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A Model of the Dependence of Economic Performance Indicators of Investment and Construction Project Participants on the Use of Innovative Materials with Consideration of Environmental Requirements

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Abstract: The article examines the current state of development of the sphere of using innovative materials in construction, analyzes the problems inherent in the implementation of innovative materials by participants in investment and construction projects, and concludes that, despite the presence of strategic objectives for the development of this area in construction, the level of innovative development of organizations remains insufficient. One of the main barriers hindering the application of innovative materials is identified as a structural imbalance in the distribution of economic effects among the participants of investment and construction projects, resulting from their implementation. As a result of the study, a model of the dependence of the economic performance indicators of participants in investment and construction projects on the use of innovative materials is developed, based on the life-cycle principle of a construction facility and the theory of value assessment. The proposed approach contributes to the formation of a balanced system of economic relationships among all participants in investment and construction activities and creates a basis for achieving the planned indicators of innovative development in construction.

Keywords: innovative materials, investment and construction project, construction sector, innovations

1. Introduction

The application of innovative materials currently acts as one of the sources for developing the potential of the national investment and construction sector. In accordance with the Strategy for Innovative Development of the Construction Industry of the Russian Federation until 2030, a systemic transformation is envisaged, characterized by a planned increase to 20% in the share of innovative products in the total volume of works and services of construction organizations, an increase to 15% in the proportion of organizations implementing technological, organizational, and marketing innovations, as well as an increase to 20% in the volume of financing of technological innovations from the own funds of construction participants (Ministry of Construction of the Russian Federation, 2015). As of the end of 2024, the share of expenditures on innovation in construction amounted to 0.8%, which is 3.2 times lower than the national average; however, when considering the dynamics of this indicator within the construction sector, growth is observed from 0.2% in 2021 (Rosstat, 2024a).

A key constraint on the implementation of innovations in construction is the fragmented nature of the sector, which creates objective barriers to the adoption of technological innovations (Kushnir, 2024). At the same time, O. V. Kornitskaya, N. I. Trukhina, O. A. Popova, and E. V. Vasilchikova argue that the critical problem lies not in the generation of new technologies but in their commercialization, as a significant volume of promising developments does not reach the stage of practical implementation due to institutional and economic barriers (Kornitskaya et al., 2021). The institutional environment of the construction sector is characterized by conservatism and an orientation toward established informal practices, which significantly limits the diffusion of technological achievements (Kushnir, 2024). At the same time, the potential to increase innovative activity lies in the development of cooperation between design and construction organizations and the introduction of flexible contractual models.

M. S. Oborin emphasizes the systemic nature of innovative transformations, highlighting their role in optimizing interactions among participants in investment and construction projects, and substantiates that their implementation contributes to the rational use of resources and the integration of new technological solutions (Oborin, 2020). Of particular importance in the context of financing innovation processes is the study by D. A. Demyantseva, which justifies the need to establish a sustainable financial infrastructure to support the innovative activities of construction organizations (Demyantseva, 2024).

According to O. I. Makarenko, technological modernization of the construction sector is directly associated with the implementation of innovative materials, which the author considers a key factor of technological progress (Makarenko, 2020). Modern materials have the potential to significantly improve the operational characteristics of capital construction facilities, including enhanced strength, durability, and energy efficiency, while simultaneously reducing operating costs.

Among current trends, the development of environmentally friendly solutions is highlighted, particularly "green" concrete, characterized by a reduced carbon footprint due to the use of alternative binder components, as well as materials produced from recycled construction waste (Alfimova et al., 2024; Berwal et al., 2024). Considerable scientific interest is also attracted by self-healing composites, in which encapsulated bacterial cultures or chemical agents provide autonomous elimination of microcracks, thereby extending the service life of structures (Zhukova & Saifulina, 2020).

A promising direction is the implementation of photocatalytic materials based on titanium dioxide, which, under the influence of solar radiation, acquire self-cleaning properties and contribute to the neutralization of atmospheric pollutants (Antonenko et al., 2020). The use of composite materials, including carbon fiber and fiberglass, also offers significant opportunities, as they combine high strength characteristics with corrosion resistance (Nizin & Leontyev, 2025; Głodkowska & Ziarkiewicz, 2019).

A distinct category comprises smart materials with adaptive properties, such as electrochromic glass with adjustable transparency and electrically conductive concrete, which expand the functional capabilities of building structures (Sokolov, 2024). At the same time, the development of lightweight high-strength materials is progressing, with aerogels and similar solutions enabling exceptional thermal insulation performance at minimal weight, which is particularly relevant in the segment of high-rise construction (Makeeva et al., 2017).

