanisms for the Modernization of Utility Infrastructure within Comprehensive Territorial Development

This article examines a comprehensive approach to modernizing public utility infrastructure within the framework of integrated territorial development (ITD). The study focuses on the combined use of investment instruments and life-cycle-based performance indicators, including life cycle cost (LCC) and total cost of ownership (TCO), as a means of improving the efficiency, financial sustainability, and institutional coordination of infrastructure modernization projects. The purpose of the research is to identify and systematize the legal, financial, and organizational instruments available under the Russian legislation for the integrated development of territories and related utility sectors, with particular attention to fiscally subsidized regions. The methodology includes an analysis of the regulatory framework, including Federal Law No. 494-FZ and housing and utilities modernization programs; a review of ITD projects implemented in subsidized regions; and a comparative assessment of investment mechanisms such as concessions, public-private partnerships, infrastructure budget loans, infrastructure bonds, subsidies, grants, and long-term management contracts. The study classifies modernization mechanisms by funding source and risk level, develops an applicability matrix for different stages of the infrastructure life cycle, and proposes an organizational model for a regional project office with a mechanism for the distribution of responsibilities among stakeholders. The findings demonstrate the priority of portfolio-based financing, the need for long-term tariff regulation, and the importance of improving the regulatory framework to scale effective modernization practices. The practical significance of the research lies in substantiating the relationship between investment mechanisms and institutional coordination towards regional infrastructure development.

Keywords: *infrastructure modernization, comprehensive territorial development, utility infrastructure, investment mechanisms, public-private partnership, concessions, life-cycle cost, tariff regulation*



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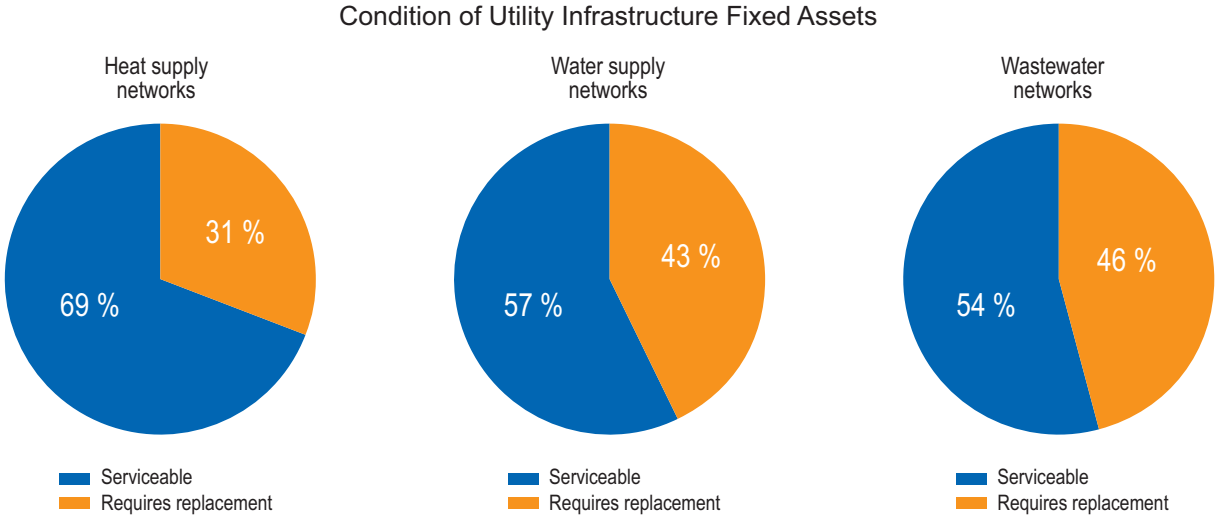
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INTRODUCTION

Utility infrastructure in Russian cities is affected by chronic deterioration, largely caused by substantial underfinancing, which negatively affects the quality of the urban environment and living standards. According to the estimates made by the Federal State Statistics Service cited in the article, 43–46 % of water supply and wastewater networks require complete renewal. In some regions, the situation reaches a critical level: in the Republic of Tuva, up to 95 % of water supply networks are considered worn out, while in several North Caucasian regions, including the Republic of Dagestan, the Republic of Ingushetia, and the Kabardino-Balkarian Republic, more than half of heating networks require replacement [1]. This condition produces a large number of emergency situations. In 2024–2025, roughly 220–230 serious utility accidents were registered daily on average. Such frequency of incidents highlights the urgent need to raise additional funding for the modernization of the housing and utilities sector (Fig.).

