

AI-Driven Smart Construction: Digitalization of Design, Management, and Monitoring of Residential Construction Projects in Palestine

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Abstract— The construction industry worldwide is adopting artificial intelligence (AI) tools. However, in developing countries, especially Palestine, challenges such as weak IT infrastructure, fragmented workflow, manual processes, and bureaucratic delays, hinder AI adoption in the residential construction sector. This study examines the traditional practices across the design, permitting, execution, and monitoring phases of residential projects. It then explores the potential of using AI tools at each phase, including generative AI design systems, predictive procurement models, Automated permit review algorithms. These tools can improve design accuracy, speed up approvals, improve resource planning, reduce execution errors, shorten project duration and lower cost. This paper proposes a practical framework for using AI tools in lower- resource settings. It shows that integrating stakeholders and contractors through AI-based system is feasible and essential for achieving accurate, efficient, timely, and sustainable construction. The success in modernization of this sector depends on advancing digital infrastructure, regulatory reform, and skilled human capital.

I. INTRODUCTION

The construction and civil engineering sectors have been greatly impacted by the recent advancements in artificial intelligence (AI), which offer benefits for every stage of a project, from planning and design to monitoring and execution. These technologies are instrumental in achieving resource efficiency, improving performance, reducing project costs, fast-tracking safety procedures, and improving project efficiency. The widespread advantages of the rapid advancements of AI technologies and tools have been discussed in several studies, for instance, Gill et al. (2024) revealed that upon incorporating AI into project management, the team noticed the significant improvement in the project performance due to the use of AI tools. Regona et al. (2024) affirm that AI is critical in the successful achievement of sustainability and efficiency in the construction sector. AI provides maximum productivity and transforms construction by implementing automation and optimizing processes. With technology fundamentally reshaping the industry in many ways, AI allows for the development of intelligent construction systems that can make real time decisions to prevent risks before they happen and use resources effectively.

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The revolution is especially important in building homes, where affordability, safety, and timeliness are extremely critical.

The transformative potential of AI in modernizing abilities in construction sectors in analytics, productivity, and sustainability is profound. AI will increasingly be integral in modernizing construction, especially with growing project complexity. Since the traditional methods of managing the construction project phases fail when confronted with fragmented data and rigid workflows, whereas AI bridges this gap through data integration, automated, decision, and cross-disciplinary collaboration (Abioye et al., 2021). As the notations of smart infrastructure and climate resilience become the backbone of discourse, AI enables designs that are data-driven, material efficient, and geared towards predictive maintenance for long-term sustainability (Pan & Zhang, 2021). Collectively, this demonstrates that AI should not be viewed as an opportunity for mere technological enhancement, but as the very foundation of future-ready construction practices.

II. LITERATURE REVIEW

Artificial Intelligence is gaining more attention in construction engineering. AI refers to systems that mimic and exceed human cognitive abilities. Its applications range from simple rule-based algorithms to advanced deep learning models that enhance decision-making and operational efficiency across the sector (Booch et al., 2021). Li et al. (2024) explored a broad set of AI methods – including neural networks to evolutionary algorithms, fuzzy logic, and expert systems - now recognized for their effectiveness in solving complex engineering problems. These tools can be used to support design, project management, and decision-making under different uncertainty conditions.

Building on this groundwork, several studies have expanded the applications of AI in construction. Huang et al. (2019) demonstrated the value of machine learning and deep learning in structural maintenance and adaptive design. Xu and Guo (2025) extended AI use to lifecycle management of smart infrastructure, Khan (2025) emphasized the important role of AI in structural health monitoring and real-time site surveillance. In construction project management, AI plays a key role in cost estimation, procurement forecasting, and risk mitigation. Gebregiorgis Atnafie (2025) demonstrated that

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hybrid machine learning models improve the accuracy of material cost predictions and procurement scheduling. Wang et al. (2021a) found that AI methods support resource planning and help reduce budget overruns. Kamari & Ham (2022) explored the use of generative AI and digital twins in disaster risk and safety planning.

Most existing studies come from resource-abundant regions, while limited attention has been given to how AI technologies can be applied in resource-poor regions. This gap is critical in residential construction, where system limitations are evident due to a significant lack of data.