2. Methodology

The study applies an economic, mathematical, and systems-based approach to analyze the impact of tightening environmental regulations on the economic efficiency of construction organizations. The methodological framework is based on the development of a functional model that describes the dependence of an integral economic indicator on the degree of tightening of environmental regulation and a set of internal economic factors. The model accounts for the nonlinear nature of the impact of environmental constraints, allowing consideration of changes in economic effects as the regulatory parameter increases. The analysis of results relies on a qualitative interpretation of the character of the obtained relationship, without the use of formalized scenarios or sensitivity analysis methods. Statistical data and results of previously published scientific studies are used to substantiate the model parameters. The findings are model-based and reflect general economic regularities associated with the tightening of environmental regulation in the construction sector.

3. Result and Discussion

The innovative materials listed above are oriented toward the creation of multifunctional, environmentally safe, and energy-efficient facilities that comply with the principles of sustainable development and digital transformation of construction (Ablyazov, 2024; Zabaznova & Ablyazov, 2025). It is noted that the construction sector ranks among the leading industries in terms of carbon dioxide emissions, accounting for 38% of total emissions (UN, 2024). As a result, it is projected that by 2029, the global market for innovative construction materials will reach USD 610 billion, with an average annual growth rate of 11.6% (DigitalDeveloper, 2025).

The market for innovative materials is developing rapidly, driven by technological advances, the growing significance of sustainable development, and the increasing demand for advanced infrastructure. As urbanization accelerates, demand for innovative materials that enhance efficiency, reduce environmental impact, and improve facility safety increases. According to Verified Market Reports, the Asia–Pacific region holds the largest share of the innovative construction materials market in terms of revenue (35%), followed by North America (30%), Europe (25%), Latin America (5%), and the Middle East and Africa (5%) (Verified Market Reports, 2025b). The Asia–Pacific region is also the fastest-growing, due to rapid urbanization and the active implementation of investment and construction projects, particularly in China and India.

At the global level, the main areas of application of innovative materials are residential construction (45%), commercial construction (35%), and industrial construction (20%) (Verified Market Reports, 2025b). In addition, it is projected that the industrial construction segment will become the most in-demand market for innovative materials, driven by infrastructure development and growing demand in the industrial sector (Verified Market Reports, 2025b).

The use of innovative construction materials represents a trend that affects all forecasting horizons, from the short term (3–5 years) to the long term (over 10 years). An analysis of the current state of the construction materials market indicates the dominance of traditional materials with modified characteristics that have undergone technological adaptation (Fig. 1). However, the most significant growth potential is concentrated in the segment of innovative solutions, including smart and adaptive materials that represent a qualitatively new category of construction technologies. Self-healing cement, which can autonomously regenerate microcracks, has the potential to increase the service life of building structures substantially. Smart glass with adjustable optical properties creates new opportunities in energy efficiency and adaptive design. Phase-change materials, capable of accumulating and releasing thermal energy during changes in their physical state, create prerequisites for the development of passive building thermoregulation systems that significantly reduce energy consumption. Composite materials, which combine heterogeneous components to achieve a synergistic effect, exhibit higher specific strength, corrosion resistance, and durability than traditional materials, which is particularly important under conditions of resource constraints and the tightening of environmental standards (Smirnova et al., 2022).

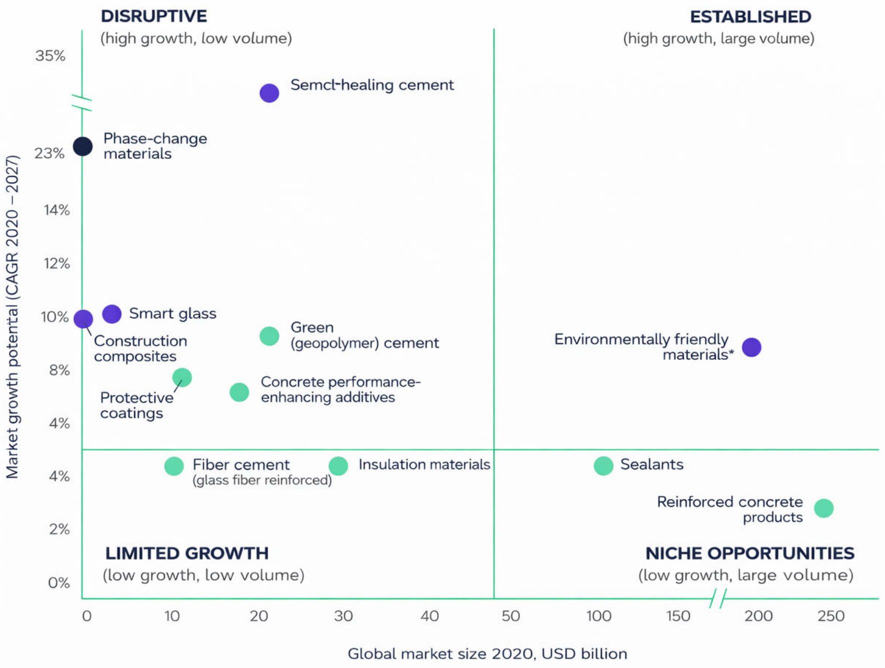

Fig. 1. Assessment of the Innovative Construction Materials Market (Moscow Innovation Agency, 2021)