Although the housing and utilities sector performs an important social function, its investment attractiveness remains low. Private investment in utility infrastructure is limited because project payback periods are long and tariff regulation is strict. As a result, by the end of 2023 the total value of concession agreements in heat supply was about RUB 830 billion, significantly below the initial forecast of RUB 2 trillion [2]. Private companies are reluctant to enter the housing and utilities market because of low margins and material risks related to tariffs, political factors, and institutional constraints. By the end of 2025, accumulated household debt for utility services reached almost RUB 900 billion, and together with organizational debt approached RUB 1.5 trillion, worsening the financial position of resource-supplying organizations [2]. The main research task, therefore, is to develop effective financial instruments capable of attracting investment into utility infrastructure modernization without causing excessive tariff growth for households.

Comprehensive territorial development (CTD) is an innovative approach to the urban environment modernization. It combines housing construction, the resettlement of dilapidated and emergency housing, and the development of infrastructure facilities. Federal Law No. 494-FZ of 30 December 2020 established the legal foundations for CTD projects by replacing earlier approaches based on point development and the development of already built-up areas. CTD projects involve not only the construction of new housing to replace emergency housing, but also the creation of social facilities and the modernization of engineering infrastructure. By the end of 2024, decisions had been approved to implement more than 1,100 CTD projects in 86 constituent entities of the Russian Federation. The total construction area involved in these projects is estimated at 76.3 million square meters of new housing, and by 2030 the CTD potential is expected to rise to approximately 198 million square meters. CTD is therefore a promising mechanism for renewing urban infrastructure, but its effectiveness depends directly on the availability of sufficient financing for utility infrastructure and related facilities.



Condition of fixed assets of utility infrastructure

Russian scholarly and policy discussions offer different views on attracting investment into the housing and utilities sector. A number of studies emphasize the importance of public-private partnership (PPP) as a modernization instrument. In particular, concession agreements in water supply and heat supply can attract extra-budgetary resources and address long-term infrastructure problems. A concession gives the investor a long-term revenue basis and a mechanism for recovering invested funds, while the region receives network renewal financed by private capital. However, critical reviews of PPP practice show that substantial results are difficult to achieve without public support in the form of guarantees and auxiliary measures such as co-financing and subsidies. For example, DOM.RF has implemented an infrastructure bond mechanism which, from 2021 to September 2025, attracted more than RUB 45 billion to finance 14 projects. Some experts also argue for targeted financing of housing and utilities modernization programs from the federal budget and for the creation of special funds for these purposes [3].

MATERIALS AND METHODS

The analysis is based on public official sources and specialized publications issued by government bodies. The regulatory framework includes federal acts and program documents that define investment mechanisms in housing and utilities and CTD, including legislation on CTD, concessions and PPP, the Budget Code, and the passports of the national project Infrastructure for Life and the federal project Modernization of Utility Infrastructure. Statistical data were collected from the Ministry of Construction of the Russian Federation, Federal State statistics Service, Russian Government portals, development institutions including the Territorial Development Fund, regional authorities, and specialized media.

The research design includes three analytical blocks. First, regulatory and program analysis was used to examine current laws and subordinate acts and to classify investment instruments by type, including budget investments, infrastructure loans and bonds, concessions, and subsidies. Second, quantitative analysis was used to summarize official statistics on wear, accident rates, commissioning and repair of facilities, and financing volumes. Third, a case study was carried out for Zabaykalsky Krai, where declared program targets were compared with the actual progress of heat-supply and water-supply works.

RESULTS

1. Investment mechanisms available for CTD projects. Current legislation offers a variety of investment mechanisms to support and finance infrastructure development within CTD projects. Federal Law No. 494-FZ, which introduced Chapter 10, Comprehensive Territorial Development, into the Urban Planning Code of the Russian Federation, does not list specific federal financial mechanisms. In practice, regions and municipalities are empowered to conclude territorial development agreements with flexible conditions and obligations for investors. Such projects have revealed the need for public support, implemented through the special federal mechanism known as the infrastructure menu, designed to stimulate developer interest. The menu has infrastructure bonds, infrastructure budget loans, subsidies for low-margin projects, and the use of the National Welfare Fund.

