JOURNAL OF RESILIENT ECONOMIES

PLATINUM OPEN ACCESS

Journal homepage: https://journals.jcu.edu.au/jre/index

Digital Shift in Construction in Australia: Unlocking Potentials with AI and Blockchain

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Abstract

For any country, the construction industry forms the backbone of economic growth and development. In recent times, Australian construction sector has been struggling to keep up with the increasing demands of economic growth. Being one of the least digitalised industries, the construction industry faces myriad challenges, including inaccurate cost efficiencies, labour shortages, poor quality management, and limited visibility to all the stakeholders. The advancement of digital technologies such as Artificial Intelligence (AI) and Blockchain has proven to be transformational in other sectors such as finance and banking. This research paper examines the benefits of Artificial Intelligence (AI) and blockchain throughout the different phases of the construction project lifecycle. The adoption of AI is met with resistance from leadership and a sceptic approach from users. The role of leadership becomes pivotal in the widespread adoption of AI, thus changing users' attitudes from "resistance to change" to "receptiveness to change." Furthermore, various management strategies and recommendations have been discussed in detail to help the leadership teams to accelerate the digital transformation in the Australian construction industry.

Keywords: Artificial Intelligence (AI), Blockchain, Construction Industry, Leadership, Digital Transformation, Digital Leadership

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DOI: https://doi.org/10.25120/jre.4.2.2024.4155

1. Introduction

In Australia, the construction industry employs over U$169 billion worth of work and contributes to 10% of the gross domestic product (GDP), making it the fifth largest economy in the nation, according to the International Trade Administration. Australia's construction sector encompasses numerous activities, including civil infrastructure, residential building, commercial construction, and specialised sectors such as mining infrastructure and public utilities. In recent years, government-led initiatives have further fuelled growth, with large-scale investments in transportation networks, urban development, and energy infrastructure.

Despite its rapid growth, the construction industry in Australia faces a myriad of challenges, including inaccurate cost efficiencies, labour shortages and, poor quality management and limited visibility to all the stakeholders. According to the Australian Securities and Investments Commission (ASIC), these issues have led to cost overruns and a 42% increase in insolvencies within this sector. These persistent issues have caused concern among industry stakeholders.

As a sector responsible for shaping the nation's infrastructure and housing, it plays a pivotal role in ensuring economic stability. However, productivity in the construction industry has increased by only 1% annually in the last twenty years, raising concerns about the sector's overall efficiency. In an age where digital transformation is reshaping multiple industries, it is clear that the construction industry must adopt new technologies to overcome its challenges and maintain competitiveness. A leading digital innovation, Artificial Intelligence (AI) and blockchain has made significant contributions in recent years, improving business operations, service processes, and overall industry productivity. (Massimo Regona, 2022)

A considerable amount of research has been made into AI and blockchain applications in construction, with a focus on using AI and its subfields to address industry-specific challenges. Despite the recognised potential of these applications, construction has remained one of the least innovative sectors, experiencing limited productivity and growth. (Chui, 2017)

Numerous studies identify several barriers to adoption, including, high initial costs, cultural resistance, and concerns about trust and safety, shortages of skilled personnel, and limitations in computing power and internet connectivity. Several studies also underscore the critical role of leadership, which has driven calls for more robust technological solutions, especially through digital transformation initiatives, to modernise construction practices, improve project outcomes, and optimise resources. However, significant uncertainties remain regarding the application of AI and blockchain in various construction processes, as well as the future opportunities and challenges that must be addressed to encourage widespread adoption in the industry.

To address the uncertainties in the applications of AI and blockchain technology in the construction industry, This paper explores the following:

(1) How each stage of the construction project lifecycle can be enhanced by these technologies. These innovations have the potential to improve project management, optimise supply chains, and increase safety. Furthermore, the use of smart contracts can enhance transparency, security, and trust, mitigating issues such as fraud, payment disputes, and data silos. Ultimately, these advancements help address challenges related to cost overruns in construction projects.

(2) The role of leadership in facilitating digital transformation involves embracing, adopting, and utilising new innovations. However, the slow progress of digital transformation is often hindered by resistance to change, including three key factors: commitment from executives, active involvement and integration, and the establishment of training to develop necessary competencies.