The global market for environmentally friendly construction materials was valued at USD 301.6 billion in 2024 and is expected to reach USD 907.1 billion by 2034, with a compound annual growth rate of 11.9% from 2025 to 2034 (Global Market Insights, 2025). The global trend toward implementing the sustainable development concept is driving construction organizations to use environmentally friendly materials, including recycled, biodegradable, and energy-efficient materials. It is expected that by 2034, the global market volume of recycled plastics used to produce environmentally friendly, innovative materials will reach USD 12.24 billion, with a compound annual growth rate of 8.71% (Verified Market Reports, 2025a). Moreover, the market for recycled concrete aggregates is projected to increase to USD 18.74 billion by 2034, with an annual growth rate of 6.75% (Towards Chem and Materials, 2025).

In addition, the global lightweight aggregate concrete market is growing at an average annual rate of 4.9% and is expected to reach USD 5.5 billion by 2030 (Research and Markets, 2025). By replacing traditional coarse aggregates with lightweight alternatives such as expanded clay, shale, or perlite, lightweight aggregate concrete reduces structural loads, thereby enabling the construction of less expensive foundations. The share of self-healing concrete is also increasing: the market is projected to grow at a compound annual rate of 36.8% and reach USD 1.04 trillion by 2032 (Fortune Business Insights, 2025). The growth of this market segment indicates the increasingly widespread use of self-repair mechanisms, such as bacteria, microcapsules, and polymer agents, which activate when cracks form, allowing concrete to repair itself autonomously. Moreover, bacteria-based self-healing concrete demonstrates 25.9% higher compressive strength, while simultaneously restoring cracks through biological processes (Mahmood et al., 2022).

Nevertheless, participants in investment and construction projects recognize the high cost of materials, structures, and products as a factor limiting construction activities (46% of surveyed organizations) (Rosstat, 2024b). In addition, only 8.2% of construction organizations invest in innovative technologies and new materials in particular, which is 16.3% lower than the national average in Russia (Rosstat, 2025). Taken together, two opposing trends can be observed: the high cost of traditional construction materials as a constraining factor and the insufficient innovative activity of participants in investment and construction activities in the application of new technologies, due to a lack of initial investment required for their implementation.

The use of innovative materials in construction is associated with several challenges stemming from legislative, technological, economic, and human resource factors. From a legislative perspective, building codes and regulations do not always align with current requirements; nevertheless, designers are required to plan projects from the outset, taking into account the actual properties of innovative materials (Chernyaev & Abakumov, 2017). In addition, experts note the lack of a unified system of standards for testing and certifying new products (Akhnevsky, 2024). Technological factors limiting the application of innovative materials in construction include the need to modernize construction equipment and the lack of methodologies for theoretical service-life assessment and accelerated material testing (Zaytseva, 2019).

The financial aspect of using innovative materials is associated with high commissioning costs and significant initial expenditures required for the implementation of new technologies, as well as with pricing and cost-estimation issues, since existing cost-estimation regulatory frameworks do not fully account for the cost of innovative materials. This reduces the accuracy of estimating construction costs and the economic efficiency of project implementation (Akhnevsky, 2024; Sergeeva, 2019). From the perspective of human resource provision in construction, a shortage of specialists capable of operating under conditions involving the use of innovative materials is observed, as many young professionals possess knowledge primarily of outdated, conventional technologies and materials, while the professional development system remains insufficiently adapted to new methods of implementing investment and construction projects (Sergeeva, 2019).

According to Rosstat data, material costs account, on average, for 55% of the total cost structure of construction and installation works, thereby affecting the efficiency of investment in innovative materials (Kuznetsova & Farkhutdinov, 2023). Consequently, among the participants of an investment and construction project, the main financial burden associated with the use of innovative materials falls on design and construction organizations that directly implement them. Designers face increased labor intensity due to the absence of unified methodological guidelines and a well-established regulatory framework, since, according to expert assessments by the Ministry of Construction of the Russian Federation, the procedures for developing new and updating existing regulatory documents in the construction sector are carried out with an insufficient level of scientific justification, without comprehensive experimental studies, and without broad professional discussion of the results of testing innovative solutions under real construction conditions (Ministry of Construction of the Russian Federation, 2015).