In 2021–2022, the Ministry of Construction issued low-interest infrastructure loans to regions in a total amount exceeding RUB 483 billion. The interest rate was 3 % per year and the repayment period was 15 years. Importantly, access to these loans required at least 50 % co-financing from the regions [4]. The funding mission was to create engineering infrastructure, including water supply, wastewater systems, and roads, in new residential districts. Repayment was expected to come from tax revenues and payments from residents of the new districts. DOM.RF has issued infrastructure bonds through a special project arm that offers them in the financial market. The funds thus raised go to regional operators under the guarantee of the constituent entity of the Russian Federation. Regional operators are obliged to develop local infrastructure. Investors receive bonds with a high rating, while regions obtain financing with payment deferral of 15–20 years.

Concession agreements in housing and utilities, governed by Federal Law No. 115-FZ On Concession Agreements, are also important. This mechanism is used to transfer utility infrastructure facilities to private investors for modernization and operation purposes. In CTD projects, concessions can be used both for the construction of new nodal facilities and for the reconstruction of individual networks within renovated neighborhoods [5]. Under a concession agreement, the investor contributes cash and expects repayments through a pre-set tariff and, if necessary, an additional concession-grantor payment from the budget. Presently, concessions are the most common form

of PPP in housing and utilities: more than 2,700 agreements have been concluded with a total value of about RUB 1.2 trillion [6]. They cover heat supply, water supply, and wastewater facilities across Russia. Nevertheless, in large CTD projects concessions are used selectively, primarily for water and heat supply facilities.

Direct budget investment is implemented through the federal project Modernization of Utility Infrastructure, launched in 2024 within the Infrastructure for Life project. The project provides for an annual federal contribution of at least RUB 150 billion for network reconstruction. The total amount to be invested into housing and utilities modernization by 2030, including private investment, is expected to reach RUB 4.5 trillion. In addition to budget allocations, the program requires about RUB 750–800 billion annually from regional and private sources. Regions draft comprehensive modernization plans for housing and utility infrastructure up to 2030. These plans contain detailed measures, such as the replacement of boiler houses and pipelines, and identify financing sources for each measure. According to the Ministry of Construction, by September 2025, 37 regions had approved their comprehensive modernization plans, while 9 projects were still in the process of approval. This combination of a modernization plan and federal-investor financing functions as a new instrument.

Existing mechanisms do not apply to the whole infrastructure life cycle. Capital repair and network renovation continue to be financed mainly through depreciation included in tariffs and through consumer payments, which are insufficient [6]. At the same time, legislation allows the necessary instruments to be introduced gradually. In 2023, amendments were made to the PPP and concession legislation to simplify the implementation of housing and utilities projects. Among other things, these changes allow investors to propose projects on their own initiative and simplify the conversion of lease agreements into concessions.

2. Case study: Zabaykalsky Krai. Zabaykalsky Krai, know for its low budget revenues, faces acute problems of dilapidated housing and network wear. By 2024, more than 1,400 buildings had been registered as emergency housing, while the deterioration of heating networks reached up to 70 %. The region was among the first to adopt a regional law on CTD in 2022. In Chita, 34 renovation sites have been identified, and the program is expected to cover approximately 97 % of the emergency housing stock. Developers are required to resettle residents and improve territories. In 2026–2027, seven sites are expected to be launched, with the resettlement of about 20,000 square meters of emergency housing and approximately 1,140 people.

The key to success is the modernization of external engineering networks in older residential districts, many of which were built in the 1970s. Private developers usually do not invest into mains because of high costs and vague payback prospects, so public investment is required. In 2022, the region received a RUB 1.3 billion infrastructure budget loan for a new boiler house and a main heat pipeline for one of the pilot CTD sites. Under the federal housing and utilities modernization project for 2024–2025, RUB 2.4 billion was allocated, including at least RUB 1 billion for Chita. The financing scheme is combined: developers build housing and courtyard networks, while the region and the federation finance the mains infrastructure, including boiler houses and main pipelines. In-kind compensation is also involved: investors build apartments for resettled residents and, in return, receive land plots for commercial development and the right to sell the remaining floor area.

A concession was also involved: the city concluded a 15-year agreement for the reconstruction of the water utility. The concessionaire is to invest approximately RUB 600 million in treatment facilities and water supply networks, which will increase the reliability of water supply at CTD sites. Payback is secured through an increase in the water tariffs: the regional regulator committed to raising the tariff by 15 % over five years. The case shows that even a subsidized region can attract private resources if regulatory support and predictable tariff policy are in place.

