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NAVIGATING SUSTAINABILITY AND DIGITALISATION IN THE CONSTRUCTION INDUSTRY: A LITERATURE REVIEW

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ABSTRACT

This critical literature review explores the intersection of sustainable practices and digitalisation within the construction industry. Though digitalisation offers promising avenues for addressing challenges faced by the construction industry, its impact on sustainability remains underexplored. Drawing from a comprehensive synthesis of the literature, this review identifies key challenges in traditional construction industry practices, examines the benefits and challenges of digitalisation, and assesses its implications for sustainability. However, the adoption of digitalisation in the construction industry faces hurdles such as legal ambiguities, financial constraints, and resistance to change. Moreover, its impact on sustainability spans economic, environmental, and social dimensions. While digitalisation offers cost savings, improved project delivery, and enhanced worker safety, it also raises concerns about electronic waste, energy consumption, and job displacement. A holistic understanding of sustainability is crucial in navigating these complexities, encompassing economic viability, environmental stewardship, and social equity. Integrating digital technologies in construction industry practices presents opportunities and challenges for advancing sustainability goals. Ultimately, embracing sustainable digitalisation in the construction industry is essential for fostering long-term resilience and competitiveness in the dynamic construction landscape.

Keywords: *Construction Industry; Digitalisation; Sustainability.*

1. INTRODUCTION

The Construction Industry (CI) is an indispensable part of the economy, and it contributes significantly to the Gross Domestic Product (GDP) product in most countries (Saka & Adegbembo, 2022; Shiha & Dorra, 2023). Furthermore, the CI is characterised by complex operational requirements in both its internal and external environments, making it a dynamic, risky, and hazardous field (Ibem et al., 2011). According to Zhang, (2023) construction project management is indeed a challenging task due to the inherent complexity, uncertainties, and multitude of activities involved in a single project environment. Despite rapid growth, the industry faces persistent challenges such as

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collaboration issues, low productivity, resource wastage, and project delays (Pinto, 2023; Korke et al., 2023). Collaboration issues, particularly regarding trust and information sharing, significantly hinder project success (Mahmudnia et al., 2022). Moreover, documentation problems and payment failures are other challenges in traditional construction practices (Mahmudnia et al., 2022). According to Zulu et al. (2023), the absence of adequate digital expertise and technology adoption within the construction industry has also been linked to these challenges.

Embracing technological advancements in construction industry practices yields numerous benefits by overcoming the challenges faced by traditional construction industry practices, including reduced rework, reduced coordination problems, better communication between various stakeholders, reduced document errors, fewer claims, reduced paperwork, reduction in time and cost overrun, and reduction in lifecycle cost (Li et al., 2019). However, when implementing the digital application, sustainability aspects also need to be considered (Balasubramanian et al., 2022). The concept of sustainability has evolved to encompass not only environmentalism yet economic and social development as well (Ford & Despeisse, 2016). Furthermore, sustainability concepts showcase the significant value of the construction industry (Stanitsas et al., 2021). Beltrami et al. (2021) highlighted that both digital applications and sustainability have gained momentum in academic, managerial, and policy debates. According to Balasubramanian et al. (2022), digital applications impact the Triple Bottom Line (TBL) of sustainability in both positive and negative ways in the construction industry. Therefore, examining the influence of sustainable digitalisation on the perspective of the construction industry is essential.

The implementation of the digitalising construction industry globally has been discussed in numerous research studies (Maskuriy, Selamat, Ali, et al., 2019; Newman et al., 2021). However, as noted by Balasubramanian et al. (2022), the previous literature is unable to provide much clarity on the relationship between digitalisation and sustainability. Reliable and comprehensive information addressing the sustainable digitalisation of the construction industry is limited.

Therefore, the study aims to review how the integration of sustainable practices and digitalisation can address the challenges faced by the construction industry and to assess the implications of such integration on the economic, environmental, and social dimensions of sustainability. Three objectives have been set up to achieve this aim i.e. (i) identify challenges in the traditional construction industry practices, (ii) define sustainable digitalisation, and (iii) assess positive and negative implications of construction industry practices digitalisation aligned with the sustainable perspectives.

