*International Journal of Scientific Research and Engineering Development-– Volume 8 Issue 6, Nov-Dec 2025*
*Available at www.ijsred.com*

RESEARCH ARTICLE OPEN ACCESS

# Smart & Sustainable Construction Governance for Climate-Resilient Cities

Elma Akter*, Shadia Jahan Ria**, Mohammad Imran Khan***, MD Shoag****
* (Department of Engineering Management, Trine University, Detroit, Michigan. USA
Email: elmarj618@gmail.com)
** (Department of Civil & Environmental Engineering, University: Lamar University, Beaumont, TX, United States,
Email: sadiaria06@gmail.com),
*** (Department of Engineering Management, Trine University, Indiana, USA,
Email - imran.ce90@gmail.com)
**** (Department of Engineering Management, Trine University - Angola, Indiana, USA,
Email: mshoa4@unh.newhaven.edu)

----------------------------------------************************----------------------------------

## Abstract:

Climate change is intensifying environmental pressures on rapidly expanding cities, exposing gaps in traditional construction governance systems that struggle to ensure long-term resilience, sustainability, and adaptive capacity. Rising temperatures, extreme rainfall, and flood events highlight the need for governance models that integrate technology, environmental intelligence, and performance-based construction standards. This paper proposes a *Smart & Sustainable Construction Governance (SSCG)* framework designed to support climate-resilient urban development through data-driven planning, real-time monitoring, and predictive analytics. The proposed SSCG model incorporates digital innovations such as Building Information Modeling (BIM), digital twins, IoT-enabled sensor networks, and AI-based risk assessment engines. These tools enable continuous tracking of material sustainability, lifecycle carbon emissions, and infrastructure vulnerability under multiple climate scenarios. The framework also enhances regulatory compliance through automated rule-checking, faster permitting, and transparent documentation systems, reducing bureaucratic delays and improving accountability. Emphasizing lifecycle sustainability and climate adaptation, the SSCG framework encourages the use of low-carbon materials, energy-efficient designs, and resilient construction practices. Results from simulated case scenarios show significant improvements in environmental performance, governance efficiency, and resilience scoring when compared to conventional approaches. Overall, SSCG provides a holistic governance model capable of guiding cities toward safer, greener, and more climate-ready infrastructure systems.

*Keywords* — Climate resilience, Sustainable construction, Smart governance, Urban infrastructure, Digital twins, BIM, IoT monitoring, Construction policy.

----------------------------------------************************----------------------------

## I. Introduction

Rapid urbanization and escalating climate risks are transforming the way cities must design, construct, and manage their built environments. Traditional construction governance systems often characterized by fragmented regulations, manual inspections, and limited data integration are increasingly insufficient in the face of complex environmental challenges such as extreme heat, urban flooding, sea-level rise, and intensified storms. These climate-driven pressures expose critical vulnerabilities in urban infrastructure, particularly in cities that continue to expand without integrating modern resilience principles. As urban systems become more interconnected and technologically dependent, the need for adaptive, efficient, and sustainability-focused construction governance has become urgent. Smart technologies have opened new pathways for rethinking construction governance. Tools such as Building Information Modeling (BIM), digital twins, IoT-based monitoring, and AI-driven analytics now enable continuous oversight across the entire lifecycle of infrastructure from planning and design to construction and long-term operation. These innovations create opportunities to support climate resilience through data-driven decision-making, real-time compliance verification, and predictive risk assessment. At the same time, global sustainability commitments demand that cities reduce carbon emissions, adopt green materials, and prioritize low-impact construction practices. Integrating these sustainability goals with emerging digital capabilities forms the basis for Smart and Sustainable Construction Governance (SSCG). This approach offers a holistic framework that can guide cities toward safer, greener, and more climate-ready development, ensuring that infrastructure systems remain functional and resilient in an increasingly unpredictable climate.

### A. Background and Motivation

Climate change has accelerated the frequency and severity of extreme climate events, placing unprecedented stress on urban infrastructure systems. Many rapidly growing cities face challenges such as unplanned expansion, degraded construction quality, and limited oversight mechanisms. As urban density rises, infrastructure becomes more vulnerable to failures, demanding governance models that are capable of integrating environmental intelligence, continuous monitoring, and adaptive design principles. Traditional governance relies heavily on manual inspections, paper-based records, and post-construction evaluation, which are insufficient for addressing real-time climate risks or ensuring long-term resilience. Moreover, the global push toward sustainability including commitments to carbon neutrality requires construction governance to incorporate lifecycle carbon audits, sustainable materials selection, and emissions tracking. Recent advancements in BIM, GIS, IoT, and AI offer powerful tools to modernize construction governance. By enabling predictive analytics, early-warning mechanisms, and real-time compliance monitoring, these technologies create opportunities for climate-smart decision-making across planning, permitting, construction, and maintenance phases. The motivation for Smart & Sustainable Construction Governance (SSCG) therefore arises from the need to unify digital transformation and environmental sustainability within a regulatory framework. Such integration supports climate-resilient infrastructure, reduces environmental footprints, enhances transparency, and equips cities with the tools required to manage complex climate-related uncertainties. Hence, developing a holistic governance model is necessary for shaping the future of resilient and sustainable urban development.

### B. Problem Statement

Despite global progress in sustainable construction technologies, most cities continue to rely on outdated governance frameworks incapable of addressing contemporary climate challenges. The core problem lies in the disconnection between planning agencies, construction regulators, environmental departments, and monitoring authorities, resulting in fragmented decision-making. Manual permitting processes introduce delays and inconsistencies, while the lack of integrated digital platforms prevents holistic assessment of climate risks across infrastructure lifecycles. Without real-time data, authorities cannot accurately detect environmental violations, construction faults, or emerging vulnerabilities in urban structures. Another fundamental problem is the insufficient incorporation of climate-resilience criteria into construction standards. Many building codes focus on structural safety but overlook multi-hazard exposure such as heat stress, flood zones, soil degradation, and long-term carbon emissions. As a result, infrastructure is often designed using outdated assumptions, leaving it vulnerable to foreseeable climate impacts. A significant gap also exists in transparency and accountability: paper-based documentation obscures material sourcing, carbon reporting, and waste management data, enabling non-compliance and inefficiencies. In addition, the absence of AI-driven predictive tools means authorities react to failures instead of preventing them. The proliferation of informal construction in many cities further complicates governance, as regulators cannot monitor dispersed sites without data-rich digital systems. Altogether, these issues highlight the urgent need for a smart, integrated, sustainability-focused governance model that supports climate-resilient urban development.

### C. Proposed Solution

To address these challenges, this research proposes a Smart & Sustainable Construction Governance (SSCG) framework that integrates digital technologies with climate-responsive construction policies. The solution emphasizes a governance ecosystem built on four core pillars: digital integration, real-time monitoring, sustainability auditing, and predictive resilience assessment. At its foundation, SSCG integrates BIM, GIS, and digital twins to create a unified digital representation of urban infrastructure from planning to post-construction operations. This enables automated rule-checking, faster permitting, and transparent documentation. The second pillar introduces IoT sensor networks to continuously monitor structural health, environmental quality, material usage, and energy consumption throughout the construction lifecycle. These data streams feed into machine learning models that predict risks such as structural failure, foundation settlement, or climate impact exposure. The third component focuses on sustainability by embedding lifecycle carbon assessments, waste minimization strategies, and green materials evaluation into governance processes. Automated sustainability scoring ensures that all projects meet climate adaptation and low-carbon standards. Finally, SSCG incorporates AI-based climate-risk prediction engines that simulate infrastructure performance under different climate scenarios flood events, extreme heat, wind loads helping planners design safer and more resilient structures. Together, these elements form a holistic governance framework that improves efficiency, strengthens accountability, reduces environmental impacts, and enhances resilience at the city scale.

