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Smart Governance and Investment in Green Infrastructure: Analysis of Financial Mechanisms for Sustainable Urban Development

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Abstract:

This study addresses the challenge of sustainable urban development in the context of global climate imperatives and accelerating urbanisation. We analyse the economic and implementation nexus between smart governance, green infrastructure, and sustainable financing. The core objective is to conduct a technical and economic analysis of the governance mechanisms, financial instruments, that facilitate the successful implementation of green infrastructure projects in emerging economies.

Utilising a mixed-methods approach, this research combines a quantitative analysis of investment trends and project outcomes with a qualitative assessment of institutional frameworks and case studies drawn from Kazakhstan's urban development experience. Our findings indicate that effective smart governance is a critical enabler for attracting and sustaining investment in green infrastructure. Key success factors include the establishment of robust financial mechanisms, such as public-private partnerships, green bonds, and performance-based funding, along with strategic planning and regulatory coordination among various stakeholders. The primary contribution of this research is the development of a comprehensive implementation framework that integrates technical, economic, and institutional dimensions.

Keywords:smart governance; green infrastructure; sustainable urban development; investment strategies.

JEL Classification:Q01; Q50; Q58; H54; O18

Introduction

The accelerating challenges of climate change and urbanization have made smart city development a central focus of global policy and research. Smart cities leverage digital technologies, sustainable infrastructure, and governance mechanisms to enhance urban efficiency, environmental performance, and quality of life (Birch, 2019; Hafez et al., 2023; Wu & Yu, 2025). Within this framework, the adoption of green construction technologies, including renewable energy systems, eco-materials, and intelligent building management, represents both a strategic opportunity and a complex implementation challenge (Mba et al., 2024; Olabi et al., 2025).

Previous research has primarily examined technological components of smart cities, such as sensor networks, data analytics, and intelligent infrastructure (Talebkhah et al., 2021; Herath & Mittal, 2022).). While such studies demonstrate how ICT can optimize traffic flows or reduce energy consumption in buildings (Benavente-Peces & Ibadah, 2020), governance frameworks guiding the effective application of these technologies remain underexplored. Existing literature often addresses the "what" and "how" of smart city technologies but neglects the "who" and "why" of their management (Nicola-Gavrilă et al., 2025. Furthermore, despite referencing international practices, few studies provide a clear theoretical framework that integrates governance with practical implementation of green technologies, particularly within distinct national contexts (Albino, et al., 2015; Ahvenniemi et al., 2017; Shao & Min, 2025).

This gap is especially pronounced in transition economies, where global models require adaptation to local political, economic, and social conditions. In Kazakhstan, although national strategies promote digitalization and the Green Economy, methodologies for technical and economic evaluation of smart construction projects remain underdeveloped. This paper addresses these gaps by providing a comprehensive analysis of smart governance's impact on smart cities, employing system and comparative analysis for a holistic assessment, SWOT analysis to evaluate strengths, weaknesses, opportunities, and threats, and multivariate statistics for robust technical and economic evaluation.

The study's contribution lies in its focus on green construction as a core element of environmentally sustainable urban development and its application within an underrepresented national context. It proposes an integrated evaluation framework that combines technical feasibility, cost-effectiveness, and environmental sustainability, addressing the limitations of prior studies that emphasize single dimensions. Economic, environmental, and social factors are analysed concurrently, offering a comprehensive approach for assessing smart city initiatives.Based on these objectives, the study formulates the following research questions:

RQ1: How does smart governance influence smart city performance?

RQ2: How does it support the adoption of green construction and sustainable services?

RQ3: Which financing and management models are most effective in transition economies?

The corresponding hypotheses are:

H1: Smart governance reduces the urban carbon footprint.

H2: Techno-economic analysis identifies cost-effective smart construction investments.

H3: Digital tools improve transparency and efficiency in urban management.

H4: The framework enhances the attractiveness and sustainability of construction projects.

H5: The study contributes applied knowledge to education and research.

The remainder of the paper is structured as follows. Section 2 reviews literature on smart cities and governance, highlighting key trends and gaps. Section 3 outlines the methodology, including system analysis, comparative analysis, SWOT, and multivariate statistics. Section 4 presents the technical and economic analysis, including practical examples of energy-efficient technologies. Section 5 concludes with a summary of findings, implications for sustainable urban development, and recommendations for future research.