Interim results as of mid-2025 are moderate but significant. Design documentation was prepared for seven CTD sites, about 5 % of emergency housing stock was resettled, one modular boiler house was commissioned, and about three kilometers of heating networks were modernized. An effective financial model has been created by combining federal grants and low-interest loans, regional co-financing, concessions, and investments from developers and utility operators. Projects become unstable without any one of these elements. By comparison, in the Amur Region, the launch of CTD is delayed because of a shortage of funds for the engineering site preparation: developers cannot start without the infrastructure in place, while the region cannot finance it.

3. Comparative assessment of instruments. The analysis identified the full set of investment mechanisms applicable to utility infrastructure modernization in CTD projects and assessed their comparative effectiveness. Direct budget financing, including subsidies and capital investments, is advantageous because it does not create a debt burden and guarantees the receipt of funds. For example, the resettlement program supported by the Housing and Utilities Fund ensures transfers for new housing and infrastructure. Its disadvantages are limited amounts and narrow targeting: in 2022, only about 5 % of the Russian regions obtained support for housing and utilities modernization, and the amounts were often only sufficient for partial repair. The new federal program up to 2030, with a total amount of RUB 4.5 trillion, expands coverage, but the federal contribution is about RUB 150 billion per year, with the rest being expected from investors [7]. Consequently, subsidies are necessary but insufficient, and a combined approach is required.

Infrastructure budget loans are in high demand: by 2022, applications totaling RUB 483 billion had been approved. Their advantages are a 3 % rate and a long repayment period. They are used to construct social facilities and mains required for housing development. Their disadvantages are the 50 % co-financing requirement, which forces poorer regions to raise debt funding, and the future repayments from the budget, with repayment peaks after 2032. Nevertheless, in 2021–2024 these loans became a key CTD driver, and in 2023 the instrument was extended.

DOM.RF infrastructure bonds remain relatively small in scale, but they have demonstrated a strong potential. The 2021 pilot amounted to RUB 30 billion for 12 regions to finance infrastructure for housing projects [8]. Their advantage is flexibility: market funds are raised under public guarantees without direct growth of regional debt, because obligations are formally assumed by DOM.RF. The rate for regions is below market level, approximately 7 % compared with more than 10 %. The limitation is the need to create a regional subsidiary and organize interaction with DOM.RF, so not all regions have been able to use the instrument. By 2023, the Moscow Region and Tatarstan were leaders, each attracting more than RUB 10 billion. For small subsidized regions, the mechanism is used rarely, often because they lack large housing programs; therefore, a standard road map for the instrument would be useful.

PPP and concessions are the classic channel for private investment. At the beginning of 2024, 2,763 concessions were in force, ranging from large city water utilities, such as in Rostov-on-Don, to

boiler houses in district centers. Their effect is to reduce losses and optimize expenditure by combining investment and operation functions in one private operator. A standard result is a reduction in network accidents after modernization. Problems include the requirement of tariff payback, which limits access to regions with low tariffs unless subsidies are available; fragmentation, because a concession often covers only one subsystem while CTD requires a comprehensive solution; and a lengthy preparation period, usually one to two years. However, over the last five years private operators have invested about RUB 1 trillion in housing and utilities [6], confirming the effectiveness of the mechanism. Concessions remain appropriate for large systems with stable payment flows, such as the heat or water supply of a new CTD micro-district.

Although interest-rate subsidies for developers are not direct investments in networks, they indirectly influence infrastructure. In 2020, Government Resolution No. 629 launched the subsidization of loan rates for developers in low-profitability regions [9]. In 2020–2022, around 1,800 projects were supported, which helped start construction in lagging regions. As a result, previously unprofitable projects became feasible and new housing was added to modernized networks. Zabaykalsky Krai serves as an example: several residential facilities in Chita were financed and later included in CTD [10]. Further, this mechanism could be supplemented with direct infrastructure grants for low-payback projects, which is being considered in the reform of developers' investment quotas.