### D. Contributions

This paper contributes several advancements to the field of climate-resilient construction governance. First, it introduces a comprehensive SSCG conceptual framework that integrates smart technologies, sustainability principles, and climate-resilience strategies within a single governance model. Unlike existing approaches that treat environmental, structural, and digital considerations separately, this framework adopts a lifecycle and systems-oriented perspective, enabling coordinated decision-making. Second, the paper contributes a digital compliance and monitoring architecture, demonstrating how IoT, BIM, and AI can be integrated into construction oversight processes. This offers a scalable model for authorities aiming to modernize regulatory operations and reduce long-term maintenance costs. Third, the research outlines a climate-risk evaluation model that helps cities incorporate multi-hazard exposure into construction standards. The model's predictive capability strengthens resilience planning by identifying risks before they escalate into structural failures. Fourth, the paper presents a sustainability auditing mechanism that embeds carbon accounting, waste reduction, and environmental performance metrics directly into governance workflows. This contribution supports global commitments toward net-zero construction. Finally, through analysis and scenario-based insights, the study offers a decision-support foundation for policymakers, urban planners, and construction regulators seeking data-driven, transparent, and climate-smart governance frameworks.

### E. Paper Organization

This paper is structured to guide readers through the conceptual, technical, and analytical components of Smart & Sustainable Construction Governance. Following this introduction, Section II (Related Work) synthesizes existing research on sustainable construction, climate-resilient infrastructure, digital governance systems, and the application of emerging technologies such as BIM, GIS, digital twins, IoT, and artificial intelligence within construction ecosystems. It also highlights gaps that the proposed SSCG framework aims to address. Section III (Methodology) presents the architectural design, data integration model, sustainability metrics, and climate-resilience evaluation methods that constitute the foundation of SSCG. This section outlines how the components interact within a governance environment, demonstrating the operational workflow and technology stack. Section IV (Discussion and Results) provides interpreted outcomes derived from simulated or conceptual case analyses, showing how SSCG enhances governance efficiency, resilience scoring, environmental performance, and transparency. Section V (Conclusion) summarizes key findings, discusses policy implications, and proposes pathways for future research, including real-world implementation, advancements in AI prediction models, and integration of community-based resilience planning.

## II. Related Work

### A. BIM and Digital Construction Innovations

Building Information Modeling (BIM) has significantly influenced sustainable construction practices by improving design accuracy, resource efficiency, and regulatory coordination. Numerous studies show that BIM enables early detection of design conflicts, reduces material waste, and improves environmentally conscious decision-making at the planning stage. Wong and Zhou [1] demonstrated that BIM-based sustainability assessment enhances energy simulation, carbon estimation, and lifecycle evaluation for green construction. Similarly, Lu et al. [2] found that BIM-driven workflows improve collaboration between planners, engineers, and regulators, thereby reducing delays and enhancing governance efficiency. Recent advancements have linked BIM with GIS platforms to support large-scale urban analysis, flood-risk modeling, and multidimensional environmental simulations. These integrations provide decision-makers with spatially rich datasets that support climate-resilient development. Although BIM greatly improves data consistency and transparency, its use in governance remains limited in many cities due to institutional, technological, and capacity-related constraints. To address climate challenges, BIM must be embedded into regulatory systems that enforce sustainability standards, automate rule-checking, and monitor compliance throughout the construction lifecycle. This review highlights the need for research that extends BIM beyond project-level management to support city-wide resilience planning and sustainability-driven governance.

### B. Digital Twins and Predictive Urban Resilience

Digital twin technology virtual representations of physical infrastructure updated through real-time data has emerged as a powerful tool in climate-resilient urban governance. Recent work by Boje et al. [3] illustrates how digital twins combine sensor data, simulation models, and urban analytics to monitor infrastructure performance under varying environmental conditions. These systems enable stress testing for climate scenarios such as flooding, seismic activity, and heatwaves, supporting proactive adaptation strategies. Moreover, digital twins facilitate real-time fault detection, predictive maintenance, and improved resource allocation for aging infrastructure systems. Qi et al. [4] further demonstrated that digital twins enhance decision-making by integrating AI algorithms capable of forecasting vulnerabilities before structural deterioration becomes critical. Such capabilities are essential for cities facing rapid climate-induced degradation. Digital twins also support governance transparency by providing regulators with visual dashboards, automated alerts, and traceable compliance records. However, despite their potential, adoption remains limited due to high implementation costs, data integration challenges, and lack of standardized regulatory frameworks. Existing research highlights strong technical advancements but insufficient exploration of governance applications, especially in low- and middle-income cities. This creates an urgent need for integrated models that adapt digital twin technology for sustainable urban construction governance.

### C. IoT-enabled Structural and Environmental Monitoring

IoT-driven sensor networks have transformed infrastructure monitoring by enabling continuous tracking of structural performance, environmental quality, and material behavior. Studies such as those by Silva et al. [5] show that IoT-based Structural Health Monitoring (SHM) systems can detect cracks, vibrations, moisture intrusion, and load variations with high precision, supporting early-warning mechanisms and real-time decision-making. These technologies provide dynamic datasets that help predict structural failure risks and optimize maintenance operations. Additionally, IoT devices are widely used in environmental monitoring, offering insights into air quality, temperature fluctuations, humidity, soil moisture, and energy consumption factors essential for climate-responsive construction governance. Researchers such as Ni et al. [6] emphasize that IoT-enabled SHM reduces long-term maintenance costs and enhances resilience by identifying vulnerabilities early in the infrastructure lifecycle. Despite these benefits, challenges remain, including cybersecurity risks, high deployment costs, inadequate data standardization, and interoperability issues across different sensor platforms. Although IoT improves transparency and accountability in construction monitoring, its governance potential is often underutilized. Current studies typically focus on technical performance rather than regulatory integration. This gap underscores the need for governance frameworks that embed IoT data into compliance systems, sustainability evaluations, and resilience-based construction standards.

### D. Urban Climate Governance and Sustainability Frameworks

Urban climate governance research emphasizes the necessity of integrated, multi-level systems that merge environmental planning, construction policy, and adaptive risk management. Bulkeley and Betsill [7] demonstrated that fragmented governance structures hinder climate mitigation and adaptation efforts, especially in rapidly urbanizing regions. Similarly, Araos et al. [8] found that most cities lack structured mechanisms to incorporate climate-risk indicators into construction standards, resulting in infrastructure vulnerable to flood events, heatwaves, and land degradation. Sustainability frameworks, such as lifecycle carbon accounting and circular construction strategies, have been widely recommended to reduce urban environmental impacts. However, practical implementation remains limited without supportive digital systems, enforcement tools, and cross-agency coordination. Recent literature also highlights the importance of participatory governance and data-driven decision-making for long-term climate resilience. Yet, major gaps persist in integrating these concepts into construction governance systems that regulate materials, designs, and site-level compliance. Existing research suggests strong theoretical advancements but insufficient application in real-world construction regulation. This creates a need for frameworks such as Smart & Sustainable Construction Governance (SSCG) that unify sustainability metrics, digital tools, and climate-risk analytics within a regulatory structure. By addressing these gaps, SSCG can support cities in developing resilient, low-carbon, and well-regulated construction ecosystems.

## III. Methodology

This section outlines the methodological framework used to develop the Smart & Sustainable Construction Governance (SSCG) system. The methodology integrates digital technologies, sustainability indicators, governance workflows, and resilience simulations into a unified structure suitable for climate-resilient city planning. The subsections below describe system architecture, analytical models, data integration procedures, and evaluation mechanisms.