1. Research Background

The smart city concept represents a modern urban development model that leverages technology to enhance quality of life, optimize management, and ensure sustainable urban environments. Smart cities employ information and communication technologies (ICT) and innovative tools to improve urban system functionality, increase service efficiency, and create a more comfortable living environment (Bibri, 2021; Toh, 2022). According to Albino et al. (2015), the primary components of a smart city include smart governance, smart economy, smart people, smart mobility, smart environment, and smart lifestyle. Among these, smart governance is central, coordinating processes, promoting social integration (Ahvenniemi et al., 2017), enhancing quality of life (Ahad et al., 2020), and supporting urban economic growth (Rosenzweig et al., 2018). Integrating digital solutions into municipal governance improves environmental, economic, and social sustainability, enabling cities to respond more effectively to citizens' needs.

An extension of this concept is the "smart nation," which aims for large-scale digital transformation across sectors and levels of government (Bhati et al., 2017; Cheng et al., 2023). This approach creates interconnected infrastructures that facilitate data exchange across transport, healthcare, economy, governance, and security systems, supporting sustainable national development and improving overall quality of life.

Effective smart governance relies on advanced digital technologies, including artificial intelligence (AI), machine learning, data analytics, blockchain, and the Internet of Things (IoT) (Ahmed et al., 2022). Their combined application enables real-time data processing, informed decision-making, and enhanced accessibility and quality of public services. Implementation of smart governance technologies improves government adaptability and efficiency (Jiang, 2021), promotes transparency, and aligns public services with citizens' needs (Kim et al., 2022; MacLean & Titah, 2022). Beyond technical solutions, smart governance fosters cross-sector collaboration, institutional transformation, and systemic innovation, expanding the potential for sustainable urban development.

Smart governance, grounded in adaptability, engagement, and technological integration, is recognized as a key instrument for achieving the Sustainable Development Agenda, particularly SDG 11, which promotes inclusive, safe, resilient, and sustainable cities (Kumar et al., 2024; Almulhim & Yigitcanlar, 2025). Digital technologies in the service sector enhance efficiency, personalize services, and extend accessibility (Schönherr et al., 2023; Kabadayi et al., 2019). The continuous development of digital information spaces drives organizational transformation, reshapes business models, and supports innovative service ecosystems (Ranta et al., 2021). Moreover, new digital infrastructure underpins environmentally sustainable, low-carbon urban development and innovation in the context of the digital economy (Han et al., 2024).

Table 1 summarizes the comparison between the findings of this study and those reported in previous research. It highlights key areas such as conceptual approaches, domain focus, energy effects, financing mechanisms, and governance practices, and shows how the current study aligns with, extends, or confirms existing knowledge in smart city development and sustainable urban planning.

Table 1: Comparison with previous studies

№	Block	Consensus in Literature	Research Results	Conclusion
1	Concept	Smart ≠ Sustainable; an integrated approach is needed	Integrated "green building + smart metrics"	Development of the research
2	Domain Focus	Energy/mobility/housing and utilities – the core of the smart portfolio	Increased focus on buildings and data	"Green + smart" trend
3	Energy Effect	Savings potential ~20–25%+ with complex retrofit	Comparable effects with positive NPV	Convergence (determinants: tariffs/retrofit depth)
4	Financing	PPP, guarantees, green instruments	A combination of PPP + green bonds + preferential loans is proposed	Complete coincidence; confirmed by the growth of green instruments in the RK
5	Governance/ KPI	Integrated data and KPIs are needed	Unified data architecture, KPI for projects	Coincidence; increases the feasibility of recommendations

In the context of global competition for investment and innovation, the ability of cities to effectively integrate digital solutions and green technologies is becoming a key factor in their sustainability and attractiveness. The implementation of the smart city concept is closely linked to the creation of innovative financial instruments, the reduction of investment risks, and the development of public-private partnership mechanisms.