Contractors incur additional costs due to the lack of well-established mass-installation technologies for new materials: in the short term, the estimated construction cost with innovative materials is higher than with traditional materials and technologies (Klyavlin et al., 2017). In the long term, the systemic economic effect of using innovative materials manifests as reduced direct construction costs, shorter project payback periods, increased capital turnover, and improved financial sustainability for construction organizations; however, this requires prior experience with such advanced materials.

It is also recognized that the main economic benefits from the use of innovative materials are realized at the operational stage of the life cycle of a facility and are appropriated by operating organizations and users, which is reflected in increased structural durability, reduced maintenance and repair costs, and lower energy consumption (Sycheva, 2020; Makarenko, 2023).

According to the author, the use of innovative materials in construction leads to an imbalance in the distribution of economic effects among participants in an investment and construction project, necessitating a model that accounts for the time lag between the occurrence of costs and the realization of economic benefits.

The conceptual framework of the model is based on the life-cycle principle of a construction facility and the theory of value-based assessment. The key hypothesis assumes that the additional costs incurred at the design and construction stages when using innovative materials should be compensated by the discounted value of future operational benefits.

The mathematical apparatus of the model includes a system of interrelated functions and is based on the net present value (Net Present Value, NPV) method, which is the most widely used approach for assessing life-cycle value in construction. This method allows determining the value of future cash flows generated by an investment project by discounting them at an appropriate rate.

The first element of the model is the cost function for the investment and construction project, which aggregates all costs arising at different stages of the life cycle and provides a methodological basis for the subsequent analysis of the economic efficiency of using innovative materials. The cost function reflects the model's adaptability to different types of construction facilities and various categories of innovative materials, thereby expanding its practical application.

The following function describes the design costs taking into account the use of innovative materials:

$$\text{Cproj} = \text{C}^{\text{o}}\text{proj} \times \text{Qm} \times (1 + \alpha \times \text{Rn}), \qquad (1)$$

where:
$\text{C}^{\text{o}}\text{proj}$ — baseline unit design costs (RUB per unit),
Qm — volume of application of innovative materials (m^2, m^3, t),
α — elasticity coefficient of design costs with respect to regulatory uncertainty ($\alpha \geq 0$),
Rn — regulatory uncertainty coefficient, taking values in the range from 0 to 1, where 0 corresponds to full regulatory and legal support, and 1 corresponds to the complete absence of a regulatory framework.

Regulatory uncertainty, formalized through the coefficient Rn, determines an increase in the labor intensity of design works caused by the absence of unified calculation methodologies and standardized solutions. The design cost function shows a linear dependence on the regulatory uncertainty coefficient, reflected in an increase in design labor intensity in the absence of standard solutions and approved regulatory requirements. In addition, the elasticity coefficient reflects the extent to which design costs increase in the absence of an approved regulatory framework and standard solutions for innovative materials, ensuring adequate representation of real design conditions when using these materials and enabling quantitative assessment of the risks associated with regulatory uncertainty.

The following formula defines the construction cost function:

$$\text{Cbuild} = \text{C}^{\text{o}}\text{build} \times \text{Qm} \times (1 + \beta \times (1 - \text{Te})), \qquad (2)$$

where:
$\text{C}^{\text{o}}\text{build}$ — baseline unit construction costs (RUB per unit),
β — coefficient reflecting the impact of technological maturity on construction costs ($\beta \geq 0$),
Te — technological maturity indicator, taking values from 0 to 1, where 0 corresponds to experimental materials without established application technologies, and 1 corresponds to mass, standardized production technology.

The function Cbuild mathematically formalizes the dependence of the cost of construction and installation works on the level of technological maturity of the materials used. The construction cost function enables quantitatively assessing the impact of technological risks on project implementation costs, reasonably planning project budgets involving innovative materials, and developing measures to raise the technological level of project execution. The structure of the function demonstrates the nonlinear nature of cost growth as the value of the indicator T_e decreases, reflecting real production processes in construction. Technological maturity, as measured by the parameter Te, determines the efficiency of production processes and affects labor productivity in the execution of construction and installation works. The coefficient β reflects the extent to which the costs of construction and installation works increase when new, insufficiently mature materials and technologies are used: the higher its value, the more significant the impact of material application on the overall project cost.

