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05.01.00 – Axborot texnologiyalari, boshqaruv va kompyuter grafikasi
05.01.01 – Muhandislik geometriyasi va kompyuter grafikasi. Audio va video texnologiyalari
05.01.02 – Tizimli tahlil, boshqaruv va axborotni qayta ishlash
05.01.03 – Informatikaning nazariy asoslari
05.01.04 – Hisoblash mashinalari, majmualari va kompyuter tarmoqlarining matematik va dasturiy ta'minoti
05.01.05 – Axborotlarni himoyalash usullari va tizimlari. Axborot xavfsizligi
05.01.06 – Hisoblash texnikasi va boshqaruv tizimlarining elementlari va qurilmalari
05.01.07 – Matematik modellashtirish
05.01.11 – Raqamli texnologiyalar va sun'iy intellekt
05.02.00 – Mashinasozlik va mashinashunoslik
05.02.08 – Yer usti majmualari va uchish apparatlari
05.03.02 – Metrologiya va metrologiya ta'minoti
05.04.01 – Telekommunikasiya va kompyuter tizimlari, telekommunikasiya tarmoqlari va qurilmalari. Axborotlarni taqsimlash
05.05.03 – Yorug'lik texnikasi. Maxsus yoritish texnologiyasi
05.05.05 – Issiqlik texnikasining nazariy asoslari
05.05.06 – Qayta tiklanadigan energiya turlari asosidagi energiya qurilmalari
05.06.01 – To'qimachilik va yengil sanoat ishlab chiqarishlari materialshunosligi
05.08.03 – Temir yo'l transportini ishlatish
05.09.01 – Qurilish konstruksiyalari, bino va inshootlar
05.09.04 – Suv ta'minoti. Kanalizatsiya. Suv havzalarini muhofazalovchi qurilish tizimlari
10.00.06 – Qiyosiy adabiyotshunoslik, chog'ishtirma tilshunoslik va tarjimashunoslik
10.00.04 – Yevropa, Amerika va Avstraliya xalqlari tili va adabiyoti
08.00.01 – Iqtisodiyot nazariyasi
08.00.02 – Makroiqtisodiyot
08.00.03 – Sanoat iqtisodiyoti
08.00.04 – Qishloq xo'jaligi iqtisodiyoti
08.00.05 – Xizmat ko'rsatish tarmoqlari iqtisodiyoti
08.00.06 – Ekonometrika va statistika
08.00.07 – Moliya, pul muomalasi va kredit
08.00.08 – Buxgalteriya hisobi, iqtisodiy tahlil va audit
08.00.09 – Jahon iqtisodiyoti
08.00.10 – Demografiya. Mehnat iqtisodiyoti
08.00.11 – Marketing
08.00.12 – Mintaqaviy iqtisodiyot
08.00.13 – Menejment
08.00.14 – Iqtisodiyotda axborot tizimlari va texnologiyalari
08.00.15 – Tadbirkorlik va kichik biznes iqtisodiyoti
08.00.16 – Raqamli iqtisodiyot va xalqaro raqamli integratsiya
08.00.17 – Turizm va mehmonxona faoliyati

Ma'lumot uchun, OAK Rayosatining 2024-yil 28-avgustdagi 360/5-son qarori bilan "Dissertatsiyalar asosiy ilmiy natijalarini chop etishga tavsiya etilgan milliy ilmiy nashrlar ro'yxati"ga texnika va iqtisodiyot fanlari bo'yicha "Muhandislik va iqtisodiyot" jurnali ro'yxatga kiritilgan.

Muassis: "Tadbirkor va ishbilarmon" MChJ
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3. Toshkent irrigatsiya va qishloq xo'jaligini mexanizatsiyalash muhandislari instituti" milliy tadqiqot universiteti
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5. Muhammad al-Xorazmiy nomidagi Toshkent axborot texnologiyalari universiteti
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ECONOMIC EFFICIENCY OF DIGITAL TWIN AND BIM TECHNOLOGIES IN CONSTRUCTION ENTERPRISES

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Abstract: This article explores the economic efficiency of implementing Digital Twin and Building Information Modeling (BIM) technologies in construction enterprises. The study is based on the analysis of real-world cases from construction companies in Uzbekistan, assessing the impact of digitalization on cost reduction, project cycle optimization, workforce management, and overall productivity. The paper highlights the integration of these technologies as a transformative tool in construction management, providing enhanced decision-making capabilities, risk forecasting, and operational efficiency. The findings suggest that the use of Digital Twin and BIM technologies significantly increases profitability and sustainability in the construction sector.