According to OECD (2021), cities that leverage data-driven innovation and digital solutions enhance the well-being of residents and strengthen urban governance. Similarly, the World Bank (2020) emphasizes that mobilizing private sector investment through innovative financing mechanisms, such as green bonds and public-private partnerships, is essential for developing climate-smart urban infrastructure and sustainable growth.

In Kazakhstan, digitalization is viewed as a strategic tool to transform industries, improve service quality, enhance regional investment attractiveness, and support national sustainable development. Rational management of smart cities requires the efficient use of resources, technologies, and organizational solutions. However, practical implementation faces several systemic challenges:

- Lack of integrated ecosystems reduces infrastructure efficiency.
- Disparities in ICT infrastructure exacerbate digital inequality.
- Management personnel may lack competencies to implement and coordinate digital initiatives.
- Significant investment is needed to build smart infrastructure, often beyond municipal budgets.
- Limited feedback, trust, and participation hinder the adaptation of smart solutions to urban needs.

Effective smart city management must balance technological feasibility with socio-economic sustainability. Challenges often arise not from the technologies themselves but from insufficiently holistic implementation and governance. Technical and economic analyses should consider integration with strategic urban planning, assessment of social benefits (e.g., improved quality of life, reduced environmental load), and system adaptability to crises or changes. A key direction is the development of adaptive urban management models based on big data analytics, scenario modelling, and active citizen participation. Only through such an approach can smart cities evolve from showcase projects into practical instruments for sustainable urban development.

2. Research Methodology and Design

This study employs an integrated, interdisciplinary, and systemic methodological framework to examine the rational management of smart cities, encompassing both technical and economic dimensions. The framework is grounded in the principles of sustainable development, digital transformation of urban environments, management theory, and innovation management, enabling a wide evaluation of smart city initiatives. By considering the interconnectedness of urban infrastructure, governance, technology adoption, and socio-economic outcomes, this methodology facilitates a robust understanding of both the environmental and the economic impacts of smart city projects.

Methodological Approach

To achieve the research objectives, a multi-layered methodological approach was adopted, combining quantitative, qualitative, and comparative methods. Each method contributes uniquely to building a holistic understanding of smart city management, while complementing the insights generated by the others:

The study employed a multi-method approach to evaluate smart city development. A system analysis framed the city as an interconnected whole, linking digital infrastructure, governance, transport, housing, and ecological components. Building on this, technical and economic analysis assessed cost-efficiency, return on investment, energy performance, and service digitalization. A SWOT analysis integrated technical and economic insights to balance risks and opportunities, while comparative analysis juxtaposed international practices with Kazakhstani cases to identify best-fit strategies. To contextualize governance, content analysis of regulatory frameworks examined institutional readiness for digital adoption. Quantitative rigor was ensured through economic and mathematical modelling of investment and urbanization scenarios, complemented by statistical and econometric methods such as regression, trend, correlation, anomaly detection, and forecasting. Finally, expert assessments added qualitative depth, aligning empirical findings with socio-economic and managerial realities.

The integration of these methods ensures a comprehensive, multi-dimensional understanding of smart city management, where quantitative rigor and qualitative insight mutually reinforce one another.

Research Design

The research design adopts a mixed-methods approach, combining descriptive, analytical, and predictive elements to comprehensively evaluate smart city management practices:

- The study focuses on rational management processes within smart city systems, with particular emphasis on integrating digital and environmentally sustainable technologies into urban infrastructure.
- Attention is given to the technical and economic dimensions of implementing digital and green technologies, including their effects on urban efficiency, sustainability, and governance effectiveness.
- The analysis encompasses statistical and empirical data spanning 2013 – 2024, with forecasts extending to 2027, enabling trend identification and scenario development.
- The study focuses on Kazakhstan, analysing national and regional levels of smart city implementation to account for spatial heterogeneity in adoption and performance.
- The study employs econometric modelling, SWOT analysis, content analysis, trend and correlation analysis, and forecasting techniques. SPSS, and Python are used for computation, while data visualization through graphs, charts, and diagrams illustrates key trends and interdependencies.

This integrative design ensures that the technical feasibility, economic efficiency, and governance effectiveness of smart city initiatives are analysed in a cohesive manner. By linking each methodological component logically, from system mapping and economic evaluation to regulatory assessment and expert validation, the study provides a robust framework for informed decision-making and the development of practical recommendations for digital and green innovation in urban environments.