The function of operating costs in period $t$when using innovative materials is expressed by the following formula:

$$\text{Coper(t)} = \text{C}^{\text{o}}\text{oper} \times \text{Qm} \times (1 - \gamma)\text{\^{}t}, \qquad (3)$$

where:
$\text{C}^{\text{o}}\text{oper}$ — baseline unit operating costs in the first year of operation (RUB per unit per year),
γ — annual coefficient of reduction in operating costs due to the use of innovative materials ($0 \leq \gamma < 1$), reflects the improved operational characteristics of innovative materials (increased durability, energy efficiency, and reduced maintenance requirements),
t — period of operation (year), t = 1, 2, ..., T.

The function C_oper(t) describes an exponential decrease in the operating costs of a construction facility over time due to the use of innovative materials and reflects the cumulative nature of the accumulation of operational advantages. The annual coefficient of reduction in operating costs resulting from the use of innovative materials, γ γ, serves as an integrated indicator that aggregates information on material durability and wear resistance, thermal and energy-saving properties, and maintenance and repair requirements. The indicator γ approaches 1 for innovative materials and 0 for traditional materials.

The second element of constructing the model of the dependence of the economic performance indicators of participants in investment and construction projects on the use of innovative materials concerns the assessment of economic effects during the facility's operation, structured into operational and socioeconomic components.

Operational savings from the use of innovative materials in period t t are defined as the difference between operating costs when using traditional materials and innovative materials:

$$\Delta \text{Eoper(t)} = \text{Ctradoper(t)} - \text{Coper(t)}, \tag{4}$$

where:
Ctradoper(t) — operating costs when using traditional materials in period t,
Coper(t) — operating costs when using innovative materials in period t.

Operational savings are a key indicator of the effectiveness of implementing innovative materials, quantifying the difference in operating costs between traditional and innovative solutions. This indicator is fundamental for substantiating the economic feasibility of using new materials in investment and construction projects, as operational savings assessments enable justification of initial investments in innovative materials, evaluation of the effectiveness of implemented solutions, and development of economically efficient strategies for facility operation.

Socioeconomic effects, including environmental benefits and improvements in environmental quality, are assessed by the function:

$$\Delta \text{Esocial(t)} = \text{Eeco(t)} + \text{Ecomfort(t)}, \tag{5}$$

where:
Eeco(t) — monetary value of environmental benefits in period t (reduction of CO_2 emissions, decrease in the consumption of non-renewable resources),
Ecomfort(t) — benefits from improved operational comfort (RUB).

The function ΔEsocial(t) represents a comprehensive indicator that quantitatively expresses the additional benefits arising from the use of innovative materials that are not reflected in direct operating costs, thereby making it possible to monetize the positive effects associated with the application of modern construction materials. Benefits from improved operational comfort include reduced morbidity of the population, increased labor productivity, and a reduction in the time and costs required for maintenance and repair of the facility. The assessment of socioeconomic effects enables evaluation of the contribution to achieving sustainable development goals and can also be used to substantiate government support for innovative projects.

Within the application of the net present value (NPV) method in the development of the model, the cumulative discounted flow of economic benefits over the calculation period T is calculated as follows:

$$\text{E}\Sigma = \frac{\sum_{t=1}^{T} \Delta\text{Eoper(t)} + \Delta\text{Esocial(t)}}{(1+\text{r})^{t}}, \tag{6}$$

where:
r — discount rate (real rate excluding inflation),
T — calculated life-cycle period of the facility (years).

The cash flow represents a mathematical formalization of the process of discounting economic benefits at different points in time to a single reference moment, enabling accurate comparison and aggregation of cash flows across the facility's life cycle.

The model describing the dependence of the economic performance indicators of participants in investment and construction projects on the use of innovative materials is based on the assessment of the key efficiency criterion—the net present value of the project when innovative materials are applied:

$$\text{NPV} = -\text{Cproj} - \text{Cbuild} + \text{E}\Sigma. \tag{7}$$

The net present value of the project is calculated as the difference between the discounted value of future benefits and the total capital expenditures.

A positive value of the net present value indicator is a condition for the economic feasibility of using innovative materials.

$$\text{NPV} > 0. \tag{8}$$

Thus, the discounted value of future benefits from the use of innovative materials should exceed the additional capital costs of implementing them.

In addition, when assessing the efficiency of implementing innovative materials, additional indicators are calculated, including the discounted payback period, profitability index, and internal rate of return.

The discounted payback period (DPP) is determined based on the following condition:

$$\frac{\sum_{t=1}^{DPP} \Delta\mathrm{Eoper(t)} + \Delta\mathrm{Esocial(t)}}{(1+\mathrm{r})^{t}} = \mathrm{Cproj} + \mathrm{Cbuild}, \tag{9}$$

provided that the condition DPP < Tcritical, where Tcritical is the critical payback period for a given type of project.