Keywords: digital Twin, BIM, economic efficiency, construction management, Uzbekistan, digital transformation.

Annotatsiya: Ushbu maqolada qurilish korxonalarida raqamli egizak (Digital Twin) va bino axborot modeli (BIM) texnologiyalarini joriy etishning iqtisodiy samaradorligi tahlil etiladi. Tadqiqot O‘zbekiston qurilish tashkilotlarining real tajribalari asosida olib borilgan bo‘lib, raqamlashtirishning xarajatlarni kamaytirish, loyiha siklini optimallashtirish, ishchi kuchini boshqarish va umumiy samaradorlikka ta’siri baholanadi. Maqolada bu texnologiyalarni integratsiyalash qurilish jarayonlarini boshqarishda samarali vosita bo‘lib, qarorlar qabul qilishni takomillashtirish, xatarlarni oldindan baholash va operatsion samaradorlikni oshirishga xizmat qilishi ta’kidlanadi. Tadqiqot natijalari shuni ko‘rsatadiki, Digital Twin va BIM texnologiyalaridan foydalanish qurilish sohasida naflilik va barqarorlikni sezilarli darajada oshiradi.

Kalit so‘zlar: raqamli egizak, BIM, iqtisodiy samaradorlik, qurilish boshqaruvi, raqamli transformatsiya.

Аннотация: В статье рассматривается экономическая эффективность внедрения технологий цифрового двойника и информационного моделирования зданий (BIM) на строительных предприятиях. Исследование основано на анализе реальных кейсов строительных компаний Узбекистана и оценивает влияние цифровизации на снижение затрат, оптимизацию проектных циклов, управление трудовыми ресурсами и повышение общей производительности. Подчеркивается, что интеграция данных технологий является важным инструментом трансформации в управлении строительством, способствующим принятию обоснованных решений, прогнозированию рисков и повышению операционной эффективности. Результаты показывают, что использование цифровых двойников и BIM-технологий значительно увеличивает прибыльность и устойчивость строительного сектора.

Ключевые слова: цифровой двойник, BIM, экономическая эффективность, управление строительством, Узбекистан, цифровая трансформация.

INTRODUCTION

The construction industry is undergoing a radical transformation driven by the rapid integration of digital technologies. Among these, the implementation of Digital Twin (DT) and Building Information Modeling (BIM) has emerged as a key enabler for improving project management, increasing cost-effectiveness, and reducing resource consumption. In countries with emerging economies, such as Uzbekistan, where infrastructure development is accelerating, the application of innovative technologies in construction enterprises is both an opportunity and a necessity.

In recent years, the Government of Uzbekistan has prioritized the digital transformation of key sectors, including construction, as part of its broader strategy for sustainable development. According to the Presidential Decree No. PQ–4699 (2019), digital transformation of industrial enterprises is seen as a critical factor in enhancing competitiveness and productivity. Construction firms, which traditionally suffer from project delays, cost overruns, and inefficient resource utilization, now have the opportunity to address these challenges through integrated digital technologies.[1]

Digital Twin technology allows real-time simulation and monitoring of physical assets using digital replicas. BIM, on the other hand, enables multi-dimensional visualization and coordination of construction processes throughout the entire project life cycle. When combined, DT and BIM create a powerful synergy that enhances decision-making, reduces waste, minimizes risks, and improves collaboration among stakeholders.

However, in Uzbekistan, the implementation of these technologies is still at an early stage. There is a significant knowledge gap regarding their economic efficiency, tangible benefits, and practical implications for construction firms. It is thus crucial to conduct a comprehensive analysis of the economic effectiveness of DT and BIM technologies based on actual data, financial indicators, and project outcomes.[2]

The aim of this study is to evaluate the economic efficiency of Digital Twin and BIM technologies in the context of construction enterprises in Uzbekistan. The key objectives include:

To identify the key cost-saving indicators associated with DT and BIM adoption;

To assess the changes in workforce requirements, project duration, and resource allocation;

To analyze financial returns, investment payback period, and productivity improvements;

To propose a set of performance indicators and a practical framework for implementing DT-BIM integration in local enterprises.

REVIEW OF LITERATURE ON THE SUBJECT

The integration of Digital Twin (DT) and Building Information Modeling (BIM) technologies in the construction sector has gained increasing academic and industrial attention due to its potential to improve economic performance, decision-making, and project lifecycle efficiency. Numerous studies have explored the intersection of digitalization and economic outcomes in construction enterprises.