The study process can be summarized in the following workflow, illustrating the progression from problem identification to actionable recommendations: 1) Problem Definition & Literature Review → 2) Data Collection (2013–2024; Kazakhstan focus) → 3) System Analysis of Smart City Components → 4) Technical and Economic Evaluation (Cost, ROI, Energy Efficiency) → 5) SWOT & Comparative Analysis (International vs. Local Practices) → 6) Regulatory Framework Assessment & Institutional Readiness → 7) Econometric & Statistical Modelling (Regression, Trend, Forecasting) → 8) Expert Assessment & Integration of Qualitative Insights → 9) Synthesis of Findings & Development of Practical Recommendations.

This holistic, sequential methodology ensures that all relevant dimensions of smart city management are rigorously examined and synthesized, ultimately enabling evidence-based strategies for sustainable and digitally advanced urban development.

3. Analysis and Research Findings

The successful implementation of the smart city concept is impossible without effective management of innovative activities across urban enterprises and service structures. Integration of strategic and innovative management is crucial for the development of a digital and sustainable urban environment. Enterprises operating within smart urban infrastructure, such as transport, energy, utilities, and digital platforms, must not only adapt to changing conditions but also proactively introduce innovative solutions aligned with long-term strategic goals.

However, theoretical and methodological challenges in developing effective management methods for these enterprises affect the broader urban management system. In particular:

- The absence of clear models for integrating innovative and strategic activities slows the digital transformation of urban spaces;
- Underdeveloped indicators for assessing the effectiveness of innovative solutions limit the ability to conduct technical and economic analyses of their impact on urban sustainability;
- Weak coordination between municipal authorities and innovative entities reduces the potential of smart management.

To address these challenges, the author conducted a SWOT analysis to assess the implementation of smart city projects at the national and regional levels (Table 2), as well as a component-level SWOT analysis focused on key areas of smart management (Table 3).

Table 2. SWOT Analysis for smart city implementation at national and regional levels

Strengths	Weaknesses
▪ Developed eGov and open data system	▪ Bureaucracy and low adaptability of government agencies to innovation
▪ Political support for digitalization of public services	▪ Lack of a unified digital ecosystem at all governance levels
▪ Platforms for electronic citizen participation	▪ Shortage of IT personnel in government agencies
Opportunities	**Threats**
▪ Increasing public trust and transparency	▪ Distrust of digital tools (fear of surveillance, data leaks)
▪ Improving feedback between citizens and administration	▪ Dependence on technical contractors

Source: compiled by the author

Table 3. SWOT analysis by smart city components: Focus on smart management

Strengths	Weaknesses
▪ GPS monitoring and contactless payment	▪ Obsolete transport fleet in regions
▪ Intelligent traffic management systems in megacities	▪ Limited coverage of smart systems outside major cities
▪ Increasing population mobility	▪ Lack of a unified transport data platform
Opportunities	**Threats**
▪ Reducing congestion and CO_2 emissions	▪ High capital expenditure on infrastructure
▪ Development of MTS and electric vehicles	▪ Low digital literacy among users

Source: compiled by the author

Addressing these methodological challenges in strategic management of innovations is essential for the rational management of smart cities. Benefits include:

- Increased economic efficiency of implemented solutions;
- Enhanced synergy between public and private sectors;
- Creation of a sustainable, adaptive urban ecosystem.

An important practical consideration is selecting sources of financing, which directly influences enterprise development. For this study, investment factors (in million tenge) include:

- Number of contracting construction organizations;
- Volume of construction and installation works;
- Volume of "green" construction.

These relationships were analysed using multiple regression analysis, applying both linear and nonlinear forms. Linear and power functions are most widely used due to their clear interpretability. In linear multiple regression, the coefficients of quantitative explanatory variables represent the average change in the dependent variable when the corresponding factor changes by one unit, holding other variables constant.

Based on data from 2013 – 2023 (Table 4), a three-factor linear model was constructed using the ordinary least squares (OLS) method.