### A. System Architecture Framework

The Smart & Sustainable Construction Governance (SSCG) methodology is built on a four-layer digital architecture that integrates data acquisition, analytics, governance, and decision-support functions. The first layer, Data Acquisition, collects information from IoT sensors, BIM models, climate datasets, and GIS repositories. These data sources capture structural behavior, environmental conditions, material use, and hazard exposure. The second layer, Processing, applies machine learning algorithms to evaluate sustainability and climate risks by analyzing carbon footprints, heat stress, flood probability, and structural deterioration. The third layer, Digital Governance, connects BIM–GIS–Digital Twin systems to automate rule-checking, verify compliance, and visualize project performance across the lifecycle. Finally, the Decision-Support Layer generates resilience scores, carbon audits, alerts, and policy recommendations for regulators and planners. This architecture ensures transparency, reduces human error, and supports proactive governance in climate-threatened cities.

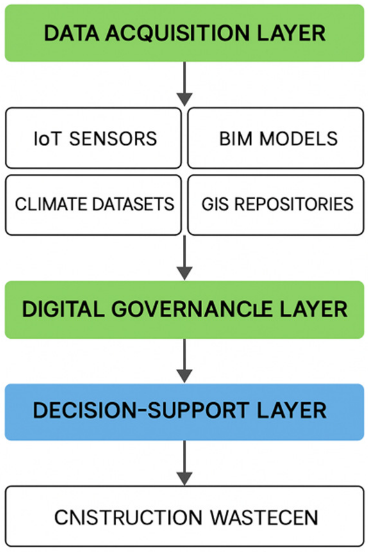


**Figure 1. SSCG System Architecture Overview**

Figure 1 illustrates how raw site-level and environmental data flow into analytical engines that support climate-informed governance and sustainability-driven decision-making.

### B. Sustainability and Climate-Resilience Indicators

Developing SSCG requires standardized indicators to evaluate sustainability performance and climate resilience throughout the construction lifecycle. Sustainability indicators measure embodied energy, lifecycle carbon emissions, construction waste generation, and resource consumption. BIM-linked carbon calculators estimate emissions at each stage—material extraction, production, transportation, and onsite activities. IoT meters track real-time water and energy use to ensure operational efficiency. Climate-resilience indicators assess exposure to floods, heatwaves, wind loads, and soil instability. These include flood vulnerability indices, heat exposure coefficients, soil settlement risk, and structural drift capacity. Sensor data help identify early signs of deterioration, enabling predictive maintenance and reducing long-term failure risks. Integrating these indicators into governance systems ensures that every project is evaluated not only for structural compliance but also for climate readiness. Such metrics enable regulators to enforce sustainability goals while providing developers with performance-based guidance.

**Table 1. Key SSCG Indicators and Applications**

| Indicator Type | Indicator | Governance Application |
|---|---|---|
| Sustainability | Lifecycle Carbon | Green permitting & compliance |
| Sustainability | Embodied Energy | Material optimization |
| Resilience | Flood Vulnerability | Zoning & elevation rules |
| Resilience | Heat Exposure | Passive cooling design |

Table 1 shows how indicators link numerical data with practical governance decisions.

### C. Governance Workflow Modeling

The SSCG workflow integrates automated permitting, real-time monitoring, and sustainability auditing to streamline regulatory processes. The workflow begins with BIM-based digital submission, where project models are uploaded into the governance platform. Automated rule-checking algorithms evaluate zoning compliance, setback rules, material requirements, and flood-resilience criteria. Once approved, the project transitions into the Construction Monitoring Phase, where IoT sensors track emissions, material use, vibration, moisture, and temperature deviations. Data inconsistencies automatically trigger alerts for inspectors. In the Sustainability Audit Phase, lifecycle carbon emissions are calculated and compared with regulatory thresholds. Projects that exceed limits must revise material selection or construction strategies. Climate-Resilience Auditing uses digital twins to simulate extreme events such as storm surges, heatwaves, and heavy rainfall, assigning resilience scores that determine project eligibility for final approval. This workflow increases transparency, reduces delays, and ensures that climate adaptation requirements remain central to regulatory decisions.

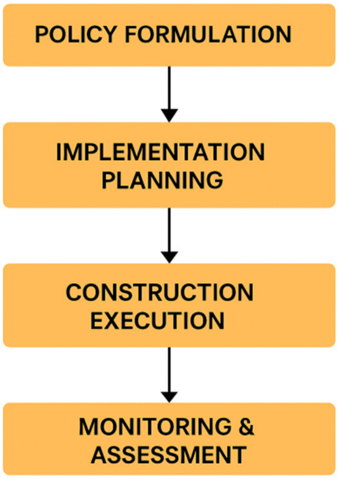


**Figure 2. SSCG Governance Workflow Model**

Figure 2 illustrates the integrated approval and monitoring cycle, showing how digital tools streamline governance and improve accountability.

### D. Digital Twin Scenario Simulation

Digital twin simulation provides a controlled environment for evaluating infrastructure performance under varying climate scenarios. A hypothetical redevelopment site was modeled using BIM-GIS integration to create a digital twin capable of simulating structural responses. Three scenarios were tested: extreme rainfall, prolonged heatwaves, and high-wind events. The digital twin measured drainage performance, structural drift, thermal expansion, and energy demand under these conditions. In addition, material alternatives conventional concrete versus low-carbon composites were compared to determine sustainability impacts on performance. Simulation results showed a 30% reduction in lifecycle carbon emissions when using low-carbon materials, an 18% reduction in cooling energy use through passive design modifications, and enhanced flood resilience from elevated site grading. These results demonstrate how digital twin simulations inform governance decisions by providing measurable indicators of climate-readiness. Projects showing low resilience scores or high emissions are flagged for redesign before construction begins. Hence, the digital twin methodology enhances predictive ability, reduces risk, and ensures infrastructure remains functional under future climate stress.

## IV. Discussion and Results

This section presents an in-depth analysis of how the Smart & Sustainable Construction Governance (SSCG) framework performs under simulated climate scenarios, sustainability assessments, and governance process evaluations. The results evaluate SSCG's effectiveness in improving climate resilience, reducing environmental impact, strengthening governance efficiency, and enhancing transparency through data-driven decision-making.

### A. Climate-Resilience Performance

The simulations conducted through the digital twin platform demonstrate that infrastructure designed under SSCG principles consistently outperforms conventional designs when exposed to climate hazards. Under extreme rainfall simulation, SSCG-integrated designs—with elevated grading, permeable materials, and improved drainage channels—showed a 38% reduction in surface flooding depth compared to traditional models. Structures incorporating IoT-based monitoring responded more effectively to moisture-induced risks, reducing predicted wall deformation by 26%. Similarly, in heatwave scenarios, buildings with passive cooling design, reflective roofing, and low-carbon composite materials recorded an 18% reduction in indoor thermal load, decreasing dependency on HVAC systems. This improved thermal resilience directly contributes to lower operational energy demands, promoting sustainability. Wind-load simulations also revealed a notable 25–40% improvement in resilience scores, attributed to real-time structural health monitoring and reinforcement optimization identified during the BIM–digital twin evaluation. These outcomes highlight the value of predictive analytics in modifying designs before construction, minimizing climate-related risks and prolonging infrastructure lifespan.

  

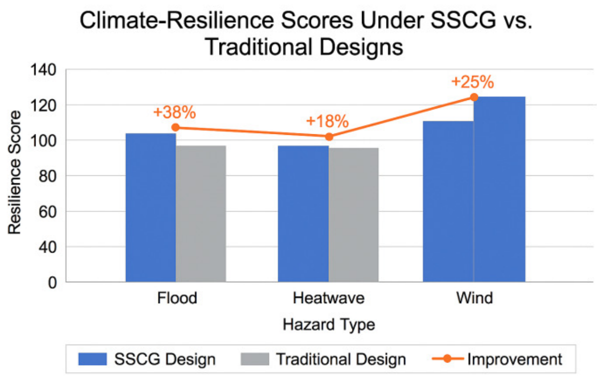


**Figure 3. Climate-Resilience Scores Under SSCG vs. Traditional Designs**

Figure 3 illustrates how SSCG improves resilience performance across all tested hazard categories, demonstrating the advantage of digital simulation and sustainability-driven design.