Recent studies have started to address this gap by focusing on developing contexts. For instance, Dele Owolabi et al. (2022) surveyed AI awareness and usage in Nigeria's construction industry, reporting moderate adoption – mainly in design and cost estimation using tools like Building Information Modeling (BIM) software. However, their study remains exploratory and limited to professional perceptions. This research takes a more targeted approach by specifically examining the use of AI in the design, approvals, and execution phases of housing project in Nigeria. This research introduces a practical recommendation for adoption of AI in environments with poor infrastructure and resources. Omrany et al. (2023) addressed BIM technology adoption in developing countries by introducing AI-based methods to improve the use of limited local resources. Mirjalili et al. (2023) investigated machine learning models for neighborhood-scale energy prediction and demonstrated the significant impact of deep learning on distributed energy systems.

Further literature focused on the roles of AI in safety and environmental sustainability. Regona et al. (2024) explored the benefits of AI in achieving the Sustainable Development Goals (SDGs), especially in water conservation, adaptability, and emission curtailment. Elrifae et al. (2025) examined the integration of AI tools and Internet of Things (IoT) technology to develop a real-time safety monitoring. Harle, S. M. (2024) pointed out challenges that cannot be resolved with AI alone – such as data inconsistency, lack of accountability, and inadequate interdisciplinary cooperation in civil engineering.

Although AI has advanced across the global construction sector, its adoption in Palestinian residential sector remains notably limited. The construction industry in Palestine has historically been slow to embrace new technologies and current research rarely addresses these specific local conditions. As a result, key areas such as design, project management, and real-time monitoring are still underdeveloped, limiting AI's impact in this crucial sector.

This study addresses that gap by exploring practical, context-sensitive strategies for integrating AI across three key phases of residential construction:

1. Integration of AI in design, planning, and execution phases.
2. Use of AI for automated, data-driven marketing and housing sales.
3. AI-based systems for real-time project monitoring and public safety.

Given the technological and regulatory constraints in this sector, this research offers a timely contribution. The analysis is tailored to Palestinian institutional and aims to support a transition towards smarter, more efficient, environmentally responsible construction practices.

III. AI-DRIVEN SMART CONSTRUCTION IN PALESTINE

In this section, an AI-driven smart construction model in Palestine has been proposed. The smart model is developed through digitalization of the traditional construction phases. Therefore, the traditional methods have been reviewed through direct contact with several Palestinian authority such as the Ministry of Local Government, the Engineers' Syndicate (PES), and municipal authorities in several Palestinian cities to gather information on traditional workflows. These resources provide insights into infrastructure constraints, procedural inefficiencies, and current regulatory practices.

This methodology enables us to propose an effective and realistic smart construction AI-enhanced approach across the three key construction phases:

1. Conception and Design
2. Planning, Permitting & Preconstruction
3. Procurement, Construction & Post-construction

In the following sections, a comparative analysis of each phase — before and after AI integration — is presented, with a focus on efficiency, regulatory alignment, and implementation feasibility:

A. *Conception and Design*

The traditional design phase in Palestinian construction relies on manual processes—land assessment, plan development, and coordination with engineers—conducted through physical meetings and hard-copy submissions. This limits early coordination with authorities and delays efficient design validation. Generative design models including both Generative Adversarial Networks (GANs) and evolutionary algorithms can assist a next-generation design phase by delivering site-specific, optimized outcomes that advance functionality and creativity (Tellios et al., 2023). Similarly using AI based structural analysis can foster safety improvements, particularly in earthquake prone areas (Huang et al., 2019).

The effective use of these tools is hampered by local limitations, examples include a lack of digital infrastructure, a lack of adoption of BIM, and a lack of AI expertise (Ujaimi et al., 2024). However, research indicates that when combined with digital readiness, AI decreases repetitive tasks, increases efficiency, and improves drawing accuracy (Regona et al., 2024). Investment in digital platforms and skill development are necessary to achieve this in Palestine (Ujaimi et al., 2024). On the other hand, AI-enabled BIM reduces redesign cycles by enabling automated code compliance and spatial optimization (Naji et al., 2024). Smart decisions in limited housing projects are facilitated by neural networks, which support early predictions of construction costs and energy performance (Wang et al., 2021). Fig. 1 depicts the proposed digital transformation process of the traditional conception and design phase processes through the AI techniques.