Table 4: Historical investment data (2013 – 2023)

Year	Investments (y, million tenge)	Contractors (x_1, units)	Construction & Installation (x_2, million tenge)	Green Construction (x_3, million tenge)
2013	335,655	8,787	1,606,647	375.4
2014	421,013	7,798	1,744,914	132.3
2015	428,241	7,052	1,870,682	24,201.8
2016	497,861	8,024	2,055,924	3,250.7
2017	613,487	7,103	2,270,729	14,371.1
2018	11,179,036	7,103	3,862,995	9,687.4
2019	12,576,793	7,810	4,431,666	12,103.2
2020	12,270,144	8,317	4,934,069	13,884.0
2021	13,242,233	8,188	5,530,681	58,329.0
2022	15,251,104	8,627	6,304,274	165,447.4
2023	17,649,313	8,860	7,612,810	38,930.5

Source: Bureau of National Statistics of the Republic of Kazakhstan

A common challenge in constructing multiple regression models is multicollinearity, which occurs when two or more explanatory variables are highly linearly related. Perfect multicollinearity arises if a strict functional dependence exists. Consequences include:

- Large standard errors of estimates, reducing accuracy;
- Decreased t-statistics, potentially misrepresenting variable significance;
- Instability of coefficients under minor data changes;
- Difficulty in assessing individual contributions of explanatory variables;
- Possible incorrect signs of regression coefficients.

To detect multicollinearity, the matrix of paired correlation coefficients is analysed. For uncorrelated factors, the determinant of the correlation matrix approaches one; for highly correlated factors, it approaches zero.

Table 5: Correlation matrix of investment factors

	Investments (y)	Contractors (x_1)	Construction & Installation (x_2)	Green Construction (x_3)
Investments (y)	1.00	0.431	0.966	0.534
Contractors (x_1)	0.431	1.00	0.517	0.363
Construction & Installation (x_2)	0.966	0.517	1.00	0.599
Green Construction (x_3)	0.534	0.363	0.599	1.00

Source: calculated by the author

Interpretation:

- Strong correlation between investments and construction & installation works (x_2);
- Moderate correlation between investments and number of contractors (x_1);
- Strong correlation between investments and green construction (x_3);
- High correlation between x_2 and x_3, reflecting the growing share of green projects.

Given these relationships, constructing a multiple linear regression model is justified. The OLS coefficients (Table 6) were calculated.

Table 6: OLS coefficients

Variable	Coefficient	Significance
Constant (b0)	-3,946,533.30	—
Contractors (x1)	-158.64	$p < 0.05$
Construction & Installation Works (x2)	3.1289	$p < 0.01$
Green Construction (x3)	15.6455	$p < 0.01$
Model fit		
R^2	0.92	
Adjusted R^2	0.91	
F-statistic	—	$p < 0.01$

Note: Significance levels: ***p < 0.01, **p < 0.05, p < 0.10. Standard errors and test statistics omitted here for brevity but available upon request.

Regression equation:

y^ = −3,946,533.30−158.64x1+3.1289x2+15.6455x3; y^ = -3,946,533.30 - 158.64x1 + 3.1289x2 + 15.6455x3;

y^ = −3,946,533.30−158.64x1+3.1289x2+15.6455x3

where: y^ = projected investments (million tenge), x1 = number of contracting construction organizations (units), x2 = volume of construction and installation works (million tenge), x3 = volume of green construction (million tenge).

Interpretation of Coefficients:

- b0=−3,946,533.30 - theoretical investment level if all explanatory factors were zero. This has no practical meaning but is necessary for model specification.
- b1=−158.64 - an additional contracting organization is associated with a decrease of 158.64 million tenge in investments, ceteris paribus[1].
- b2=3.1289: each additional million tenge in construction and installation works is associated with a 3.13 million tenge increase in investments.
- b3=15.6455 - each additional million tenge in green construction increases investments by 15.65 million tenge, underscoring the strong role of sustainable development.