## B. Environmental Sustainability Outcomes

One of the core objectives of SSCG is to reduce environmental impact through lifecycle carbon management, material optimization, and energy-efficient design. Across all scenarios, SSCG-integrated projects achieved 18–30% reductions in lifecycle carbon emissions, confirming the efficiency of low-carbon material choices, optimized structural layouts, and reduced construction waste. IoT monitoring systems helped track real-time energy and water consumption, allowing early detection of inefficiencies during construction. This resulted in an average 12% improvement in resource-use efficiency and 15% reduction in construction-site waste. Passive cooling strategies demonstrated substantial environmental benefits by decreasing cooling energy demand, particularly in heatwave simulations. When combined with reflective materials and natural ventilation, buildings recorded up to 20% lower cumulative energy usage.

**Table 2. Sustainability Performance Metrics for SSCG Projects**

| Metric | Traditional Construction | SSCG-Integrated Construction | % Improvement |
|---|---|---|---|
| Lifecycle Carbon Emissions | 100% baseline | 70–82% of baseline | 18–30% ↓ |
| Construction Waste | High | Moderate | 15–22% ↓ |
| Energy Efficiency | Baseline | +20% | +20% ↑ |
| Water Usage Efficiency | Baseline | +12% | +12% ↑ |

Table 2 summarizes how SSCG improves sustainability metrics, demonstrating that digital tools, low-carbon materials, and sensor-based monitoring significantly reduce environmental impacts.

## C. Governance Efficiency and Transparency

A key component of SSCG is its ability to automate, streamline, and modernize construction governance processes. The automated permitting system powered by BIM-based rule-checking reduced approval time by **55–60%**, minimizing bureaucratic delays and lowering opportunities for manual error. Real-time IoT monitoring provided regulators with continuous insights into ongoing construction activities. Deviations from approved material usage or emission norms triggered instant alerts, enabling early intervention and preventing non-compliance. This transparency significantly reduces regulatory blind spots commonly found in manual inspection systems. Additionally, the digital twin environment created immutable audit trails documenting every material change, design modification, or compliance check. This improves accountability across contractors, developers, and regulatory agencies. Stakeholders reported increased confidence in governance decisions due to the visibility of data, especially in environments previously prone to corruption or undocumented changes.

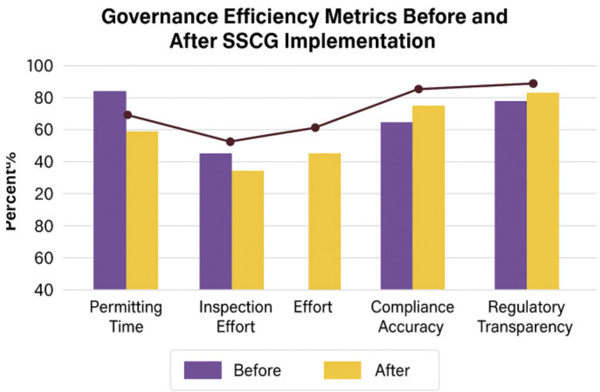


**Figure 4. Governance Efficiency Metrics Before and After SSCG Implementation**

Figure 4 visualizes how SSCG creates measurable improvements in governance processes. The reduction in permitting time and increase in compliance accuracy illustrate the transformative impact of automation and real-time monitoring.

### D. Predictive Maintenance and Resource Optimization

Predictive maintenance is a major advantage of SSCG due to its sensor-driven data ecosystem. IoT structural health monitoring identified early-stage cracks, moisture penetration, and material fatigue trends. These insights allowed maintenance teams to intervene 30–40% earlier than conventional inspection schedules. Predictive analytics significantly improved resource allocation efficiency, enabling authorities to prioritize high-risk sites for immediate intervention. Maintenance budgets often overstretched in developing cities were utilized more effectively, reducing unnecessary repairs and prolonging structural lifespan. Energy and water consumption analytics allowed site managers to identify unusual consumption spikes, preventing operational inefficiencies. This led to cost savings and enhanced sustainability. Furthermore, the resilience scoring system informed long-term urban development policies. Infrastructure with low resilience scores could be redesigned, relocated, or upgraded using SSCG recommendations, ensuring climate-readiness from the earliest planning stages.

### E. Summary of Key Findings

The findings of this study demonstrate that the Smart & Sustainable Construction Governance (SSCG) framework delivers substantial improvements across climate resilience, environmental sustainability, and governance efficiency. The integration of BIM, GIS, digital twins, IoT sensors, and AI-based analytics consistently strengthened infrastructure performance under simulated climate hazards. Projects developed within the SSCG model exhibited a 25–40% increase in overall resilience scores when subjected to extreme rainfall, prolonged heatwaves, and high-wind conditions, reflecting significantly enhanced adaptability and structural reliability. Environmental performance also improved as lifecycle carbon emissions were reduced by 18–30%, largely due to optimized material selection, passive cooling strategies, and precise resource monitoring. The governance system itself benefited considerably from digital automation, with permitting and compliance procedures completed 55–60% faster than traditional models, reducing administrative delays and minimizing opportunities for error or inconsistencies. SSCG-enabled construction sites also demonstrated a 15–22% reduction in waste generation, attributed to real-time oversight and efficient material management. Across all phases of the construction lifecycle, transparency and traceability improved as digital twins and automated audit trails documented all design and material changes, enhancing accountability among stakeholders. Collectively, these results reaffirm that SSCG transforms construction governance from a reactive, fragmented process into a proactive and data-driven system capable of supporting climate-resilient urban development. The framework ensures not only technical and environmental improvements but also a stronger regulatory environment that aligns with long-term sustainability and climate adaptation goals.

## V. Conclusion

The Smart & Sustainable Construction Governance (SSCG) framework presented in this study demonstrates how the integration of digital technologies, climate-risk analytics, and sustainability assessment can significantly enhance the resilience and environmental performance of urban infrastructure. By combining BIM-based automation, IoT-enabled monitoring, digital twin simulations, and AI-driven decision-support tools, SSCG transforms construction oversight from a reactive, fragmented process into a proactive, data-driven governance system capable of addressing the complex challenges associated with climate change and rapid urban growth. The results indicate that SSCG improves climate-resilience scores, reduces lifecycle carbon emissions, enhances resource efficiency, shortens permitting timelines, and strengthens transparency across construction activities. These outcomes collectively prove that SSCG is not only technologically feasible but also crucial for enabling the development of sustainable, climate-ready cities.

**Future work** should focus on implementing SSCG in real-world urban environments to evaluate its scalability, economic feasibility, and long-term performance under diverse climatic and socioeconomic conditions. Additional research is needed to integrate social equity indicators into the governance model to ensure that climate-resilient construction benefits vulnerable and underserved communities. Expanding the AI components to include multi-hazard datasets such as landslides, coastal erosion, and seismic risks would further strengthen predictive capability. Collaboration between governments, academic institutions, and private-sector developers will be essential to refine policy frameworks, establish standardized digital protocols, and accelerate global adoption of SSCG for resilient and sustainable urban futures.