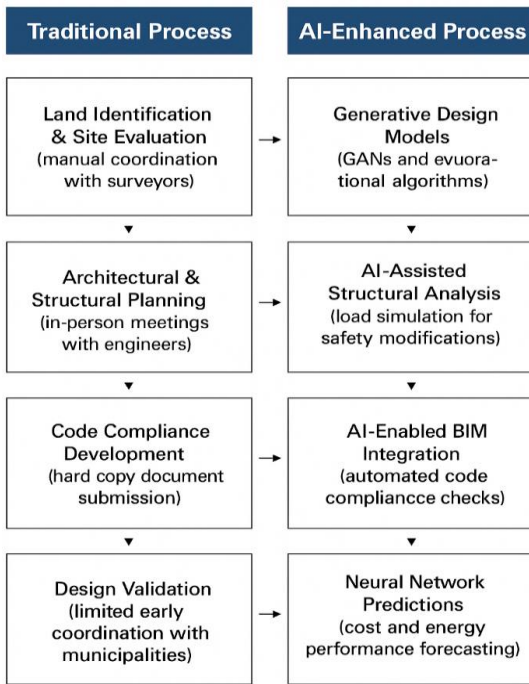


Figure 1. Digitization of traditional conception and design phase through AI-driven tools

B. Planning, Building Permits and Preconstruction

Traditionally, finalized designs are manually submitted for multi-agency certification and municipal permits, which cover zoning, fire safety, and land use, in the Palestinian construction workflow. This process frequently takes more than 100 days because of bureaucratic hold-ups. Important documents, such as soil reports and title deeds, are managed in hard copy, and supervising engineers organize stakeholder coordination and site preparations offline.

In contrast, AI technologies streamline this phase through intelligent scheduling based on reinforcement learning and past data, improving resource efficiency and shortening timelines (Shema & Abdulmalik, 2024). Natural language processing tools automate permit reviews, accelerating compliance checks and reducing errors (Ruiz et al., 2023). Neural networks offer accurate, market-specific cost forecasts (Wang et al., 2021), while AI-powered digital twins simulate risks—like weather or safety threats—using GIS-integrated data now utilized by Palestinian authorities (Kamari & Ham, 2022). These tools collectively enhance transparency and planning precision in preconstruction stages. Fig. 2 presents the digitalization process of traditional planning, building permits and preconstruction phase through proposing the most appropriate AI tools.

C. Procurement, Construction and Post-Construction

In Palestine, contractor selection often occurs through informal bidding or direct agreements, without centralized procurement systems. Licensed engineers oversee construction to ensure regulatory compliance, while permits—such as for concrete casting—are obtained via manual coordination with entities like PES and municipalities. Site inspections and final certifications (e.g., fire safety, occupancy) are handled on paper, resulting in communication gaps and project delays.

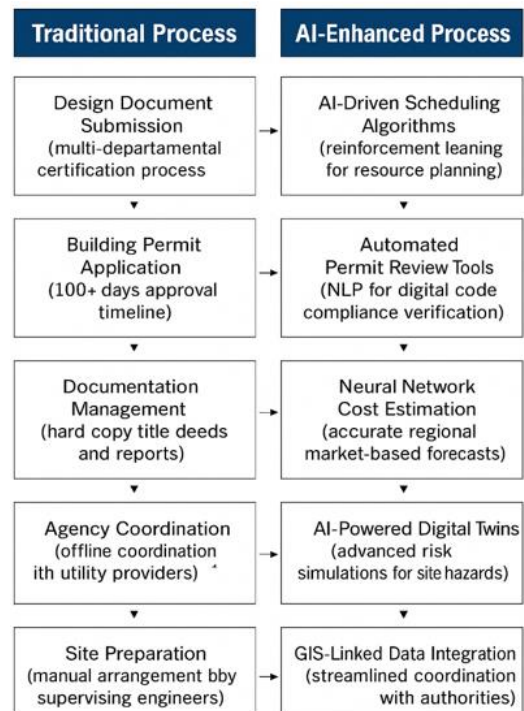


Figure 2. Digitization of traditional planning, building permits, and preconstruction phase through AI-driven tools

The planning and permitting stage are similarly hindered by bureaucratic fragmentation and the absence of integrated digital systems. Regulatory frameworks have not yet accommodated AI tools in preconstruction workflows (Demaidi, 2023), and siloed government databases further obstruct permit streamlining. However, successful models in similar low-resource settings—like Syria’s AI-BIM smart permitting platform—demonstrate efficiency gains and error reduction (Mohamed et al., 2025). Globally, AI-driven predictive tools help anticipate delays and budget issues before construction begins (Wang et al., 2021). Realizing such benefits in Palestine requires upgrades in infrastructure, regulation, and training (Ujaimi et al., 2024).