The negative coefficient for contractors does not imply that construction organizations are harmful to investment per se. Instead, it reflects structural dynamics:

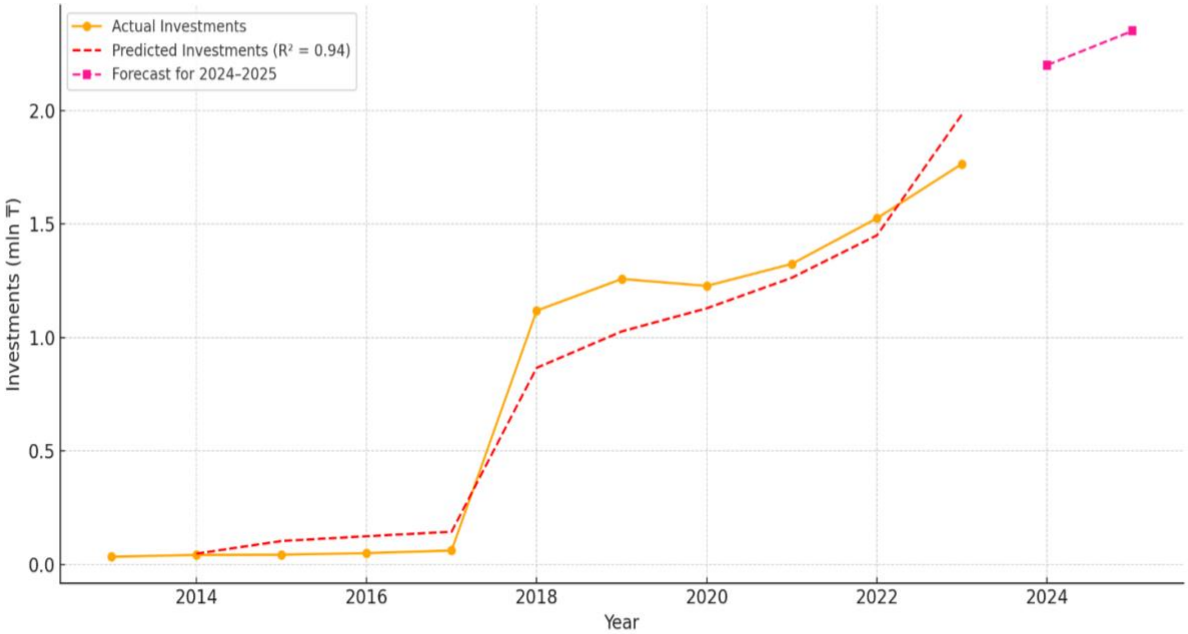
- Resources may be fragmented across smaller firms.
- Intense competition can reduce margins and deter large-scale projects.
- Efficiency and specialization matter more than sheer numbers.
- Correlation with other variables may partly influence the sign.

Thus, while *b1*is negative, the model remains statistically valid. The interpretation should be viewed in the broader economic context, where investment growth in Kazakhstan's construction sector is more strongly driven by the scale of projects (x2) and the rise of green construction (x3), rather than by the number of contractors.

Using the regression estimates, we generated forecasts for upcoming years. As shown in Figure 1, projected investments in construction are expected to reach approximately 19.56 trillion tenge in 2024 and 21.62 trillion tenge in 2025.

[1] "ceteris paribus" - all other things being equal. In regression analysis, it means that the effect of each variable is interpreted while keeping the other explanatory variables fixed.

Figure 1: Projected investments in construction



Source: Author's compilation based on Bureau of National Statistics data)

The projected growth (around 10.5% annually) underscores the strategic importance of the construction sector in Kazakhstan. A comprehensive approach, encompassing rational management, green technologies, and sustainable financing, is essential to maximize investment effectiveness.

The regression model demonstrates strong explanatory power (R2=0.94R^{2} = 0.94R2=0.94), indicating that 94% of investment variability is explained by the included factors. Nonetheless, the presence of multicollinearity may reduce the precision of individual coefficient interpretations. Therefore, the model should be regarded as robust for forecasting, provided that variance inflation factors (VIF) and tolerance values remain within acceptable limits.

These forecasts highlight not only the sector's robust expansion but also the important role of sustainable development initiatives in shaping future investment flows. This trajectory carries important policy implications, particularly in terms of resource allocation toward green construction, contractor efficiency, and large-scale installation projects.