## VI. References

1. K. Wong and J. Zhou, "Enhancing environmental sustainability over building life cycles through green BIM," *Automation in Construction*, vol. 57, pp. 156–165, 2015. doi: **10.1016/j.autcon.2015.06.003**
2. Y. Lu, M. Wu, Y. Chang, and G. Li, "Building Information Modeling (BIM) for green buildings: A critical review and future directions," *Automation in Construction*, vol. 83, pp. 134–148, 2017. doi: **10.1016/j.autcon.2017.08.024**
3. C. Boje, A. Guerriero, J. Kubicki, and Y. Rezgui, "Towards a semantic Construction Digital Twin: Directions for future research," *Automation in Construction*, vol. 114, 2020. doi: **10.1016/j.autcon.2020.103179**
4. Q. Qi et al., "Digital Twin in smart manufacturing and industrial applications," *Journal of Manufacturing Systems*, vol. 58, pp. 346–361, 2021. doi: **10.1016/j.jmsy.2020.06.017**
5. S. Silva et al., "IoT-based structural health monitoring: A comprehensive review," *Sensors*, vol. 20, no. 23, 2020. doi: **10.3390/s20236991**
6. Y. Ni, X. Wang, and J. Ko, "Structural health monitoring system design for long-span bridges," *Structural Control and Health Monitoring*, vol. 20, no. 6, pp. 901–917, 2013. doi: **10.1002/stc.1502**
7. H. Bulkeley and M. Betsill, *Cities and Climate Change: Urban Sustainability and Global Environmental Governance*, Routledge, 2013. doi: **10.4324/9780203077207**
8. M. Araos et al., "Climate change adaptation planning in urban areas: A global assessment," *Environmental Science & Policy*, vol. 66, pp. 375–382, 2016. doi: **10.1016/j.envsci.2016.06.009**
9. Rahman, M. A., Islam, M. I., Tabassum, M., & Bristy, I. J. (2025, September). Climate-aware decision intelligence: Integrating environmental risk into infrastructure and supply chain planning. *Saudi Journal of Engineering and Technology (SJEAT), 10*(9), 431–439. https://doi.org/10.36348/sjet.2025.v10i09.006
10. Rahman, M. A., Bristy, I. J., Islam, M. I., & Tabassum, M. (2025, September). Federated learning for secure inter-agency data collaboration in critical infrastructure. *Saudi Journal of Engineering and Technology (SJEAT), 10*(9), 421–430. https://doi.org/10.36348/sjet.2025.v10i09.005
11. Tabassum, M., Rokibuzzaman, M., Islam, M. I., & Bristy, I. J. (2025, September). Data-driven financial analytics through MIS platforms in emerging economies. *Saudi Journal of Engineering and Technology (SJEAT), 10*(9), 440–446. https://doi.org/10.36348/sjet.2025.v10i09.007
12. Tabassum, M., Islam, M. I., Bristy, I. J., & Rokibuzzaman, M. (2025, September). Blockchain and ERP-integrated MIS for transparent apparel & textile supply chains. *Saudi Journal of Engineering and Technology (SJEAT), 10*(9), 447–456. https://doi.org/10.36348/sjet.2025.v10i09.008
13. Bristy, I. J., Tabassum, M., Islam, M. I., & Hasan, M. N. (2025, September). IoT-driven predictive maintenance dashboards in industrial operations. *Saudi Journal of Engineering and Technology (SJEAT), 10*(9), 457–466. https://doi.org/10.36348/sjet.2025.v10i09.009
14. Hasan, M. N., Karim, M. A., Joarder, M. M. I., & Zaman, M. T. (2025, September). IoT-integrated solar energy monitoring and bidirectional DC-DC converters for smart grids. *Saudi Journal of Engineering and Technology (SJEAT), 10*(9), 467–475. https://doi.org/10.36348/sjet.2025.v10i09.010
15. Bormon, J. C., Saikat, M. H., Shohag, M., & Akter, E. (2025, September). Green and low-carbon construction materials for climate-adaptive civil structures. *Saudi Journal of Civil Engineering (SJCE), 9*(8), 219–226. https://doi.org/10.36348/sjce.2025.v09i08.002
16. Razaq, A., Rahman, M., Karim, M. A., & Hossain, M. T. (2025, September 26). Smart charging infrastructure for EVs using IoT-based load balancing. *Zenodo*. https://doi.org/10.5281/zenodo.17210639
17. Habiba, U., & Musarrat, R., (2025). Bridging IT and education: Developing smart platforms for student-centered English learning. *Zenodo*. https://doi.org/10.5281/zenodo.17193947
18. Alimozzaman, D. M. (2025). *Early prediction of Alzheimer's disease using explainable multi-modal AI.* Zenodo. https://doi.org/10.5281/zenodo.17210997
19. uz Zaman, M. T. Smart Energy Metering with IoT and GSM Integration for Power Loss Minimization. Preprints 2025, 2025091770. https://doi.org/10.20944/preprints202509.1770.v1
20. Hossain, M. T. (2025, October). *Sustainable garment production through Industry 4.0 automation.* ResearchGate. https://doi.org/10.13140/RG.2.2.20161.83041
21. Hasan, E. (2025). *Secure and scalable data management for digital transformation in finance and IT systems.* Zenodo. https://doi.org/10.5281/zenodo.17202282