2. Literature Review

2.1 AI & Blockchain Concepts in the Construction Industry

The definition of AI given by E. Rich, K. Knight refers to "tasks that can be performed automatically using autonomous mechanical and electronic devices with intelligent control." AI consists of key components such as learning, knowledge representation, perception, planning, action, and communication. In the construction industry, AI applications are divided into several subfields, including machine learning, computer vision, natural language processing, knowledge-based systems, optimisation, robotics, and automated planning and scheduling.

Figure 1 demonstrates the major subfields of AI in construction: (a) machine learning; (b) knowledge-based systems; (c) computer vision; (d) robotics; (e) natural language processing; (f) automated planning and scheduling, and (g) optimisation.

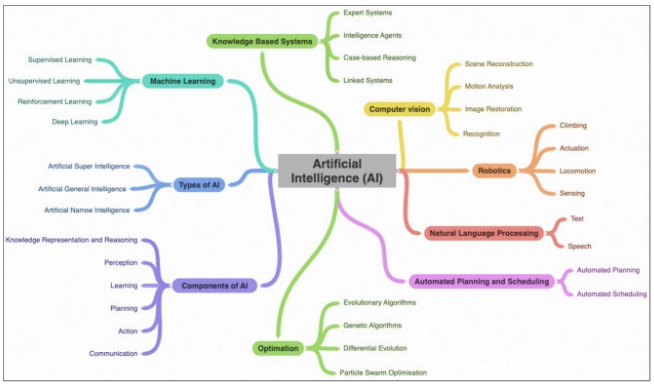

Figure 1: Components, types, and subfield of AI, (Moumita Das, 2022)

Blockchain is a technology of distributed ledgers. A distributed ledger is a system that ensures fairness and security by providing all transaction information and user data across multiple computers. This decentralised approach enables better outcomes, preventing malicious changes and allowing for efficient management and quick responses. It removes the role of central administrators and runs with the consent of multiple peer members The blockchain platform architecture consists of distributed peer nodes connected via a peer-to-peer network. Central to this system is decentralisation, where the blockchain is spread across multiple nodes. Each node verifies actions, and can create, authenticate, and validate new transactions for the blockchain. This design enhances security and robustness by ensuring tamper resistance and eliminating single points of failure. Each peer node includes (1) a distributed ledger and (2) smart contracts, as illustrated in Figure 2.

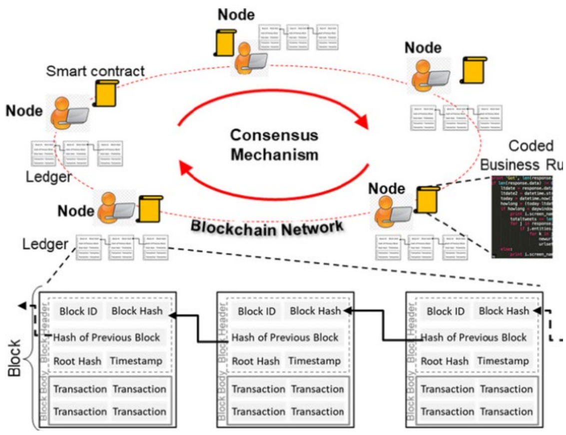

Figure 2: System architecture of a blockchain platform (Moumita Das, 2022)

The next section provides a comprehensive overview of the use of AI and blockchain technologies throughout the construction process. It covers each phase, including planning, design, procurement, construction, and operation and maintenance. The goal is to highlight the key AI and blockchain technologies currently used in the construction industry, as well as to explore the opportunities these technologies present across the entire project lifecycle, from initiation to completion.

2.1.1 *Planning Phase*

The planning phase is crucial in the construction process, as it has a significant impact on a project's success by influencing key factors such as cost, time, quality, and quantity.

Several studies have shown that AI is enhancing the speed and accuracy of planning for construction projects. Specifically, machine learning and natural language processing are playing key roles. Machine learning (ML), a vital subset of AI, involves developing computer programs that learn from experience or historical data without being explicitly programmed. ML helps identify patterns, detect trends, and create models for planning and managing construction projects. It is used for tasks such as predicting costs and timelines through regression analysis. (Sofiat O. Abioye, 2021) AI also automates various tasks, including scheduling, estimating costs, and allocating resources. Natural language processing (NLP) interprets written language to provide insights into contracts and other documents related to construction projects. (Obinnaya Chikezie Victor, 2023) By analysing historical data and project features, machine learning enables precise budget forecasts and efficient resource utilisation, setting new standards in the industry.