The parameter Tcritical is established based on industry standards, the average service life of the materials used, investor requirements for capital recovery, and macroeconomic forecasts. The discounted payback period is the time required for the discounted value of the cumulative economic benefits from the use of innovative materials to equal the initial investment. A DPP value of less than 5 years indicates high investment attractiveness of using innovative materials, whereas a DPP exceeding 15 years indicates low investment attractiveness and the economic infeasibility of implementing innovations.

The profitability index (PI) is calculated using the following formula:

$$\mathrm{PI} = \mathrm{E}\Sigma \,/\, (\mathrm{Cproj} + \mathrm{Cbuild}) > 1 + \lambda, \tag{10}$$

where:
λ — innovation risk premium.

The profitability index is a relative indicator of the efficiency of investments in innovative materials, expressed as the ratio of the discounted value of future benefits to the initial investment. The risk premium compensates for technological uncertainty, as well as regulatory, market, and operational risks (typically assumed to be in the range of 0.1–0.3). The PI criterion is particularly useful when selecting among alternative materials and comparing projects of different scales.

The internal rate of return (IRR) is determined using the following formula:

$$-\mathrm{Cproj} - \mathrm{Cbuild} + \frac{\sum_{t=1}^{T} \Delta\mathrm{Eoper(t)} + \Delta\mathrm{Esocial(t)}}{(1+IRR)^{t}} = 0, \tag{11}$$

provided that the condition IRR > r + ρ, где ρ — is satisfied, where ρ ρ denotes an additional risk premium.

The internal rate of return represents the discount rate at which the net present value of the project is equal to zero. An advantage of the IRR criterion is that it does not require precise specification of the discount rate; however, it does not account for investment scale and assumes reinvestment exclusively at the IRR level, which limits its use as a primary criterion for efficiency assessment.

The task of optimizing the volume of application of innovative materials within the framework of the developed model is formulated as a nonlinear programming problem with the objective function of maximizing net present value and a system of technological, budgetary, and regulatory constraints:

$$\max \mathrm{NPV(Qm)}. \tag{12}$$

The following parameters define the constraints applied in constructing the model:
0 ≤ Qm ≤ Qmax — technological limit of material application;
Cproj + Cbuild ≤ Ibudget — investor's budget constraint, where Ibudget – denotes the project budget;
Rn ≤ Racceptable — acceptable level of regulatory uncertainty;
Te ≥ Tmin — minimum permissible level of technological maturity.

The final stage of model development involves a sensitivity analysis of the results with respect to changes in key parameters (r, γ, Rn, Te), enabling identification of the model's critical parameters and the development of effective measures to manage the risks associated with implementing innovative materials. For each parameter, a range of possible values is determined, and their impact on the final project performance indicators (NPV, payback period, profitability) is calculated. The parameters are then ranked according to the degree of their influence on project results, and the most significant factors require special attention in risk management.

The practical implementation of the model is carried out in the following sequence, forming the algorithm for applying the model:

1. Determination of the initial model parameters: volume of application of innovative materials Qm, coefficients Rn, Te, γ, discount rate r, and calculation periodT.
2. Estimation of baseline unit costs C^0proj, C^0build, C^0oper, and Ctradoper based on cost estimates and statistical data.
3. Calculation of capital expenditures for design Cproj using formula (1) and for construction Cbuild using formula (2).
4. Forecasting of operational effects ΔEoper(t) for each period t = 1, ..., T using formula (4).
5. Assessment of socioeconomic effects ΔEsocial(t) using formula (5).
6. Discounting of benefit flows and calculation of the cumulative effect EΣ using formula (6).
7. Calculation of the net present value NPV using formula (7).
8. Verification of efficiency criteria: $NPV > 0$, $DPP < T_{critical}$, $PI > 1 + \lambda$, $IRR > r + \rho$.
9. If necessary, optimization of the volume Qm to maximize NPV subject to the constraints.
10. Sensitivity analysis of the results with respect to changes in key parameters (r, γ, Rn, Te).

The developed mathematical framework enables transforming the structural asymmetry in costs and results into a balanced set of economic indicators for participants in an investment and construction project, thereby providing a methodological basis for substantiating decisions on the implementation of innovative materials. The practical implementation of the model involves iterative calibration of parameters based on retrospective data and verification of predictive accuracy.

4. Conclusion

The application of innovative materials is of strategic importance for the development of the Russian construction sector; however, despite nationally established target indicators, the actual level of expenditure on innovation in construction remains extremely low, while the structural imbalance in the distribution of economic effects among participants in investment and construction projects creates a systemic barrier to the technological modernization of construction.