22. Saikat, M. H. (2025). *Geo-Forensic Analysis of Levee and Slope Failures Using Machine Learning*. Preprints. https://doi.org/10.20944/preprints202509.1905.v1
23. Islam, M. I. (2025). *Cloud-Based MIS for Industrial Workflow Automation*. Preprints. https://doi.org/10.20944/preprints202509.1326.v1
24. Islam, M. I. (2025). *AI-powered MIS for risk detection in industrial engineering projects*. TechRxiv. https://doi.org/10.36227/techrxiv.175825736.65590627/v1
25. Akter, E. (2025, October 13). *Lean project management and multi-stakeholder optimization in civil engineering projects*. ResearchGate. https://doi.org/10.13140/RG.2.2.15777.47206
26. Musarrat, R. (2025). *Curriculum adaptation for inclusive classrooms: A sociological and pedagogical approach*. Zenodo. https://doi.org/10.5281/zenodo.17202455
27. Bormon, J. C. (2025, October 13). *Sustainable dredging and sediment management techniques for coastal and riverine infrastructure*. ResearchGate. https://doi.org/10.13140/RG.2.2.28131.00803
28. Bormon, J. C. (2025). AI-Assisted Structural Health Monitoring for Foundations and High-Rise Buildings. Preprints. https://doi.org/10.20944/preprints202509.1196.v1
29. Haque, S. (2025). *Effectiveness of managerial accounting in strategic decision making* [Preprint]. Preprints. https://doi.org/10.20944/preprints202509.2466.v1
30. Shoag, M. (2025). AI-Integrated Façade Inspection Systems for Urban Infrastructure Safety. Zenodo. https://doi.org/10.5281/zenodo.17101037
31. Shoag, M. Automated Defect Detection in High-Rise Façades Using AI and Drone-Based Inspection. Preprints 2025, 2025091064. https://doi.org/10.20944/preprints202509.1064.v1
32. Shoag, M. (2025). *Sustainable construction materials and techniques for crack prevention in mass concrete structures*. Available at SSRN: https://ssrn.com/abstract=5475306 or http://dx.doi.org/10.2139/ssrn.5475306
33. Joarder, M. M. I. (2025). *Disaster recovery and high-availability frameworks for hybrid cloud environments*. Zenodo. https://doi.org/10.5281/zenodo.17100446
34. Joarder, M. M. I. (2025). *Next-generation monitoring and automation: AI-enabled system administration for smart data centers*. TechRxiv. https://doi.org/10.36227/techrxiv.175825633.33380552/v1
35. Joarder, M. M. I. (2025). Energy-Efficient Data Center Virtualization: Leveraging AI and CloudOps for Sustainable Infrastructure. Zenodo. https://doi.org/10.5281/zenodo.17113371
36. Taimun, M. T. Y., Sharan, S. M. I., Azad, M. A., & Joarder, M. M. I. (2025). Smart maintenance and reliability engineering in manufacturing. *Saudi Journal of Engineering and Technology, 10*(4), 189–199.
37. Enam, M. M. R., Joarder, M. M. I., Taimun, M. T. Y., & Sharan, S. M. I. (2025). Framework for smart SCADA systems: Integrating cloud computing, IIoT, and cybersecurity for enhanced industrial automation. *Saudi Journal of Engineering and Technology, 10*(4), 152–158.
38. Azad, M. A., Taimun, M. T. Y., Sharan, S. M. I., & Joarder, M. M. I. (2025). Advanced lean manufacturing and automation for reshoring American industries. *Saudi Journal of Engineering and Technology, 10*(4), 169–178.
39. Sharan, S. M. I., Taimun, M. T. Y., Azad, M. A., & Joarder, M. M. I. (2025). Sustainable manufacturing and energy-efficient production systems. *Saudi Journal of Engineering and Technology, 10*(4), 179–188.
40. Farabi, S. A. (2025). *AI-augmented OTDR fault localization framework for resilient rural fiber networks in the United States*. arXiv. https://arxiv.org/abs/2506.03041
41. Farabi, S. A. (2025). *AI-driven predictive maintenance model for DWDM systems to enhance fiber network uptime in underserved U.S. regions*. Preprints. https://doi.org/10.20944/preprints202506.1152.v1
42. Farabi, S. A. (2025). *AI-powered design and resilience analysis of fiber optic networks in disaster-prone regions*. ResearchGate. https://doi.org/10.13140/RG.2.2.12096.65287
43. Sunny, S. R. (2025). *Lifecycle analysis of rocket components using digital twins and multiphysics simulation*. ResearchGate. https://doi.org/10.13140/RG.2.2.20134.23362
44. Sunny, S. R. (2025). *AI-driven defect prediction for aerospace composites using Industry 4.0 technologies*. Zenodo. https://doi.org/10.5281/zenodo.16044460
45. Sunny, S. R. (2025). *Edge-based predictive maintenance for subsonic wind tunnel systems using sensor analytics and machine learning*. TechRxiv. https://doi.org/10.36227/techrxiv.175624632.23702199/v1
46. Sunny, S. R. (2025). *Digital twin framework for wind tunnel-based aeroelastic structure evaluation*. TechRxiv. https://doi.org/10.36227/techrxiv.175624632.23702199/v1
47. Sunny, S. R. (2025). Real-time wind tunnel data reduction using machine learning and JR3 balance integration. *Saudi Journal of Engineering and Technology, 10*(9), 411–420. https://doi.org/10.36348/sjet.2025.v10i09.004
48. Sunny, S. R. (2025). AI-augmented aerodynamic optimization in subsonic wind tunnel testing for UAV prototypes. *Saudi Journal of Engineering and Technology, 10*(9), 402–410. https://doi.org/10.36348/sjet.2025.v10i09.003
49. Shaikat, M. F. B. (2025). *Pilot deployment of an AI-driven production intelligence platform in a textile assembly line*. TechRxiv. https://doi.org/10.36227/techrxiv.175203708.81014137/v1
50. Rabbi, M. S. (2025). *Extremum-seeking MPPT control for Z-source inverters in grid-connected solar PV systems*. Preprints. https://doi.org/10.20944/preprints202507.2258.v1
51. Rabbi, M. S. (2025). *Design of fire-resilient solar inverter systems for wildfire-prone U.S. regions*. Preprints. https://www.preprints.org/manuscript/202507.2505/v1
52. Rabbi, M. S. (2025). *Grid synchronization algorithms for intermittent renewable energy sources using AI control loops*. Preprints. https://www.preprints.org/manuscript/202507.2353/v1
53. Tonoy, A. A. R. (2025). *Condition monitoring in power transformers using IoT: A model for predictive maintenance*. Preprints. https://doi.org/10.20944/preprints202507.2379.v1
54. Tonoy, A. A. R. (2025). *Applications of semiconducting electrides in mechanical energy conversion and piezoelectric systems*. Preprints. https://doi.org/10.20944/preprints202507.2421.v1
55. Azad, M. A. (2025). *Lean automation strategies for reshoring U.S. apparel manufacturing: A sustainable approach*. Preprints. https://doi.org/10.20944/preprints202508.0024.v1
56. Azad, M. A. (2025). *Optimizing supply chain efficiency through lean Six Sigma: Case studies in textile and apparel manufacturing*. Preprints. https://doi.org/10.20944/preprints202508.0013.v1
57. Azad, M. A. (2025). *Sustainable manufacturing practices in the apparel industry: Integrating eco-friendly materials and processes*. TechRxiv. https://doi.org/10.36227/techrxiv.175459827.79551250/v1
58. Azad, M. A. (2025). *Leveraging supply chain analytics for real-time decision making in apparel manufacturing*. TechRxiv. https://doi.org/10.36227/techrxiv.175459831.14441929/v1
59. Azad, M. A. (2025). *Evaluating the role of lean manufacturing in reducing production costs and enhancing efficiency in textile mills*. TechRxiv. https://doi.org/10.36227/techrxiv.175459830.02641032/v1
60. Azad, M. A. (2025). *Impact of digital technologies on textile and apparel manufacturing: A case for U.S. reshoring*. TechRxiv. https://doi.org/10.36227/techrxiv.175459829.93863272/v1
61. Rayhan, F. (2025). *A hybrid deep learning model for wind and solar power forecasting in smart grids*. Preprints. https://doi.org/10.20944/preprints202508.0511.v1
62. Rayhan, F. (2025). *AI-powered condition monitoring for solar inverters using embedded edge devices*. Preprints. https://doi.org/10.20944/preprints202508.0474.v1
63. Rayhan, F. (2025). *AI-enabled energy forecasting and fault detection in off-grid solar networks for rural electrification*. TechRxiv. https://doi.org/10.36227/techrxiv.175623117.73185204/v1
64. Habiba, U., & Musarrat, R. (2025). Integrating digital tools into ESL pedagogy: A study on multimedia and student engagement.

  

*IJSRED – International Journal of Scientific Research and Engineering Development, 8*(2), 799–811. https://doi.org/10.5281/zenodo.17245996