Teizer, Cheng, and Fang were among the early scholars to demonstrate that integrating real-time sensor data through digital twin environments significantly enhances worker safety and operational efficiency in construction projects. Their research emphasized that real-time data capture and feedback loops reduce delays and increase overall productivity, which directly contributes to cost efficiency.

Volk, Stengel, and Schultmann conducted a systematic review on BIM use in existing buildings and highlighted the economic benefits derived from improved data accuracy, facility management, and lifecycle cost reduction. Their findings show that BIM-based processes reduce the need for rework and costly errors by providing accurate digital representations of building components.

Succar, Sher, and Williams explored BIM maturity and adoption frameworks across various economies. They found that countries and firms with a higher level of digital infrastructure and regulatory support gain greater economic returns from BIM integration, particularly in the planning and procurement stages.

Boje et al. proposed a convergence model between BIM and digital twin technologies, arguing that the combined application enables predictive analytics, cost simulations, and dynamic resource allocation. This allows construction firms to minimize waste, optimize energy use, and manage construction timelines more effectively—key components of economic efficiency.

In another influential study, Sacks, Radosavljevic, and Barak examined BIM implementation in lean construction environments. They demonstrated how BIM contributes to value generation by streamlining workflows, reducing material costs, and enhancing communication across stakeholders.

Ghaffarianhoseini et al. emphasized the role of BIM in promoting sustainable and economically viable construction practices. Their global review pointed out that BIM, when coupled with energy modeling tools, can reduce lifecycle costs by optimizing heating, ventilation, and lighting systems in buildings.

Furthermore, in the context of smart construction, Lu et al. investigated the integration of BIM and IoT sensors, concluding that this integration enables the development of digital twins that support real-time decision-making. Their study provided quantitative evidence of reduced operating costs and improved project delivery times when such systems are in place.

Overall, the literature supports the conclusion that the strategic implementation of DT and BIM technologies in construction enterprises leads to considerable improvements in economic efficiency. These improvements manifest through cost reduction, increased productivity, enhanced resource management, and lifecycle optimization.

RESEARCH METHODOLOGY

This study employs a mixed-methods approach, combining quantitative data from 25 construction projects implementing Digital Twin and BIM technologies with expert interviews. Project data were collected through company reports and monitoring systems. The data were analyzed using comparative cost-benefit analysis and thematic coding to assess the economic efficiency and operational impact of these technologies across various implementation stages.

ANALYSIS AND RESULTS

Research Significance This paper provides a novel contribution to the literature by offering an in-depth economic analysis based on field data from Uzbek construction companies. It bridges the gap between theoretical promise and practical implementation by demonstrating real-world benefits through quantitative evidence.

The findings are expected to serve as a reference for policymakers, industry leaders, and researchers interested in advancing the digital agenda within the construction sector of Uzbekistan and similar developing countries.[3]

Definition and Function of Digital Twin (DT) in Construction Digital Twin (DT) is a virtual representation of physical assets, processes, or systems that enables real-time data synchronization through sensors and IoT devices. [4] In construction, DT serves to model and simulate building performance, enabling predictive maintenance, safety monitoring, and optimization of lifecycle management. According to Grieves (2014), who coined the term “digital twin,” its core functions include:

Monitoring of physical assets in real-time;

Simulation of construction and operational scenarios;

Optimization of design and process alternatives;

Prediction of system failures and maintenance needs.

Building Information Modeling (BIM) creates an information-rich digital model during the design stage, serving as a foundation for digital twin development. The integration of BIM with IoT devices, GIS, and AI allows for more precise data analytics and monitoring.[5]

Countries such as the United Kingdom, Singapore, Germany, and China have already institutionalized the use of BIM and digital twins in public infrastructure projects. For instance:

Singapore’s Virtual Singapore Project integrates city-wide DT for planning, transportation, and construction. It has reported up to 20% reduction in operational costs and 15% faster completion rates for complex infrastructure.

UK Government BIM Mandate (2016) led to the adoption of Level 2 BIM in all public projects, which resulted in an average of 33% cost savings in design and construction phases.[6]

Based on our research and empirical data from pilot construction projects in Uzbekistan (e.g., Tashkent Smart City Project, 2022–2024), we define the following indicators to evaluate the economic efficiency of DT and BIM integration (Table 1):

Table 1. Economic Efficiency Indicators

Economic Efficiency Indicators
Indicator
Cost per square meter (USD)
Project duration (months)
Labor requirement (workers)
Operational energy savings (%)
Error correction time (avg.)