Additional instruments include targeted regional infrastructure funds, municipal bonds, and project financing through infrastructure bonds. Moscow, Saint Petersburg, and Tatarstan use tariffs and budget funds to launch utility infrastructure development funds, whereas such funds are unavailable or poorly financed in subsidized regions, where municipalities have difficulty accessing cheap capital [11]. There are individual cases: in 2022, Khanty-Mansi Autonomous Area issued green bonds to finance boiler-house modernization and conversion to gas. In 2022, access to proceeds from the National Welfare Fund was simplified: its resources can be contributed to infrastructure, including housing and utilities, through investments in bonds or loans. The mechanism has been used to modernize heating in the new regions of the Russian Federation; in 2023, about RUB 50 billion from the National Welfare Fund was allocated to utility facilities there. No cases of this kind have been registered in the older regions, but the instrument has potential as a source of equity funding if access to debt financing is limited.

According to the Ministry of Construction, in 2025–2030 more than 50,000 kilometers of engineering networks and about 2,000 water supply and wastewater facilities are planned to be built or reconstructed to improve services for about 20 million people. Achieving the target network renewal rate of 2.5 % per year by 2030, compared with the current rate of about 1 %, is possible only through large-scale investment: hundreds of billions of rubles can be raised annually through loans and bonds, combined with tariff policies that stimulate concessionaire investment [12].

In CTD projects, investment mechanisms accelerate implementation and increase project completeness. Moscow and the Moscow Region, as donor regions, implement comprehensive neighborhood development projects aimed at comprehensive replacement of utilities; they renew dozens of kilometers of networks. The North Caucasus Federal District and the Far East cannot implement major renovation programs without federal support. In 2023, all North Caucasus regions approved housing and utilities modernization plans to 2030, including more than 1,700 actions worth about RUB 200 billion. The sources are subsidies, infrastructure loans, and concessions involving corporations; T Plus stated its readiness to participate if public support was available [13]. For depressed regions, public financing is a triggering mechanism that reduces risks and attracts private investors.

The first public assessments of the new instruments and their effectiveness have emerged. According to the Government of the Russian Federation, in 2019–2025 more than 12,000 kilometers of utility networks and about 5,500 facilities were built or modernized. These projects were supported by the national project Housing and Urban Environment and the launch of the infrastructure menu. Forty five kilometers of water supply networks were modernized in 16 municipal districts of Primorsky Krai in 2019-2023; financing was 60 % budgetary and 40 % from concessionaires, and water quality was improved for approximately 123,000 residents.

The socio-economic effects of CTD are impressive. Infrastructure loans totaling RUB 483 billion will create dozens of thousands of jobs and about 130 million square meters of housing by 2030. Improved housing conditions are a key value: according to the Ministry of Construction, in 2023–2024, 4.4 million families improved their living conditions, also through CTD. Not all effects are directly attributable to utility infrastructure, but its modernization is a necessary foundation for housing commissioning.

Overall, the set of instruments is broad, but each instrument has limitations. Maximum effect is achieved through a combination of budget leverage, borrowed sources, and private investment. Large-scale modernization of utility infrastructure within CTD is impossible without public involvement, including incentives and regulatory support, especially in subsidized regions.

DISCUSSION

The findings are consistent with publications on the chronic underfinancing of housing and utilities and the need for an active role of the state. The share of worn networks remains high and accident rates are significant. The analysis clarifies the balance of sources: even if tariff constraints are relaxed, private capital covers only about 20 % of the need, while about 80 % is covered by budgets and households. This corresponds to the parameters of the federal project, with approximately RUB 150 billion per year from the budget against roughly RUB 750 billion from other sources. The role of the state is therefore broader than direct investment: it creates an environment that attracts the remaining resources.

A comprehensive approach encompasses borrowing successful practices from adjacent sectors, including long-term life-cycle contracts, permanent funds, and service-oriented agreements, similar to approaches used in the European Union, where the grant component in water supply may cover 10–30 % of non-repayable costs. The Zabaykalsky Krai case confirms that subsidized resettlement and mains infrastructure make projects profitable; a combination of grants and debt instruments is required.

Concerns about the efficiency of expenditure can be mitigated through a project filter: key performance indicators, program passports, quantitative effects in loan applications, profitability requirements for infrastructure bonds combined with mandatory technology effects, such as lower heat losses. Background risks include household solvency and import pressure caused by sanctions [14]. These factors make the integration of financial mechanisms a necessary condition for closing the investment gap; the sector's deficit of approximately RUB 970 billion confirms the scale of the task [3].