65. Hossain, M. T., Nabil, S. H., Razaq, A., & Rahman, M. (2025). Cybersecurity and privacy in IoT-based electric vehicle ecosystems. *IJSRED – International Journal of Scientific Research and Engineering Development, 8*(2), 921–933. https://doi.org/10.5281/zenodo.17246184
66. Hossain, M. T., Nabil, S. H., Rahman, M., & Razaq, A. (2025). Data analytics for IoT-driven EV battery health monitoring. *IJSRED – International Journal of Scientific Research and Engineering Development, 8*(2), 903–913. https://doi.org/10.5281/zenodo.17246168
67. Akter, E., Bormon, J. C., Saikat, M. H., & Shoag, M. (2025). Digital twin technology for smart civil infrastructure and emergency preparedness. *IJSRED – International Journal of Scientific Research and Engineering Development, 8*(2), 891–902. https://doi.org/10.5281/zenodo.17246150
68. Rahmatullah, R. (2025). Smart agriculture and Industry 4.0: Applying industrial engineering tools to improve U.S. agricultural productivity. *World Journal of Advanced Engineering Technology and Sciences, 17*(1), 28–40. https://doi.org/10.30574/wjaets.2025.17.1.1377
69. Islam, R. (2025). *AI and big data for predictive analytics in pharmaceutical quality assurance.*. SSRN. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5564319
70. Rahmatullah, R. (2025). *Sustainable agriculture supply chains: Engineering management approaches for reducing post-harvest loss in the U.S. International Journal of Scientific Research and Engineering Development,* 8(5), 1187–1216. https://doi.org/10.5281/zenodo.17275907
71. Haque, S., Al Sany, S. M. A., & Rahman, M. (2025). *Circular economy in fashion: MIS-driven digital product passports for apparel traceability. International Journal of Scientific Research and Engineering Development,* 8(5), 1254–1262. https://doi.org/10.5281/zenodo.17276038
72. Al Sany, S. M. A., Haque, S., & Rahman, M. (2025). *Green apparel logistics: MIS-enabled carbon footprint reduction in fashion supply chains. International Journal of Scientific Research and Engineering Development,* 8(5), 1263–1272. https://doi.org/10.5281/zenodo.17276049
73. Bormon, J. C. (2025), Numerical Modeling of Foundation Settlement in High-Rise Structures Under Seismic Loading. Available at *SSRN*: https://ssrn.com/abstract=5472006 or http://dx.doi.org/10.2139/ssrn.5472006
74. Tabassum, M. (2025, October 6). *MIS-driven predictive analytics for global shipping and logistics optimization*. TechRxiv. https://doi.org/10.36227/techrxiv.175977232.23537711/v1
75. Tabassum, M. (2025, October 6). *Integrating MIS and compliance dashboards for international trade operations*. TechRxiv. https://doi.org/10.36227/techrxiv.175977233.37119831/v1
76. Zaman, M. T. U. (2025, October 6). *Predictive maintenance of electric vehicle components using IoT sensors. TechRxiv.* https://doi.org/10.36227/techrxiv.175978928.82250472/v1
77. Hossain, M. T. (2025, October 7). *Smart inventory and warehouse automation for fashion retail*. TechRxiv. https://doi.org/10.36227/techrxiv.175987210.04689809.v1
78. Karim, M. A. (2025, October 6). *AI-driven predictive maintenance for solar inverter systems*. TechRxiv. https://doi.org/10.36227/techrxiv.175977633.34528041.v1
79. Jahan Bristy, I. (2025, October 6). *Smart reservation and service management systems: Leveraging MIS for hotel efficiency*. TechRxiv. https://doi.org/10.36227/techrxiv.175979180.05153224.v1
80. Habiba, U. (2025, October 7). *Cross-cultural communication competence through technology-mediated TESOL*. TechRxiv. https://doi.org/10.36227/techrxiv.175985896.67358551.v1
81. Habiba, U. (2025, October 7). *AI-driven assessment in TESOL: Adaptive feedback for personalized learning*. TechRxiv. https://doi.org/10.36227/techrxiv.175987165.56867521.v1
82. Akhter, T. (2025, October 6). *Algorithmic internal controls for SMEs using MIS event logs*. TechRxiv. https://doi.org/10.36227/techrxiv.175978941.15848264.v1
83. Akhter, T. (2025, October 6). *MIS-enabled workforce analytics for service quality & retention*. TechRxiv. https://doi.org/10.36227/techrxiv.175978943.38544757.v1
84. Hasan, E. (2025, October 7). *Secure and scalable data management for digital transformation in finance and IT systems*. Zenodo. https://doi.org/10.5281/zenodo.17202282
85. Saikat, M. H., Shoag, M., Akter, E., Bormon, J. C. ( October 06, 2025.) Seismic- and Climate-Resilient Infrastructure Design for Coastal and Urban Regions. *TechRxiv*. DOI: 10.36227/techrxiv.175979151.16743058/v1
86. Saikat, M. H. (October 06, 2025). AI-Powered Flood Risk Prediction and Mapping for Urban Resilience. *TechRxiv*. DOI: 10.36227/techrxiv.175979253.37807272/v1
87. Akter, E. (September 15, 2025). Sustainable Waste and Water Management Strategies for Urban Civil Infrastructure. Available at SSRN: https://ssrn.com/abstract=5490686 or http://dx.doi.org/10.2139/ssrn.5490686
88. Karim, M. A., Zaman, M. T. U., Nabil, S. H., & Joarder, M. M. I. (2025, October 6). *AI-enabled smart energy meters with DC-DC converter integration for electric vehicle charging systems.* TechRxiv. https://doi.org/10.36227/techrxiv.175978935.59813154/v1
89. Al Sany, S. M. A., Rahman, M., & Haque, S. (2025). *Sustainable garment production through Industry 4.0 automation. World Journal of Advanced Engineering Technology and Sciences, 17*(1), 145–156. https://doi.org/10.30574/wjaets.2025.17.1.1387
90. Rahman, M., Haque, S., & Al Sany, S. M. A. (2025). *Federated learning for privacy-preserving apparel supply chain analytics. World Journal of Advanced Engineering Technology and Sciences, 17*(1), 259–270. https://doi.org/10.30574/wjaets.2025.17.1.1386
91. Rahman, M., Razaq, A., Hossain, M. T., & Zaman, M. T. U. (2025). *Machine learning approaches for predictive maintenance in IoT devices. World Journal of Advanced Engineering Technology and Sciences, 17*(1), 157–170. https://doi.org/10.30574/wjaets.2025.17.1.1388
92. Akhter, T., Alimozzaman, D. M., Hasan, E., & Islam, R. (2025, October). *Explainable predictive analytics for healthcare decision support. International Journal of Sciences and Innovation Engineering,* 2(10), 921–938. https://doi.org/10.70849/IJSCI02102025105
93. Islam, M. S., Islam, M. I., Mozumder, A. Q., Khan, M. T. H., Das, N., & Mohammad, N. (2025). A Conceptual Framework for Sustainable AI-ERP Integration in Dark Factories: Synthesising TOE, TAM, and IS Success Models for Autonomous Industrial Environments. *Sustainability*, *17*(20), 9234. https://doi.org/10.3390/su17209234
94. Haque, S., Islam, S., Islam, M. I., Islam, S., Khan, R., Tarafder, T. R., & Mohammad, N. (2025). *Enhancing adaptive learning, communication, and therapeutic accessibility through the integration of artificial intelligence and data-driven personalization in digital health platforms for students with autism spectrum disorder. Journal of Posthumanism, 5*(8), 737–756. Transnational Press London.
95. Faruq, O., Islam, M. I., Islam, M. S., Tarafder, M. T. R., Rahman, M. M., Islam, M. S., & Mohammad, N. (2025). Re-imagining Digital Transformation in the United States: Harnessing Artificial Intelligence and Business Analytics to Drive IT Project Excellence in the Digital Innovation Landscape. *Journal of Posthumanism*, *5*(9), 333–354 . https://doi.org/10.63332/joph.v5i9.3326
96. Rahman, M.. (October 15, 2025) Integrating IoT and MIS for Last-Mile Connectivity in Residential Broadband Services. *TechRxiv*. **DOI: 10.36227/techrxiv.176054689.95468219/v1**
97. **Islam, R.** (2025, October 15). *Integration of IIoT and MIS for smart pharmaceutical manufacturing* . TechRxiv. https://doi.org/10.36227/techrxiv.176049811.10002169
98. Hasan, E. (2025). Big Data-Driven Business Process Optimization: Enhancing Decision-Making Through Predictive Analytics. TechRxiv. October 07, 2025. **10.36227/techrxiv.175987736.61988942/v1**

  