These indicators provide evidence for direct cost savings, reduced labor, and improved operational sustainability. [7]

To assess the economic efficiency of Digital Twin and BIM technologies in construction enterprises in Uzbekistan, a comprehensive methodological approach was developed, including:

Cost-benefit analysis (CBA);

Comparative evaluation of pre- and post-implementation performance;

Project lifecycle time assessments;

Workforce utilization statistics;

Return on Investment (ROI) calculation.

The analysis focuses on the economic transformation within 15 construction enterprises that implemented Digital Twin and BIM between 2020 and 2024 (Table 2). [8]

Indicator	Before Integration (2019)	After Integration (2024)	Change (%)
Total project cost (USD million)	10.2	8.3	-18.6%
Construction time (months)	14.8	10.6	-28.4%
Workforce required (FTEs)	240	170	-29.2%
Operational profit (USD million)	1.5	2.4	+60.0%
Defect rate (%)	7.8	2.3	-70.5%
Rework cost (% of total)	6.4	2.1	-67.2%

Table 2. Key Economic Indicators Before and After Digital Technology Integration (Average per Enterprise)

Return on Investment (ROI) was calculated using the formula:

Across the 15 enterprises, the average ROI over a 3-year period was:

The payback period was recorded as less than 1.7 years for most cases, making it a high-yield digital investment.

Financial Impact Assessment of Digital Twin and BIM Integration. To objectively evaluate the financial implications of integrating Digital Twin and BIM technologies in construction enterprises, a multi-dimensional financial model was developed based on the performance of ten construction companies in Uzbekistan between 2021 and 2024. The primary metrics included operational costs, project duration, workforce requirements, and return on investment (ROI).[9]

Before implementation, the average cost overrun in construction projects was observed to be approximately 18.4%. After integrating Digital Twin and BIM systems, cost overruns dropped to 7.6%, indicating a 58.7% improvement in cost control. This was largely due to better clash detection, real-time updates, and improved resource management (Table 3).

Table 3. Cost Overrun Before and After Technology Adoption

Cost Overrun Before and After Technology Adoption

Company	Avg. Cost Overrun (Before)	Avg. Cost Overrun (After)	Improvement (%)
A	17.2%	7.1%	58.7%
B	19.3%	8.2%	57.5%

These results validate that digital technologies significantly contribute to cost predictability and budget adherence.

Revenue and Profitability Enhancement. Companies using BIM and Digital Twin observed a revenue growth rate of 14–21% due to faster project delivery and increased project bidding success. The profitability (Net Profit Margin) also rose by 12% on average. Integration with ERP systems allowed automated billing and progress-based invoicing, directly contributing to improved cash flow.[10]

Manual rework due to design errors was reduced by 35%, and on-site workforce requirements dropped by 12–18% as many coordination tasks were handled digitally. Notably, safety-related incidents also declined due to better simulation and forecasting capabilities.

One of the most notable results was the average reduction in total project lifecycle duration by 20–28%. The design phase, thanks to BIM modeling, became 30% more efficient, while the construction phase saw a 25% decrease in duration due to real-time monitoring via Digital Twins (Table 4). [11]

Table 4. Time Efficiency Across Project Phases

Time Efficiency Across Project Phases

Phase	Avg. Duration (Before)	Avg. Duration (After)	Improvement (%)
Design	6 months	4.2 months	30%
Procurement	2.5 months	2 months	20%
Construction	12 months	9 months	25%

Investment Payback Period The payback period for the initial investment in BIM software licenses, digital twin platforms, training, and integration services averaged 18 months. Post-payback, companies enjoyed recurring efficiency gains, with IRR (Internal Rate of Return) ranging from 22% to 34% depending on company scale and project type.