In the planning phase, smart contracts enable the creation of custom rules to manage and update blockchain ledgers. Figure 3 shows a blockchain-based construction document management system featuring a conceptual model where a peer-to-peer blockchain network and data storage network connect project participants (peers) with document management functionalities. In a given project, key participants, such as members of an architectural firm, act as full nodes, maintaining the entire history of documents and changes. External entities, like government departments, may join the blockchain network as "light nodes" on a temporary basis. These light nodes host only a subset of the records and document integrity proofs and are limited to updating specific records (e.g., approvals or rejections) and verifying document integrity using the blockchain ledger's proofs. (Moumita Das, 2022)

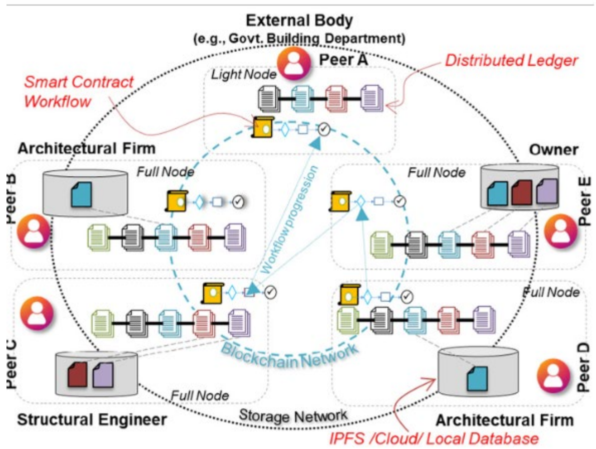

Figure 3: blockchain-based construction document management system (Moumita Das, 2022)

2.1.2 *Design Phase*

The second phase of a construction project is the design stage, also known as the pre-construction phase. During this stage, detailed plans for the structure's final design are implemented, and all necessary preparations for the commencement of construction are executed.

Automated tools, such as the 4D AutoCAD interface (a 3D computer-aided design (CAD) software developed by Autodesk, Inc.), are employed to optimise traditional design processes. Despite these technological advancements, many organisations have encountered difficulties with current platforms managing large volumes of data. This has led to increased interest in integrating AI to address these limitations (Obinnaya Chikezie Victor, 2023).

Generative design, powered by AI models, creates new content based on various inputs such as text, images, audio, video, and code. These AI algorithms generate and evaluate multiple design options based on specific project parameters and constraints. This assists in identifying and implementing strategies to minimise the carbon footprint of projects through simulations, cost-benefit analyses, and recommendations for more efficient resource and material utilisation (Mésároš, 2024). Furthermore, AI is a critical component of site analysis by analysing geographical and environmental data. It assists in identifying the most suitable construction sites by examining factors such as terrain, climate, and accessibility, which is essential for achieving optimal and sustainable construction outcomes.

2.1.3 Procurement Phase

The success of construction projects depends on the effectiveness of the construction supply chain, which involves the procurement of materials and their management throughout the project lifecycle. Efficient supply chain management is essential for the timely and cost-effective completion of projects (Olorunshogo Benjamin Ogundipe, 2024). However, challenges such as inefficient procurement processes, and limited visibility in logistics persist.

Artificial Intelligence driven procurement platforms are transforming traditional procurement by automating essential tasks, from supplier selection to order placement. These platforms utilise machine learning algorithms to evaluate supplier performance, analyse market conditions, and suggest optimal procurement strategies. Automation of routine tasks, such as evaluating requests for proposals (RFPs) and comparing bids, enhances decision-making speed, reduces manual errors, and improves overall procurement efficiency. AI also streamlines approval workflows through intelligent automation moving away from cumbersome manual processes. By analysing historical approval patterns and assessing risk factors, AI systems can expedite routine approvals (Omotayo Sanni, 2024). This will help in accelerating the procurement cycle and improving the consistency of critical decisions, ultimately reducing delays caused by bureaucratic bottlenecks.

The Internet of Things (IoT) helps with real-time tracking of logistics. By deploying IoT devices on materials, vehicles, and key assets, construction stakeholders gain continuous visibility into the location, status, and condition of materials (Nyathani, 2023). This data includes real-time GPS coordinates, temperature, and environmental conditions, providing project managers with timely insights into material movement, allowing for informed decisions.