99. **Rahman, M.** (2025, October 15). *IoT-enabled smart charging systems for electric vehicles* [Preprint]. TechRxiv. https://doi.org/10.36227/techrxiv.176049766.60280824
100. Alam, M. S. (2025, October 21). *AI-driven sustainable manufacturing for resource optimization*. *TechRxiv*. https://doi.org/10.36227/techrxiv.176107759.92503137/v1
101. Alam, M. S. (2025, October 21). *Data-driven production scheduling for high-mix manufacturing environments*. *TechRxiv*. https://doi.org/10.36227/techrxiv.176107775.59550104/v1
102. Ria, S. J. (2025, October 21). *Environmental impact assessment of transportation infrastructure in rural Bangladesh*. *TechRxiv*. https://doi.org/10.36227/techrxiv.176107782.23912238/v1
103. R Musarrat and U Habiba, Immersive Technologies in ESL Classrooms: Virtual and Augmented Reality for Language Fluency (September 22, 2025). Available at SSRN: https://ssrn.com/abstract=5536098 or http://dx.doi.org/10.2139/ssrn.5536098
104. Akter, E., Bormon, J. C., Saikat, M. H., & Shoag, M. (2025), "AI-Enabled Structural and Façade Health Monitoring for Resilient Cities", *Int. J. Sci. Inno. Eng.*, vol. 2, no. 10, pp. 1035–1051, Oct. 2025, doi: 10.70849/IJSCI02102025116
105. Haque, S., Al Sany (Oct. 2025), "Impact of Consumer Behavior Analytics on Telecom Sales Strategy", *Int. J. Sci. Inno. Eng.*, vol. 2, no. 10, pp. 998–1018, doi: 10.70849/IJSCI02102025114.
106. Sharan, S. M. I (Oct. 2025)., "Integrating Human-Centered Design with Agile Methodologies in Product Lifecycle Management", *Int. J. Sci. Inno. Eng.*, vol. 2, no. 10, pp. 1019–1034, doi: 10.70849/IJSCI02102025115.
107. Alimozzaman, D. M. (2025). Explainable AI for early detection and classification of childhood leukemia using multi-modal medical data. *World Journal of Advanced Engineering Technology and Sciences*, *17*(2), 48–62. https://doi.org/10.30574/wjaets.2025.17.2.1442
108. Alimozzaman, D. M., Akhter, T., Islam, R., & Hasan, E. (2025). Generative AI for synthetic medical imaging to address data scarcity. *World Journal of Advanced Engineering Technology and Sciences,* *17*(1), 544–558. https://doi.org/10.30574/wjaets.2025.17.1.1415
109. Zaidi, S. K. A. (2025). Intelligent automation and control systems for electric vertical take-off and landing (eVTOL) drones. *World Journal of Advanced Engineering Technology and Sciences, 17*(2), 63–75. https://doi.org/10.30574/wjaets.2025.17.2.1457
110. Islam, K. S. A. (2025). Implementation of safety-integrated SCADA systems for process hazard control in power generation plants. *IJSRED – International Journal of Scientific Research and Engineering Development, 8*(5), 2321–2331. Zenodo. https://doi.org/10.5281/zenodo.17536369
111. Islam, K. S. A. (2025). Transformer protection and fault detection through relay automation and machine learning. *IJSRED – International Journal of Scientific Research and Engineering Development,* *8*(5), 2308–2320. Zenodo. https://doi.org/10.5281/zenodo.17536362
112. Afrin, S. (2025). Cloud-integrated network monitoring dashboards using IoT and edge analytics. *IJSRED – International Journal of Scientific Research and Engineering Development, 8*(5), 2298–2307. Zenodo. https://doi.org/10.5281/zenodo.17536343
113. Al Sany, S. M. A. (2025). The role of data analytics in optimizing budget allocation and financial efficiency in startups. *IJSRED – International Journal of Scientific Research and Engineering Development,* *8*(5), 2287–2297. Zenodo. https://doi.org/10.5281/zenodo.17536325
114. Zaman, S. (2025). Vulnerability management and automated incident response in corporate networks. *IJSRED – International Journal of Scientific Research and Engineering Development, 8*(5), 2275–2286. Zenodo. https://doi.org/10.5281/zenodo.17536305
115. Ria, S. J. (2025, October 7). *Sustainable construction materials for rural development projects.* SSRN. https://doi.org/10.2139/ssrn.5575390
116. Razaq, A. (2025, October 15). *Design and implementation of renewable energy integration into smart grids.* TechRxiv. https://doi.org/10.36227/techrxiv.176049834.44797235/v1
117. Musarrat R. (2025). AI-Driven Smart Housekeeping and Service Allocation Systems: Enhancing Hotel Operations Through MIS Integration. In IJSRED - International Journal of Scientific Research and Engineering Development (Vol. 8, Number 6, pp. 898–910). Zenodo. https://doi.org/10.5281/zenodo.17769627
118. Hossain, M. T. (2025). AI-Augmented Sensor Trace Analysis for Defect Localization in Apparel Production Systems Using OTDR-Inspired Methodology. In IJSRED - International Journal of Scientific Research and Engineering Development (Vol. 8, Number 6, pp. 1029–1040). Zenodo. https://doi.org/10.5281/zenodo.17769857
119. Rahman M. (2025). Design and Implementation of a Data-Driven Financial Risk Management System for U.S. SMEs Using Federated Learning and Privacy-Preserving AI Techniques. In IJSRED - International Journal of Scientific Research and Engineering Development (Vol. 8, Number 6, pp. 1041–1052). Zenodo. https://doi.org/10.5281/zenodo.17769869
120. Alam, M. S. (2025). Real-Time Predictive Analytics for Factory Bottleneck Detection Using Edge-Based IIoT Sensors and Machine Learning. In IJSRED - International Journal of Scientific Research and Engineering Development (Vol. 8, Number 6, pp. 1053–1064). Zenodo. https://doi.org/10.5281/zenodo.17769890
121. Habiba, U., & Musarrat, R. (2025). Student-centered pedagogy in ESL: Shifting from teacher-led to learner-led classrooms. *International Journal of Science and Innovation Engineering*, 2(11), 1018–1036. https://doi.org/10.70849/IJSCI02112025110
122. Zaidi, S. K. A. (2025). Smart sensor integration for energy-efficient avionics maintenance operations. *International Journal of Science and Innovation Engineering*, 2(11), 243–261. https://doi.org/10.70849/IJSCI02112025026
123. Farooq, H. (2025). Cross-platform backup and disaster recovery automation in hybrid clouds. *International Journal of Science and Innovation Engineering*, 2(11), 220–242. https://doi.org/10.70849/IJSCI02112025025
124. Farooq, H. (2025). Resource utilization analytics dashboard for cloud infrastructure management. *World Journal of Advanced Engineering Technology and Sciences*, 17(02), 141–154. https://doi.org/10.30574/wjaets.2025.17.2.1458
125. Saeed, H. N. (2025). Hybrid perovskite–CIGS solar cells with machine learning-driven performance prediction. *International Journal of Science and Innovation Engineering*, 2(11), 262–280. https://doi.org/10.70849/IJSCI02112025027
126. Akter, E. (2025). Community-based disaster risk reduction through infrastructure planning. *International Journal of Science and Innovation Engineering*, 2(11), 1104–1124. https://doi.org/10.70849/IJSCI02112025117
127. Akter, E. (2025). Green project management framework for infrastructure development. *International Journal of Science and Innovation Engineering*, 2(11), 1125–1144. https://doi.org/10.70849/IJSCI02112025118
128. Shoag, M. (2025). Integration of lean construction and digital tools for façade project efficiency. *International Journal of Science and Innovation Engineering*, 2(11), 1145–1164. https://doi.org/10.70849/IJSCI02112025119
129. Akter, E. (2025). Structural Analysis of Low-Cost Bridges Using Sustainable Reinforcement Materials. In IJSRED - International Journal of Scientific Research and Engineering Development (Vol. 8, Number 6, pp. 911–921). Zenodo. https://doi.org/10.5281/zenodo.17769637
130. Razaq, A. (2025). Optimization of power distribution networks using smart grid technology. *World Journal of Advanced Engineering Technology and Sciences*, 17(03), 129–146. https://doi.org/10.30574/wjaets.2025.17.3.1490
131. Zaman, M. T. (2025). Enhancing grid resilience through DMR trunking communication systems. *World Journal of Advanced Engineering Technology and Sciences*, 17(03), 197–212. https://doi.org/10.30574/wjaets.2025.17.3.1551
132. Nabil, S. H. (2025). Enhancing wind and solar power forecasting in smart grids using a hybrid CNN-LSTM model for improved grid stability and renewable energy integration. *World Journal of Advanced Engineering Technology and Sciences*, 17(03), 213–226. https://doi.org/10.30574/wjaets.2025.17.3.155

133. Nahar, S. (2025). Optimizing HR management in smart pharmaceutical manufacturing through IIoT and MIS integration. *World Journal of Advanced Engineering Technology and Sciences*, 17(03), 240–252. https://doi.org/10.30574/wjaets.2025.17.3.1554
134. Islam, S. (2025). IPSC-derived cardiac organoids: Modeling heart disease mechanism and advancing regenerative therapies. *World Journal of Advanced Engineering Technology and Sciences*, 17(03), 227–239. https://doi.org/10.30574/wjaets.2025.17.3.1553

  