2. METHODOLOGY

A substantial amount of literature delves into the historical development of the subject and highlights significant sources, enriching the understanding of key themes (Saunders et al., 2014). Expanding on this idea, Snyder (2019) stressed the importance of a comprehensive synthesis of the literature to establish the theoretical foundations of a study. Therefore, this paper extends upon the insights garnered from a thorough analysis of the literature to review how to sustainably digitalise the construction industry.

To summarise these insights, a meticulous evaluation of the literature was conducted. This involved an exhaustive review of various sources including books, reports, theses,

journals, magazines, and conference proceedings. The objective was to identify challenges in the traditional construction industry practices, define sustainable digitalisation and identify positive and negative implications of construction industry practices aligned with the sustainable perspectives. To ensure a comprehensive synthesis, search terms such as ‘Construction industry, 'Digitalisation in the construction industry', 'Issues of the construction industry, and ‘Sustainable digitalisation were carefully filtered using prominent search engines such as 'Scopus,' 'Google Scholar,' 'Emerald,' and 'Science Direct.' The selection of these databases was informed by their widespread use and comprehensive coverage of relevant literature. The inclusion of the 'Emerald' database alongside other common databases was due to its extensive repository of journals and publications focused on management and business practices, which are highly relevant to the construction industry.

3. RESULTS AND FINDINGS

3.1 CHALLENGES FACED IN TRADITIONAL CONSTRUCTION INDUSTRY PRACTICE

The traditional construction industry faces numerous challenges, impacting project performance, worker productivity, and overall efficiency (Pinto, 2023). Collaboration issues, particularly regarding trust and information sharing, significantly hinder project success (Rodrigues & Lindhard, 2023). Mahmudnia et al. (2022) highlight the critical role of trust in effective information sharing and collaboration in construction projects, noting that a lack of trust leads to inefficiencies and project delays. Furthermore, Korke et al. (2023) emphasise that low productivity in construction project management practices results in inefficient labour output, resource wastage, cost overruns, and project delays. Fragmentation across various stakeholders and organisations involved in complex projects leads to communication difficulties, scheduling problems, delays, and disputes during projects (Cakir et al., 2022). Therefore, establishing trust and information sharing among these separate entities is crucial (Pamidimukkala et al., 2023). Moreover, paper-based or inefficient electronic documentation systems create problems with information loss, security vulnerabilities, and a lack of transparency (Mahmudnia et al., 2022). This can lead to wasted time, rework due to misinterpretations, and damaged trust between project parties in construction practices (Sun et al., 2020). Furthermore, payment failures can cause significant cash flow problems and strain relationships between stakeholders (Mahmudnia et al., 2022). In addition, health and safety hazards, along with a predominant focus on cost and productivity over worker well-being, highlight additional systemic challenges (Tao et al., 2023). Figure 1 illustrates the challenges faced in the traditional construction industry identified throughout the existing literature.

3.2 DIGITALISATION AND CONSTRUCTION INDUSTRY

The construction industry has been notably hesitant to adopt technological innovations compared to sectors such as banking, manufacturing, and retail (Osunsanmi et al., 2018). However, the construction industry needs to digitalise its business processes due to the continual rise in competition and challenges, coupled with the swift development of digital technologies (Stoyanova, 2020). The historical evolution of the industry is marked by four phases, each industrial revolution contributing significantly to the current state of digital development (Sajjad et al., 2023).

Digitalisation in construction offers substantial benefits; however, it faces significant challenges to widespread adoption. Cost savings are achievable through mechanisation, robotics, and automated workflows, reducing labour expenses and material losses (Pakhale & Pal, 2020). Elimination of paper-based processes lowers project overhead costs and saves time (Mesároš & Mandičák, 2017; Ibrahim et al., 2021). Enhanced documentation enables early error detection, thereby improving project quality (Luo et al., 2022). Moreover, digitalisation improves communication, collaboration among stakeholders, and workflow efficiency (Mahmudnia et al., 2022; Oesterreich & Teuteberg, 2016), enhancing workplace safety by proactively identifying and mitigating risks (Stoyanova, 2020). Despite these benefits, the widespread adoption of digitalisation in construction is hindered by several challenges. Legal uncertainties and inadequate government policies inhibit industry growth (Lau et al., 2019; Taher, 2021), compounded by high initial implementation costs (Alaloul et al., 2020; Lau et al., 2019). Low technological competency and resistance to change pose additional barriers, with some workers hesitant to adopt new digital workflows (Shafei et al., 2022; Balasubramanian et al., 2022). Technological and security challenges further complicate digitalisation efforts (Lau et al., 2019), alongside operational incompatibilities and a lack of top management support for innovation (Alaloul et al., 2020; Oesterreich & Teuteberg, 2016).