Further, AI-driven logistics solutions empower construction professionals to proactively manage potential delays. By monitoring material progress, AI systems can detect patterns that may indicate disruptions, such as transportation delays or unforeseen obstacles (Olorunshogo Benjamin Ogundipe, 2024).

2.1.4 Construction Phase

The construction phase faces challenges with timely milestone payments to contractors further impacting the project progress. Additionally, inadequate construction monitoring may lead to deviations from the schedule, budget, and quality standards. Thus, addressing these issues is crucial for successful project completion.

Computer vision, a subfield in AI, is an interdisciplinary field that focuses on enabling machines to replicate human vision. It involves capturing, processing, and analysing digital images using advanced algorithms to facilitate high-level understanding and decision-making. Sensors play a crucial role in this process by collecting and transmitting data, allowing site managers to monitor robot performance and make informed decisions in real time (Sofiat O. Abioye, 2021).

Additionally, an AI chatbot, a sophisticated AI system that allows users to have interactive conversations through instant messaging will help provide real-time updates on site activities. This would be extremely useful for project managers and other relevant stakeholders (Shengluan Hou S. Z., 2020). This will help to reduce the number of hours required to complete a project, addressing the issue of labour shortages in the Australian construction sector.

Smart contracts can streamline payments to subcontractors by automating transactions based on verified completion of work. For example, in a contract between a principal and a contractor, a blockchain-based smart contract could facilitate the agreement. Initially, the employer deposits funds into the network, which remain blocked until the work is completed. Once the task is done, the delivery time and associated data are recorded on the blockchain. Payment is automatically processed after the work is verified, preventing manipulation or delays (Dena Mahmudnia, 2022). In contrast to traditional payment systems that might require advance payments and limit flexibility, a smart contract system, managed by a cloud service provider (CSP) and data owners, ensures fair payment. The CSP submits proof of data possession and only receives payment upon successful verification (Hao Wang, 2020). Thus, Blockchain smart contracts can streamline and secure payments, preventing delays and financial disputes, which helps control project expenses

2.1.5 Operation & Maintenance Phase

During the operation and maintenance (O&M) phase, the operator often has limited control over the project's progress. As a result, managing and retrieving data from the project becomes challenging (Obinnaya Chikezie Victor, 2023).

By leveraging AI and ML technology, facility managers can make critical decisions about building performance, energy optimisation, and overall operational monitoring. Real-time data collection enhances the project's operational efficiency, allowing for predictive maintenance that proactively addresses potential issues before they arise. Further AI can revolutionise construction defect management by applying advanced frameworks that integrate technologies like Building Information Modelling (BIM), augmented reality (AR), and ontology-based data collection. By ensuring structured and accurate defect data capture, AI enhances the ability to proactively identify and prevent defects before they occur. Automated inspections through AR, combined with real-time data retrieval via domain ontologies, significantly reduce rework, project delays, and costs. This AI-driven approach streamlines the construction process, minimise human errors, and boosts overall project efficiency, further helping to reduce cost overruns (Chan-Sik Park, 2013).

2.2 Role of leadership in Digital Transformation

Implementing AI and blockchain technologies in large construction projects presents significant challenges. One of the key challenges is convincing users and project stakeholders to accept, adopt, and utilise these innovations. The slow pace of digital transformation is often linked to challenges with resistance to change (Zulu, 2023). The concept of resistance to change is deeply rooted in Lewin's (1947) model of organisational change, which suggests that driving forces exist that either promote or resist change. Research indicates that resistance to change can be understood through three dimensions: cognitive, affective, and behavioural (Lines, 2015).

- The **cognitive dimension** involves how employees perceive and think about the change, including their confidence in their ability to adapt to new roles.
- The **affective dimension** refers to the emotional reactions' employees experience in response to the change.
- The **behavioural dimension** is observable resistance manifested through actions.

Therefore, a complex industry or organisation such as construction who chooses to undergo digital transformation must strategically align their leadership to ensure the process is successful. Business leaders and managers play a pivotal role in guiding their organisations through this transformation, influencing the adoption of digital technologies such as AI, blockchain, and information models. In response, the Sino-Australia Joint Research Centre has proposed management strategies designed to help project leadership teams overcome these obstacles and accelerate digital adoption (Liao, 2019). Key to this effort are three critical factors: executive commitment, involvement and integration, and training for competencies (Longhui Liao, 2019) (Lines, 2015).