Within the framework of the conducted research, a model is proposed to describe the dependence of participants' economic performance indicators in investment and construction projects on the use of innovative materials, enabling the distribution of costs and benefits arising from their application. The model demonstrates that the existing asymmetry, whereby the main costs are borne by designers and contractors while economic benefits are realized at the operational stage, can be overcome through a mechanism of discounted compensation.

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References

Ablyazov, T.Kh. (2024). Trends in the Development of the Innovative Construction Materials Market. *Bulletin of the Altai Academy of Economics and Law*, *11-3*, 313-320. (in Russian)

Akhnevsky, E. V. (2024). Innovative technologies as a basis for strategic development of construction companies. *Current research*, *26* (208). Retrieved from: https://apni.ru/article/9724-innovacionnye-tehnologii-kak-osnova-strategicheskogo-razvitiya-stroitelnyh-kompanij (date of access: 18.11.2025). (in Russian)

Alfimova, N.I., Levitskaya, K.M., Elistratkin, M.Yu. & Bukhtiyarov, I.Yu. (2024). Supersulfated cements: a review analysis of the properties, raw materials, production and application prospects. *Bulletin of the Belgorod State Technological University named after V.G. Shukhov*, *9*(7), 8–24. (in Russian)

Antonenko, M.V., Ogurtsova, Yu.N., Strokova, V.V. & Gubareva, E.N. (2020). Photocatalytically active self-cleaning materials based on cement. Compositions, properties, and applications. *Bulletin of the Belgorod State Technological University named after V.G. Shukhov*, *5*(3), 16–25. (in Russian)

Berwal, P., Gupta, N., Kumar, R., Sherif, E. & Kumar, A. (2024). Environmental Conservation by Using Recycled Aggregates: Enhancing Sustainability in Road Construction. *Rocznik Ochrona Środowiska*, *26*, 510-524. https://doi.org/10.54740/ros.2024.047

Chernyaev, V.V., & Abakumov, R.G. (2017). Challenges of Implementing Innovative Technologies in Construction. *Innovative Science*, 2-1, 245-247. (in Russian)

Demyantseva, D.A. (2024). Financing innovations in construction // Experience and problems of reforming the management system at a modern enterprise: tactics and strategy. In*: Collection of articles from the XXIII International Scientific and Practical Conference* (180-183). Penza: Penza State Agrarian University. (in Russian)

DigitalDeveloper. (2025). The Future of Building Materials and Technologies: Trends for 2025. Retrieved from: https://digitaldeveloper.ru/articles/tpost/f5s0eyich1-buduschee-stroimaterialov-i-tehnologii-t (date of access: 09.11.2025) (in Russian)

Fortune Business Insights. (2025). Self-Healing Concrete Market. Retrieved from: https://www.fortunebusinessinsights.com/self-healing-concrete-market-109689 (date of access: 09.11.2025).

Global Market Insights. (2025). Sustainable Construction Materials Market. Retrieved from: https://www.gminsights.com/industry-analysis/sustainable-construction-materials-market/ (date of access: 09.11.2025).

Głodkowska, W., & Ziarkiewic, M. (2019). Estimation of Load Bearing Capacity of Bending Fibrocomposite Elements. *Rocznik Ochrona Środowiska*, *21*, 294-315.

Klyavlin, M.S., Klyavlina, Ya.M., Samofeev, N.S., Shildt, L.A. & Gainanova, E.S. (2017). Economic Aspects of Determining the Cost of Construction Using Innovative Materials. SCIENCE STUDY, 9 (2). Retrieved from: http://naukovedenie.ru/PDF/49TVN217.pdf (date of access: 18.11.2025). (in Russian)

Kornitskaya, O.V., Trukhina, N.I., Popova, O.A. & Vasilchikova, E.V. (2021). Features of the Development of Innovative Potential in the Construction Industry. Bulletin of the Altai Academy of Economics and Law, 12-2, 297–303. (in Russian)

Kushnir, A. M. (2024). Development of Innovative Potential in the Construction Industry and in the Building Materials Industry. Bulletin of Eurasian Science, 16(1). Retrieved from: https://esj.today/PDF/37ECVN124.pdf (date of access: 18.11.2025). (in Russian)

Kuznetsova, A. R., & Farkhutdinov, A. M. (2023). Economic Factors Constraining Production Activity in the Housing Construction Sector of the Russian Federation. Economic Sciences, 2(219), 75–81. (in Russian)

Mahmood, F., Kashif, Ur., Rehman, S., Jameel, M., Riaz, N., Javed, MF., Salmi, A., & Awad. YA. (2022). Self-Healing Bio-Concrete Using Bacillus subtilis Encapsulated in Iron Oxide Nanoparticles. *Materials (Basel)*, *15*(21), 7731. Retrieved from: doi: 10.3390/ma15217731.