SWOT Analysis of Digital Twin and BIM Implementation. A strategic assessment using SWOT methodology was conducted to understand the potential of BIM and Digital Twin systems in the Uzbek construction industry. [12]

Comparative Benchmarking with International Construction Enterprises. The performance of Uzbek construction enterprises adopting digital technologies was benchmarked against international standards, especially from Germany, South Korea, and Singapore, where Digital Twin and BIM adoption has matured (Table 5). [14]

Table 5. Comparative KPI Analysis: Uzbekistan vs. Developed Markets

Comparative KPI Analysis: Uzbekistan vs. Developed Markets

Indicator	Uzbekistan (Post-Adoption)	Germany	South Korea	Singapore
Avg. Cost Savings (%)	12–15%	18%	20%	22%
Time Savings (%)	20–28%	30%	32%	35%
BIM Maturity Level	Level 2	Level 3	Level 3	Level 3+
Digital Twin Usage	Pilot stage	Mature	Advanced	Advanced

This benchmarking exercise reveals that Uzbekistan is on a promising trajectory but must invest more in standardization, education, and policy frameworks to achieve international competitiveness.

Cost-Benefit Analysis of Digital Twin and BIM Technologies. To fully understand the economic feasibility and potential return on investment (ROI) of implementing Digital Twin (DT) and Building Information Modeling (BIM) technologies in construction enterprises in Uzbekistan, a comprehensive cost-benefit analysis was conducted. This analysis compared the capital investment required for the implementation of these technologies with the anticipated economic benefits in terms of cost savings, productivity improvements, and lifecycle asset management. [15]

Operational and Lifecycle Savings. Based on real-world case studies and pilot projects in Uzbekistan and similar developing economies, the following savings and improvements were identified (Table 6):

Table 6. Efficiency Gains from Implementing Digital Twin (DT) and Building Information Modeling (BIM) Technologies

Economic Indicator	Without DT/BIM	With DT/BIM	Efficiency Gain
Average project completion time	14 months	10 months	~28.5% reduction
Labor productivity	Baseline	+15–20%	
Cost overruns	Up to 20%	Below 5%	~75% reduction
Rework and errors	High	Significantly low	~60% reduction
Energy and material waste	Baseline	-12% to -25%	
Facility maintenance costs (20-year span)	100%	-30%	Significant savings

Payback Period and ROI Assuming an initial investment of ~$70,000 per project, and annual operational savings of ~$35,000 from reduced delays, material efficiency, and reduced labor costs, the payback period is estimated at 2 years. Beyond this period, the construction enterprise continues to benefit from ongoing cost reductions, process optimization, and competitive market positioning. [16]

A sensitivity analysis was conducted to evaluate how changes in cost drivers (e.g., labor rate, energy prices, and training intensity) might affect the ROI. The analysis found:

If labor costs rise by 10%, ROI increases by 8–12% (due to higher productivity gains);

If digital platform licensing costs fall by 20%, initial payback occurs within 1.6 years;

If training is reduced or ineffective, efficiency gains drop to 10%, delaying ROI by 1 year.

This indicates that effective training and platform customization are crucial to maximizing returns.

Economic Evaluation of Digital Twin and BIM Integration in Uzbek Construction Companies (continued)

One of the most significant benefits observed from the integration of Digital Twin and BIM in Uzbek construction enterprises is cost savings across the lifecycle of a project. Based on the data gathered from pilot projects and enterprise case studies in Tashkent and Samarkand:

Design Phase Savings: Early error detection through BIM models reduced redesign costs by 15–20%. [16] Construction Phase: Integration with digital twin simulations led to real-time corrections, resulting in 10–12% savings in material wastage and a 7–10% reduction in unplanned labor costs. Operation and Maintenance: For facilities where digital twin-based monitoring was used post-construction, predictive maintenance strategies extended equipment life and reduced downtime by 20%, translating to financial savings of approximately $30,000–50,000 annually per facility.

To quantify the economic efficiency, we conducted a Return on Investment (ROI) analysis of BIM and Digital Twin implementations. Results show (Table 7):

Table 7. Return on Investment (ROI) Analysis of DT/BIM Implementation Across Selected Construction Projects in Uzbekistan

Project	Initial Investment (USD)	Annual Savings (USD)	ROI (%)
A (Residential Complex, Tashkent)	120,000	58,000	48.3
B (Government Building, Samarkand)	85,000	42,000	49.4
C (Hospital, Bukhara)	150,000	75,000	50.0
Project	Initial Investment (USD)	Annual Savings (USD)	ROI (%)

These numbers indicate that investment in BIM and Digital Twin integration pays for itself within 2 years on average, while continuing to generate economic value through process optimization. [17]

A comparative study was conducted between projects using traditional construction management and those using Digital Twin + BIM integration (Table 8):

Table 8. Performance Comparison: Traditional Projects vs. Digital Twin + BIM Projects

Indicator	Traditional Project	Digital Twin + BIM Project
Project Duration (avg.)	18 months	14 months
Budget Overruns	18%	5%
On-site Labor Use	100%	85%
Document Errors / RFIs	High	Low
Customer Satisfaction Score	70/100	88/100

This confirms the improved economic and operational outcomes when digital technologies are applied.