(1) **Executive Commitment**: Executive commitment is essential for the successful implementation of these digital technologies particularly as construction and other industries increasingly rely on information models for project delivery. Leadership must not only recognie the shift towards data-driven, information-oriented processes but also actively embrace and champion these changes. When executives demonstrate a strong commitment, they address the **cognitive dimension** by influencing how employees perceive the change. Employees are more likely to believe in the feasibility of adapting to new roles and responsibilities when they see their leaders advocating for the transformation. Additionally, executive commitment can mitigate the **affective dimension** by reducing anxiety and fostering a sense of security. When leadership is visibly engaged and supportive, employees are more likely to feel confident and less fearful about the impending changes. Strong executive involvement also addresses the **behavioural dimension** by reducing passive resistance, as employees are encouraged to take proactive steps toward embracing the change when they see that it is a top priority for the organisation.

(2) **Involvement and Integration**: Digital transformation's success relies on involvement and integration across all levels of the organisation. Early and active participation from the stakeholder including key contractors, manufacturers, and facility management teams in the initial digital design modelling helps build trust and fosters collaboration, ensuring that all parties see the tangible benefits of new technologies. Engage stakeholders early to showcase the benefits of AI and blockchain through pilot projects influences the cognitive dimension by helping employees understand and appreciate the value these technologies bring. This early involvement gives employees time to process the changes, increasing their confidence in adapting to the new workflows. In terms of the affective dimension, early involvement helps reduce emotional resistance, as it promotes a sense of ownership and inclusion in the change process. Phased implementation of these technologies in critical areas allows employees to gradually adapt, minimising emotional overwhelm. Furthermore, the **behavioural dimension** is addressed by fostering a collaborative environment where employees are actively engaged in the transformation, reducing the likelihood of observable resistance such as disengagement or obstruction.

(3) **Training for Competencies:** Competency in digital technologies is critical to overcoming resistance and ensuring the successful adoption of new tools and practices. Organisations must provide comprehensive training programs that equip staff with the technical expertise and skills necessary to adapt to new workflows. Providing thorough training influences the **cognitive dimension** by equipping employees with the knowledge and skills needed to navigate the new digital environment. As their confidence in their abilities grows, employees are more likely to perceive the change as manageable and even beneficial. A well-designed training programs can help alleviate fears and anxieties by reducing uncertainties associated with new workflows, thus addressing the **affective dimension**. When employees feel prepared and competent, they are less likely to experience negative emotions such as frustration or fear. Furthermore, the **behavioural dimension** is impacted by these training programs as they provide clear guidance on new processes, reducing observable resistance like hesitation or pushback in daily tasks.

3. Theoretical Framework

The integration of Artificial Intelligence (AI) and blockchain in the construction industry is based on various theoretical perspectives related to digital transformation, technological adoption, and organisational innovation. This framework is heavily influenced by systems theory, which identifies construction projects as complex systems with interdependent processes that can be optimised through digital technologies such as AI and blockchain. These technologies hold the potential to revolutionize project management, design, and sustainability by enhancing data accuracy, process efficiency, and transparency. However, their adoption within the construction industry, particularly in Australia, has been slower compared to other sectors, primarily due to structural and cultural barriers to digitalisation.

A systematic literature review was conducted to establish a comprehensive foundation for this study, incorporating peer-reviewed academic journals, industry reports, and government publications from the past decade. The review focused on the applications of AI and blockchain in the construction industry and explored their potential in areas such as project management, site monitoring, design innovation, and defect detection. In doing so, it also examined the challenges and opportunities associated with the successful adoption of these technologies. One of the key findings was a notable gap in empirical studies centred on the Australian construction context, underscoring the need for localised research that addresses sector-specific issues such as labour shortages, and the slow uptake of digital tools. The literature revealed that, while AI and blockchain offer significant potential as enablers of innovation, their adoption in the Australian construction industry faces socio-technical challenges, including limited digital infrastructure, a shortage of skilled workers, and resistance to organisational change.

Further, the literature emphasised the critical role of leadership in facilitating the adoption of AI and blockchain. There is a growing consensus on the necessity for **digital leadership**—leaders who not only understand digital technologies but also actively champion their integration into traditional construction workflows. These leaders are pivotal in addressing resistance to change, fostering a culture of innovation, and ensuring that digital transformation aligns with broader organisational goals. The review also stressed the importance of transformational leadership, where leaders guide their organisations through the complexities of digital transformation by fostering collaboration, providing training for new skill sets, and promoting the long-term benefits of technological advancements.