3.3 DIGITALISATION OF THE CONSTRUCTION INDUSTRY FROM A SUSTAINABILITY PERSPECTIVE

Digitalisation in the construction industry has significant potential to enhance sustainability by balancing environmental, economic, and social development (Sajjad et al., 2023). Sustainability is a holistic and integrative concept, which addresses long-term decision-making about how to manage resources and the associated effects (Finlay, 2023). However, integrating digital technologies in construction must consider sustainability aspects (Balasubramanian et al., 2022). The concept of sustainability has evolved to encompass not only environmentalism yet economic and social development as well (Ford & Despeisse, 2016). According to Holden et al. (2014), sustainability is defined as a development that meets the present needs to reconcile economic, social, and environmental aspects (triple bottom line) without compromising future generations to meet their own needs. Sustainability concepts play a crucial role in construction projects, showcasing significant value (Stanitsas et al., 2021). The construction sector, a major global consumer of natural resources, generates significant waste annually, underscoring its environmental impact (Jain, 2021). Additionally, it holds substantial economic and social importance, contributing significantly to GDP (Alaloul et al., 2021) and employing millions of people (Babalola & Aigbavboa, 2022). Consequently, according to Goh et al. (2020), a strong link exists between construction and the three key pillars of sustainability: economy, society, and environment. Since the first industrial revolution in the 18th century, the world has faced the challenge of producing more goods from limited and diminishing natural resources to meet the increasing consumption demand, all while minimising negative environmental and social impacts (Kar & Jha, 2021). Therefore, according to Beltrami et al. (2021), both digitalisation and sustainability have gained momentum in academic, managerial, and policy debates. Consistently, the sustainability impacts of digitalisation and its potential contributions to sustainable economic, environmental, and social development are increasingly gaining attention. (Ghobakhloo, 2020).

3.3.1 Sustainable Digitalisation in Construction

Sustainable digitalisation in the construction industry involves the integration of digital tools with sustainable practices to achieve economic growth, environmental responsibility, and social well-being (Nikmehr et al., 2021). While digitalisation has the potential to positively impact sustainability, it poses challenges that need to be managed (Wang & Guo, 2022). A triple-bottom-line perspective is crucial because the various sustainability impacts of digitalisation may conflict with each other (Balasubramanian et al., 2022). For instance, blockchain could improve operational efficiency and reduce costs (enhancing economic sustainability); however, it may also increase the energy required to power the associated algorithms (diminishing environmental sustainability) (Du Plessis & Sherratt, 2020). Efforts to increase awareness and usage of digital technologies in the construction industry are essential for driving sustainable digitalisation practices forward. Figure 1 illustrates the impact of digital technologies on the triple bottom line of sustainability, encompassing both positive and negative aspects in the construction industry.

3.3.2 Digitalisation Construction Industry and Environmental Sustainability

The environmental aspect of sustainability is described as the preservation of global life-support systems, involving the ongoing protection of natural resources to prevent exceeding their limits (Moghayedi et al., 2021). Digital technologies have both positive and negative environmental implications. Digitalisation can enhance process optimisation and contribute positively to environmental sustainability by enabling more efficient resource usage (Franco et al., 2022), and a reduction in waste production (Tahmasebinia et al., 2020). On the environmental front, digital technologies can gather precise, real-time data and use analytics to gain deep insights into material usage and waste statistics, thereby reducing energy consumption and emissions (Balasubramanian et al., 2022). Alternatively, it can lead to increased waste production, such as electronic waste, and higher energy resource demand (Nikmehr et al., 2021).