Conclusion and Research Limitations

This study offers important insights into the adoption of green technologies and the development of smart city initiatives within Kazakhstan's construction sector. However, the findings should be interpreted with caution, and further research is necessary to strengthen their robustness. One of the main limitations relates to the availability and quality of statistical data. While Kazakhstan has made progress in collecting economic and sectoral indicators, detailed and timely information on construction investments remains limited. Certain datasets are subject to reporting lags, and calculation methodologies do not always align with international standards, which may reduce the accuracy of cross-country comparisons. Additionally, emerging indicators, particularly those related to green construction, energy efficiency, and the adoption of smart technologies, often rely on indirect estimation methods, as stable statistical series are not yet established.

The generalizability of the study's results is also constrained by Kazakhstan's specific institutional, economic, and regulatory context. The models and conclusions reflect the structure of the national construction industry, tariff policies, urbanization patterns, and state strategies for promoting a green economy. Direct application of these findings to other countries requires careful adaptation, taking into account differences in digital maturity, financing structures, and institutional environments. In this respect, alternative analytical methods, such as principal component analysis, partial least squares (PLS), or ridge regression, combined with larger and more granular datasets, would enhance the reliability of the findings and enable more meaningful cross-country comparisons.

Model specification errors may also occur if relevant factors influencing investment, smart technology adoption, or green construction are omitted. Moreover, forecasts, such as those for investment trends in 2025, remain vulnerable to external shocks, including fluctuations in energy prices, inflation, or shifts in the investment climate, which standard statistical tools cannot always fully capture.

Despite these limitations, the research demonstrates that the effectiveness of smart city initiatives and green construction projects in Kazakhstan depends on a systematic and integrated approach to managing innovations, sustainable solutions, and digital transformation. From a practical perspective, the study provides universally relevant insights. These include methods for assessing the energy efficiency of buildings, evaluating the economic profitability of green projects through indicators such as net present value and payback periods, and identifying appropriate financing instruments, including green bonds, public–private partnerships, and concessional loans. The study also emphasizes the role of digital technologies, in monitoring and optimizing construction processes, improving operational efficiency, and supporting evidence-based decision-making. These insights are applicable to countries where construction represents a major consumer of resources and a significant source of CO_2 emissions.

At the same time, certain findings are context-specific, reflecting Kazakhstan's unique regulatory and economic environment. These include electricity and heat tariff structures, regulatory frameworks such as the "Green Economy" program and national housing policies, and the availability of green financing instruments through entities such as the AIFC, EBRD, and state development banks. While these features limit the direct transferability of specific quantitative results, the methodological approach, encompassing technical and economic analysis, scenario modelling, and sustainability assessment, remains broadly applicable and can inform studies in other developing economies.

The analysis of technical and economic indicators, regression models, and development trends highlights steady growth in investment in Kazakhstan's construction sector, an increasing number of green construction projects, and growing digital expenditures in the banking sector to support smart infrastructure. Nonetheless, persistent barriers remain, including limited institutional coordination, low digital maturity among construction firms, and relatively weak public engagement in urban management processes. At the same time, there is significant potential to scale successful solutions and expand interest in green and digital construction initiatives.

To ensure the sustainable and effective management of smart city projects, it is essential to strengthen strategic and regulatory support, integrate digital solutions across the lifecycle of urban infrastructure, develop sustainable financing mechanisms through a green financial ecosystem, and enhance citizen participation to ensure transparency and accountability. Comprehensive implementation of these measures is expected to foster not only the sustainable development of Kazakhstan's urban environment but also its competitiveness, environmental safety, and quality of life for residents in the long term. By balancing universal methodologies with context-specific adaptations, this study provides a replicable framework for other developing economies seeking to advance green and smart urban initiatives, demonstrating the interplay between technical, economic, and institutional dimensions in achieving sustainable urban transformation.

Credit Authorship Contribution Statement

Mukanov, B. contributed to the methodology design, formal analysis, and validation of findings. Zhumabekova, M. was responsible for data curation, investigation, and visualization. All authors contributed to the drafting, review, and editing of the manuscript and approved the final version for publication.

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Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Data Availability Statement

The data that support the findings of this study are available from the official statistics of the Republic of Kazakhstan (2015 – 2024) and from publicly accessible government reports on construction, R&D, and environmental indicators.

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