By synthesising these insights, the theoretical framework positions AI and blockchain not only as technological innovations but also as leadership challenges. The integration of leadership theory with literature on AI and blockchain adoption suggests that effective leadership is a key driver of digital transformation in construction. Transformational leaders who priorities strategic alignment between technological innovations and organisational objectives can accelerate the industry's adoption of AI and blockchain, leading to improvements in productivity, sustainability, and safety. Thus, this framework serves as a guide for further exploration into how AI and blockchain can transform construction processes while highlighting the crucial role of leadership in overcoming adoption barriers within the Australian construction sector.

4. Results and Discussion

The literature review indicates that the construction sector is a significant driver of economic growth and contributes substantially to Gross Domestic Product (GDP), particularly in Australia. The adoption of advanced technological tools, such as Artificial Intelligence (AI) and blockchain in construction projects has offered numerous benefits throughout the project lifecycle. Key advantages identified include enhanced speed and accuracy in planning and budgeting, improved site analysis, efficient procurement processes, secure payment methods, and effective defect detection. These benefits suggest that leveraging AI technology can lead to more timely project delivery and overall productivity improvements in the construction industry.

However, despite the proven benefits, the current usage of AI and blockchain in the Australian construction industry remains relatively low. This reluctance to embrace digital transformation can largely be attributed to a resistance to change, as many stakeholders are accustomed to traditional methods and practices.

Additionally, integrating leadership theory into the discourse on AI and blockchain adoption indicates that effective leadership plays a crucial role in facilitating digital transformation in construction. Transformational leaders who emphasise the strategic alignment of technological innovations with organisational objectives are vital in driving the industry's adoption of AI and blockchain. These leaders can accelerate change by fostering a culture that embraces innovation, encouraging staff training in new technologies, and addressing concerns related to job displacement and operational disruptions. By prioritising the integration of AI, these leaders can significantly improve productivity, enhance sustainability, and bolster safety outcomes across construction projects.

In summary, while the potential for AI to transform the Australian construction industry is evident, addressing the barriers to adoption, including resistance to change and regulatory challenges, is crucial. Effective leadership that champions digital transformation will be a key driver in harnessing the benefits of digital transformation and ensuring that the construction industry can meet the demands of a rapidly evolving technological landscape.

5. Conclusion and Recommendations

In conclusion, integrating AI and blockchain technologies into the construction industry offers significant benefits. The integration of technologies can enhance productivity, sustainability, and overall efficiency within the projects

The broader impact of these technologies extends beyond individual projects. AI and blockchain foster a more efficient and reliable construction ecosystem, leading to reduced waste, lower costs, and improved resource management. They enable better collaboration among stakeholders, enhance data integrity, and drive innovation across the industry. Embracing these advancements not only addresses pressing challenges such as cost overruns and project delays but also contributes to a more sustainable and resilient built environment.

Effective leadership that champions digital transformation will be a key driver in harnessing the benefits of AI and ensuring that the construction industry can meet the demands of a rapidly evolving technological landscape. To facilitate the successful adoption of AI in construction, several recommendations can be made:

1. **Leadership Development**: Invest in training programs to develop transformational leadership skills in the construction sector to promote a culture of innovation and openness to change.
2. **Skill Development Initiatives**: Implement targeted educational programs and workforce training initiatives to address the skills gap and equip employees with the necessary skills to work with AI and blockchain technologies.
3. **Pilot Projects**: Encourage the development of pilot projects that demonstrate the successful integration of AI technologies in construction, providing case studies for greater adoption across the industry.

6. Limitations and Future Research

Despite these insights, the study has limitations, particularly in the Australian context, where regulatory considerations were not fully explored. Regulatory frameworks can significantly impact the adoption and implementation of AI technologies in construction. As such, future research should investigate how specific regulations may facilitate or hinder the integration of AI and blockchain in the industry.

Addressing these regulatory aspects will provide a more comprehensive understanding of the barriers to AI adoption and offer guidance for policymakers aiming to promote digital transformation within the construction sector.

This study primarily focused on secondary data from literature, which may not capture the full spectrum of challenges faced by construction firms in real-world applications of AI and blockchain. Future studies could benefit from qualitative research methods, such as interviews or surveys with industry stakeholders, to gain deeper insights into the practical barriers and facilitators of AI and blockchain adoption in the construction sector.

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