Makarenko, O.I. (2020). The Role of the Building Materials Industry in the Socioeconomic Development of the State. *Construction and Urban Economy*, *16*(4), 233–244. (in Russian)

Makarenko, O.I. (2023). Innovative imperatives for the development of modern building materials and technologies in housing construction. *Housing Strategies*, *10*(1), 43–60. (in Russian)

Makeeva, A.V., Videnkov, N.V., Dobrogorskaya, L.V., Semenov, K.V. & Fedotov, V.V. (2017). Innovative aerogel-based materials in construction. *Alfabuild*, *1*(1), 89–98. (in Russian)

Ministry of Construction of the Russian Federation. (2015). *Strategy for Innovative Development of the Construction Industry of the Russian Federation until 2030*. Retrieved from: https://sroogpo.ru/upload/files/documents/nasha_rabota_22102020.pdf?ysclid=mi1nsp2g76986824818 (date of access: 10.11.2025). (in Russian)

Moscow Innovation Agency. (2021). *Innovations in Construction: Global Trends and Development in Moscow*. Retrieved from: https://innoagency.ru/files/Innovations_in_Construction_AIM_2021.pdf?ysclid=mi1o1d6lnk1562569 (date of access: 15.11.2025). (in Russian)

Nizin, T.A., & Leontyev, N.S. (2025). Composite polymer reinforcement: analysis of production experience. *Smart composites in construction*, *6*(1), 31–45. (in Russian)

Oborin, M.S. (2020). Innovative and technological factors in the development of construction in complex macroeconomic conditions. *Bulletin of Moscow University*, *6*, 176–192. (in Russian)

Research and Markets. (2025). *Lightweight Aggregate Concrete Market - Global Strategic Business Report*. Retrieved from: https://www.researchandmarkets.com/report/global-lightweight-aggregate-concrete-market (date of access: 15.11.2025).

Rosstat. (2024a). *Russian statistical yearbook*. Moscow: Federal State Statistics Service of the Russian Federation. (in Russian)

Rosstat. (2024b). *Construction in Russia*. Moscow: Federal State Statistics Service of the Russian Federation. (in Russian)

Rosstat. (2025). *Science, innovation, and technology*. Retrieved from: https://24.rosstat.gov.ru/folder/164165 (date of access: 10.11.2025). (in Russian)

Sergeeva, M.I. (2019). Problems of introducing modern technologies into construction. *Meridian*. Retrieved from: https://meridian-journal.ru/site/article264d/ (date of access: 18.11.2025). (in Russian)

Smirnova, E., Mamedov, S., & Shkarovskiy, A. (2022). Improving the Environmental Safety Risk Assessment in Construction Using Statistical Analysis Methods. *Rocznik Ochrona Środowiska*, *24*, 110-128.

Sokolov, D.A. (2024). Smart Glass in Architecture and Design: Technological Features, Application, and Contribution to Sustainable Development. *Modern Construction and Architecture*, *12*(55), 1-9. (in Russian)

Sycheva, I.V. (2020). Energy-Saving Construction Innovations in the Energy Efficiency Market. *Construction and Urban Economy*, *1*, 57-63. (in Russian)

Towards Chem and Materials. (2025). *Recycled Plastics In Green Building Materials Market: Demand, Production, and Future Projections*. Retrieved from: https://www.towardschemandmaterials.com/insights/recycled-plastics-in-green-building-materials-market (date of access: 25.11.2025).

UN. (2024). *Emissions in the construction sector continue to grow*. Retrieved from: https://news.un.org/ru/story/2024/03/1450167 (date of access: 11.11.2025). (in Russian)

Verified Market Reports. (2025a). *Building Materials Recycling Market Insights*. Retrieved from: https://www.verifiedmarketreports.com/product/building-materials-recycling-market/ (date of access: 27.11.2025).

Verified Market Reports. (2025b). *Next Generation Construction Material Market Insights*. Retrieved from: https://www.verifiedmarketreports.com/product/next-generation-construction-material-market/ (date of access: 26.11.2025).

Zabaznova, M.V., & Ablyazov, T.Kh. (2025). Analysis of Construction Materials Market Development Trends in Russia and Abroad. *Stolypinsky Vestnik*, *7*(1). (in Russian)

Zaytseva, K.N. (2019). Radical Innovations in Construction Materials Production: Risks and Implementation Challenges. *Fundamental Research*, *5*, 36–39. (in Russian)

Zhukova, G.G., & Saifulina, A.I. (2020). Study of the Application of Self-Healing Concrete. *Construction and Geotechnics*, *11*(4), 58–68. (in Russian)