CONCLUSIONS

The proposed comprehensive financing mechanism for modernizing utility infrastructure in CTD projects combines budget investments, low-interest loans, bonds, PPP, concessions, and targeted subsidies linked to the stages of the facility life cycle. The study shows that current instruments are effective if used in a coordinated manner: isolated use, such as concessions alone or subsidies alone, does not close the investment gap. The proposed scheme distributes roles by stage: planning involves requirements for developers; construction relies on infrastructure loans and bonds; operation requires long-term tariff regulation; capital repair uses accumulative funds and innovations; and renewal launches a new CTD cycle.

Practical results are aimed at federal and regional authorities as well as investors. The subsidized-region case of Zabaykalsky Krai shows that combined federal and private resources can successfully launch CTD even when regional earnings are small. For broader dissemination, this model should be integrated into the regulatory framework and program-level solutions.

The main instruments are as follows. Firstly, each CTD project should have a uniform investment passport with a utility infrastructure constituent, including the list of facilities, estimated costs, financing sources, and risk sharing models. Secondly, raising the required RUB 2 trillion of private investment for network renewal requires flexible tariff models that account for payback periods; without tariff indexation, such investment amounts cannot be raised. Third, the powers of the Housing and Utilities Fund should be expanded or a separate infrastructure modernization fund should be launched, with mechanisms for concessionaire participation and targeted grants for network development, including resources from the National Welfare Fund. Fourth, a pilot programme of municipal infrastructure bonds supported by DOM.RF should be launched for financially stronger municipalities to disseminate tested regional issuance practices. Fifth, regulatory acts governing life-cycle management of utility facilities should be introduced through amendments to strategic federal planning; this would include mandatory assessment of asset life, incorporation of depreciation into the tariff system, and reservation of funds for renewal.

To assess the effectiveness of the proposed scheme, pilot projects should be implemented in five cities representing different types of territories, including donor regions, subsidized regions, and medium-sized centers. Combining CTD with housing and utilities modernization within these pilot projects would provide empirical data for subsequent scaling. Regional financial stability, including the accumulation of debt under low-interest loans and bonds, requires continuous co-financing rather than single-time injections. The relevance of these proposals is confirmed by stronger budget support and investment control in resource-supplying organizations planned for 2025–2026.

Utility infrastructure modernization becomes feasible when policy moves from separate single-time actions to an integrated, life-cycle-oriented strategy. Such an approach can not only improve network reliability, but also reduce total operating costs and accelerate the commissioning of housing, creating a multiplier effect for the economy and improving the quality of the urban environment. Its application will support the achievement of national goals in housing and urban development and contribute to the sustainable development of Russian regions.

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Инвестиционные механизмы модернизации коммунальной инфраструктуры в рамках комплексного развития территорий

В данной статье исследуется комплексный подход к модернизации коммунальной инфраструктуры, рассматриваемый в рамках концепции комплексного развития территорий (КРТ). Особое внимание уделяется применению комбинированных инвестиционных стратегий и учету таких показателей, как стоимость жизненного цикла (СЖЦ) и совокупная стоимость владения (ССВ), с целью повышения эффективности модернизационных процессов. Целью данного исследования является выявление и систематизация инструментов, предусмотренных российским законодательством, для комплексного развития территорий и взаимосвязанных с ними отраслей. Также будут разработаны рекомендации по комбинированному применению этих инструментов с учетом особенностей дотационных регионов. В ходе реализации данной методологии будут осуществлены следующие шаги: изучение нормативно-правовой базы (в частности, Федерального закона № 494-ФЗ и программы модернизации ЖКХ), проведение статистического обзора действующих проектов КРТ в субъектах с дотационным финансированием, а также сравнительный анализ существующих инвестиционных механизмов (концессии, государственно-частное партнерство, инфраструктурные бюджетные кредиты, инфраструктурные облигации, бюджетные субсидии и гранты, долгосрочные контракты управления). Будет осуществлено изучение реализуемых проектов КРТ. В ходе работы были определены классификации механизмов по источникам финансирования и уровням риска, разработана матрица применимости для разных этапов жизненного цикла, а также предложена организационная структура проектного офиса и распределение ответственных сторон. Выводы подтвердили приоритет портфельной модели финансирования, необходимость долгосрочного тарифного подхода и важность совершенствования нормативно-правовой базы для масштабирования эффективных практик. Важность данного научного исследования состоит в обосновании взаимосвязи между инвестиционными инструментами и институциональной координацией на региональном уровне.

Ключевые слова: *модернизация инфраструктуры, комплексное развитие территорий, инвестиционные механизмы, государственно-частное партнерство, концессии*

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