In contrast, AI-powered procurement forecasting uses hybrid neural networks to anticipate price shifts and optimize timing, helping developers mitigate risks from currency instability or border disruptions (Gebregiorgis Atnafie, 2025). Supply chain optimization tools further streamline logistics and assess supplier reliability—aligning with Palestine’s gradual move toward e-procurement, especially in donor-backed housing projects (Castro Pena et al., 2021). However, implementing AI tools fully requires capacity-building, standardized data systems, and interoperability, which can be achieved through public-private partnerships and coordinated training programs (Naji et al., 2024).

Fig. 3 illustrates the digitalization process of conventional procurement, construction and post-construction phase through using proposing the appropriate AI tool to enhance each process.

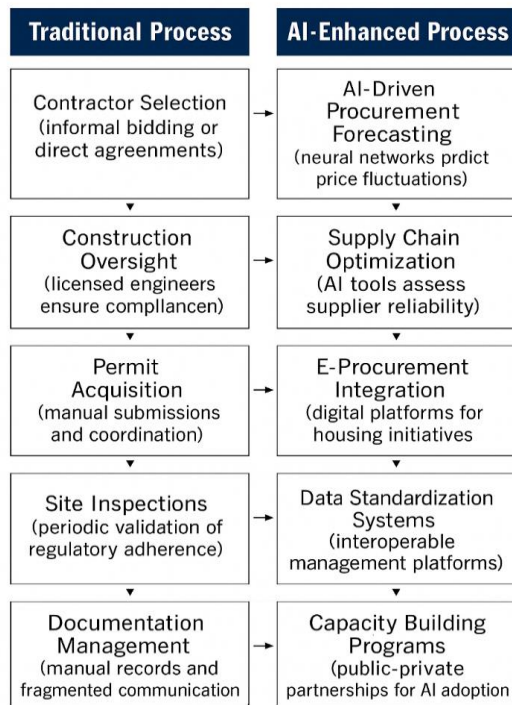


Figure 3. Digitization of traditional procurement, construction, and Post-construction phase through AI-driven tools.

Using AI-driven tools in the digitalization process of construction project phases can substantially improve the overall efficiency, accuracy, and performance of construction project. Through integrating AI into various construction projects stages, companies can reduce time, minimize cost, and improve the quality of project deliverables. Based on several studies, Table 1 provides an overview of the average improvement percentages achieved through the adoption of AI tools across different construction phases and activities. Sholeh et al. (2020) demonstrated that integration of AI-driven tools in the design phase reduces design time by 50% and planning cost by 52.4% through automation of repetitive tasks and support faster decision-making process. Abdelbary et al. (2020) reported that using BIM integrated with AI reduces rework and orders changes by approximately 48% by addressing a major cause of cost overruns and delays. In the BRISE-Vienna digitization project, permit and approval times dropped by 50%. Alnaser et al. (2023) reported a 14.6% reduction in schedule delays.

TABLE 1. THE IMPACT OF AI INTEGRATION ON CONSTRUCTION PROJECTS

Comparison Criteria metric	Traditional Implementation	With AI	Improvement (%)
Design phase duration	120 days	60 days	50%
Planning cost	\$100,000	\$47,640	52.36%
Rework / change orders	20 instances	10 instances	~48%
Permit / approval time	100 days	50 days	Up to 50%
Schedule delay (overall)	30 days delay	25.6 days delay	14.55%

IV. CASES STUDY: AI-DRIVEN DIGITALIZATION IN AL-QUDS HOUSING COMPANY

AI-Quds housing company is a med-sized Palestinian real estate development company, completed a 48-unit affordable housing complex in Al-Bireh, Ramallah, in 2024. Past projects faced delays due to poor communication, slow permitting, and long procurement processes. Similar initiatives often took over a year to start.

After reviewing the potential applications of AI tools in construction, the company adopted an AI-based digitalization strategy to streamline design, approvals, and implementation, despite Palestine's limited digital infrastructure.