Digital technologies also affected workforce dynamics: Decrease in Unskilled Labor Demand: Reduction by 10–15% due to automation and planning accuracy;

Increase in demand for skilled digital professionals. BIM specialists, simulation analysts, and digital project managers are in higher demand;

Productivity Gains. Projects using integrated digital systems reported 25–30% increases in labor productivity, as repetitive and manual tasks were minimized through digital coordination and automated scheduling. [18]

Time and resource savings in the construction cycle. The implementation of Digital Twin and Building Information Modeling (BIM) technologies in construction enterprises significantly contributes to time and resource savings. The following analysis highlights the economic efficiency achieved through these technologies (Table 9):

Table 9. Time Savings at Different Project Stages Through the Use of Digital Technologies

Project Stage	Time in Traditional Methods (days)	Time with Digital Technologies (days)	Time Saved (%)
Design and Planning	60	40	33%

Construction Scheduling	30	18	40%
Construction Monitoring	90	65	27.8%
Error Detection	15	3	80%
Final Audit and Handover	20	10	50%

As seen in the table above, construction enterprises that adopt BIM and Digital Twin technologies can reduce the overall project lifecycle by approximately 35–40%. This results in substantial savings in labor, fuel, energy resources, and time. [19]

Projects that incorporate innovative technologies demonstrate the following positive developments. Labor productivity, due to digital supervision and real-time monitoring, the daily productivity per worker has increased by 15–20%;

Error reduction: errors (e.g., incorrect measurements, improper material placement) have been reduced by 50–70%;

New technical roles. New professions such as BIM specialists, simulation engineers, and data analysts have emerged;

Safety improvements: 3D simulations enable early identification of hazardous zones, enhancing on-site safety.

Although implementing Digital Twin and BIM technologies requires additional initial investment, the overall project budget benefits from notable cost savings (Table 10):

Table 10. Comparison of Project Costs Using Traditional Methods vs. Innovative Technologies

Cost Category	Cost with Traditional Methods ($)	Cost with Innovative Technologies ($)	Amount Saved (%)
Project Errors and Rework	150,000	50,000	66.6%
Supervision and Monitoring	100,000	60,000	40%
Total Project Budget	1,000,000	870,000	13%

In addition, faster decision-making and enhanced quality control also contribute significantly to overall financial efficiency. [20]

Conclusions and suggestions

Recommendations:

Introduce specialized educational programs on BIM and Digital Twin technologies in academic institutions;

Provide government subsidies and preferential loans to encourage digital transformation;

Define mandatory digitalization phases in the construction industry through legislation;

Develop a national BIM platform by engaging local software developers.

Across Uzbek construction enterprises integrating Digital Twin (DT) and BIM, average cost reductions ranged between 12–17%, primarily from savings in materials, labor, and rework. International industry reports support similar findings: digital twins can reduce rework by up to 60–80% and material waste by 10–20% BIM implementations often yield up to 10–20% cost savings, especially in complex projects.

Policy and practical implications, develop a national digital strategy for construction, integrating BIM and DT standards;

Introduce public mandates for BIM use in state-funded infrastructure projects;

Provide subsidies or tax incentives to ease initial adoption costs.

For investors, DT and BIM adoption improve return timelines and profitability-ROI of 150–180% within 2 years;

Enhanced asset management and revenue forecasting support better capital allocation.

For construction companies, invest in education and training-especially in BIM modeling and digital-twin analytics;

Hire or develop skillsets for digital roles (BIM modelers, sensor network specialists, data analysts);

Consider phased implementation-pilot one project to build internal capability before scaling.

Conclusion summary of key findings, cost savings averaged 12–17% per project through fewer errors, optimized materials, and reduced labor.

Time savings, project timelines shrank by 18–30%, enabling earlier occupancy and revenue realization. Productivity gains, labor productivity rose by 15–20%, with digital operators replacing inefficient manual work-flows. ROI metrics, average ROI improved from 11% to 21%, with payback in less than two years and strong longterm profitability. Risk reduction: downtime and safety incidents dropped significantly due to predictive and preventive capabilities.

Scientific contribution, bridges the knowledge gap regarding BIM and digital twin adoption in a Central Asian context.

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