The AI-based digitalization strategy was divided into three phases, as follows:

➔ Phase 1: Concept and Design

- *Traditional process:* Paper-based land evaluations and manual CAD designs caused significant delays.
- *AI integration:*
 - Using generative design algorithms through GANs to generate multiple building layout options, optimize designs for sunlight, seismic safety, and airflow and ventilation. And finally, to create realistic visualizations before building.
 - Using AI-powered BIM for automated code compliance checks and reduced redesign time by 35%.
 - Using Neural networks for predicting early-stage energy efficiency, enabling informed sustainable design choices.

➔ Phase 2: Permitting and Pre-Construction

- *Traditional process:* Paper submissions to multiple agencies, with in-person reviews, took about 110 days for licensing.
- *AI integration:*
 - Using NLP models verified zoning and safety compliance, cutting municipal review time to 45 days.
 - Using Reinforcement learning optimized sequencing of soil testing, equipment delivery, and foundation work, reducing pre-construction delays by 25%.
 - Using GIS-linked digital twin simulated weather challenges, enabling proactive mitigation planning.

➔ Phase 3: Procurement, Construction, and Quality Control

- *Traditional process:* Contractor selection without formal procedures, manual tracking of material deliveries, and paper-based inspections slowed progress and increased errors.
- *AI integration:*
 - Machine learning models scored contractor bids based on historical performance, safety records, and delivery reliability.
 - Computer vision monitored construction site activities in real time, flagging deviations from safety protocols and design specs.
 - Automated inventory management systems tracked material deliveries and usage, reducing shortages and overstocking.

This project demonstrates the practical impact of AI in overcoming bureaucratic and operational bottlenecks in Palestinian construction projects. However, there are several challenges that hinder its implementation and full utilization of its capabilities. The primary challenges consist of dispersed and scarce data, high implementation costs, a shortage of skilled personnel and AI experts, inadequate infrastructure, and resistance to change.

V. CONCLUSION

This study examines the potential of AI to fundamentally enhance the three principal phases of construction in Palestine, namely: conception and design, planning and permitting, and procurement and execution. Based on the data collected, ultimately AI will not simply be a technological evolution, it will significantly improve how businesses manage projects, minimize or avoid unnecessary delays, and enhance compliance. Tools such as digital twins, neural networks, and generative design models show genuine potential to improve design accuracy, resource optimization, project cost forecasting, and risk identification in real-time (Siva Praneeth Reddy Gudibandi, 2025). The use of e-permitting platforms, compulsory requirements for BIM in public tender selections, and e-procurement initiatives are all indicators of growing institutional support. Nevertheless, structural issues, such as fragmented data, poor digital infrastructure, and a lack of trained workforce remain (Mostafa et al., 2023).

A well-coordinated reform strategy is necessary to transition from pilot projects to broad implementation. This entails investing in workforce training and applied research, growing digital infrastructure, and modernizing legal frameworks to accommodate automated permitting and AI-enabled compliance systems. In order to create AI models that are contextually relevant and based on local datasets and practices, public-private partnerships should be utilized. According to earlier research, funding AI-specific R&D helps create better forecasting models, which in turn allows for more precise cost and schedule estimates in the building industry (Juan & Liou, 2022). Complementing these efforts, countless emerging technologies, from UAVs, sensors, operative power systems, when tailored to suit specific disruption scenarios, have proven effective in optimizing infrastructure resilience by faster monitoring and recovery times (Soga et al., 2025).

This illustrates the larger trend of AI and machine learning—the paper touches on energy efficiency in smart buildings—as the techniques for modernizing infrastructure. Local data undergirding AI development, then, must be gathered and invested in to achieve more precise prediction models that improve efficiency and resilience in construction and building industry (Ghasemkhani et al., 2022).

These actions are essential to building a robust, technologically enabled construction ecosystem that fits Palestine's resource limitations and development objectives.

Although this study provides a thorough conceptual basis, it is important to recognize its limitations. The models examined are primarily designed for high-resource contexts, and the analysis excludes empirical evaluations of AI implementation in ongoing Palestinian projects. Furthermore, important aspects like data interoperability, institutional

preparedness, and resistance to digital transformation are still not adequately addressed. Future research should focus on applied case studies in local municipalities, evaluate stakeholder capacity, and create AI applications trained on data sourced locally in order to further this agenda. Additionally, investigating AI's potential for humanitarian housing and post-conflict reconstruction could offer highly effective avenues for innovation in settings with limited resources.

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