3.3.3 Digitalisation of Construction Industry and Economic Sustainability

Hübner et al. (2022) define the economic aspect of sustainability as the organisation of finances to ensure a consistent flow of income in the future. The positive economic impact of digitisation primarily arises from the translation of positive environmental benefits into economic advantages (Balasubramanian et al., 2022). Digital technology helps reduce costs, including manual labour costs, inspection and supervision costs, and savings from the automation of routine administrative tasks, thereby lowering overall construction costs (Balasubramanian et al., 2022). Moreover, artificial intelligence and machine learning algorithms can accurately predict project costs and detect possible crashes, delays, and changes in the construction process (Aung et al., 2023). Additionally, according to Ahmed (2019), improvements in tracking and scheduling, timely access to project information, reduction in labour hours, quality improvement, and reduction in project completion time. Furthermore, sustainable digitalisation significantly reduces the efforts required in conventional construction monitoring and reporting procedures (Adepoju & Aigbavboa, 2020). However, negative impacts such as the high upfront cost of implementation, costs associated with employee training, upskilling, and coordination costs across various partnering firms in the value chain, and uncertain return on investments (Ejsmont et al., 2020; Newman et al., 2021).

3.3.4 Digitalisation in Construction Industry and Social Sustainability

Pieterse (2011) states that social sustainability is actions and policies that seek to ensure equitable access and distribution of rights to enhance the quality of life in society. Social sustainability has several positive and negative implications (Chan, 2020). The positive implications include improved health and safety for workers (Tender et al., 2022). This is promising because construction is one of the sectors that constitute the largest percentage of worker deaths by accidents and injuries. Furthermore, the use of digital technologies enhances accuracy by monitoring operations and reduces effort and human errors (Qureshi et al., 2022). However, digitalisation brings several adverse societal implications. There needs to be more discourse from an ethical and humanitarian perspective on the potential job losses among unskilled blue-collar workers and their future roles in the sector (Marenco & Seidl, 2021). Increased surveillance of employees raises concerns about their freedom and privacy (Calvetti, Magalhães, et al., 2020). Additionally, further discussion is needed on issues related to data privacy, cybersecurity, and data breaches associated with digitalisation (Balasubramanian et al., 2022).

4. DISCUSSION

The traditional construction industry grapples with fragmentation, inefficient documentation, and payment failures. However, digitalisation has significantly improved project management, communication, collaboration, and risk management, leading to cost savings, better project timelines, enhanced quality control, and safer working environments. Despite these benefits, the industry faces obstacles such as legal uncertainties, insufficient government support, technological challenges, resistance to change, and data security and privacy concerns.

Sustainability is crucial in construction, and the impact of digitalisation on sustainability needs careful consideration. Sustainable digitalisation combines digital tools with sustainable practices to achieve economic growth, environmental responsibility, and social well-being. Economically, digitalisation reduces manual labour costs and automates administrative tasks, leading to lower overall construction costs and improved project efficiency. Artificial intelligence and machine learning can predict project costs and identify potential issues, contributing to economic sustainability. However, high upfront costs and training expenses pose challenges. Environmentally, digitalisation enhances process optimisation and resource efficiency, leading to reduced waste production and energy consumption. Real-time data and analytics help monitor material usage and waste statistics, positively impacting environmental sustainability. Nonetheless, digitalisation can also increase electronic waste and demand for energy resources. Socially, digital technologies improve worker health and safety by monitoring operations and reducing human errors. However, there are concerns about potential job losses among unskilled workers and issues related to data privacy and surveillance. Addressing these ethical considerations is crucial to ensuring that digitalisation contributes to social well-being.

Embracing sustainable digitalisation in the construction industry is essential for achieving long-term viability, resilience, and competitiveness in the evolving digital landscape. A balanced approach that considers economic, environmental, and social aspects is necessary for sustainable digitalisation. Efforts to increase awareness and usage of digital technologies, coupled with supportive policies and regulations, can drive sustainable

practices forward. Additionally, ongoing research and development are needed to address challenges and uncertainties associated with digitalisation and maximise its benefits for sustainability.

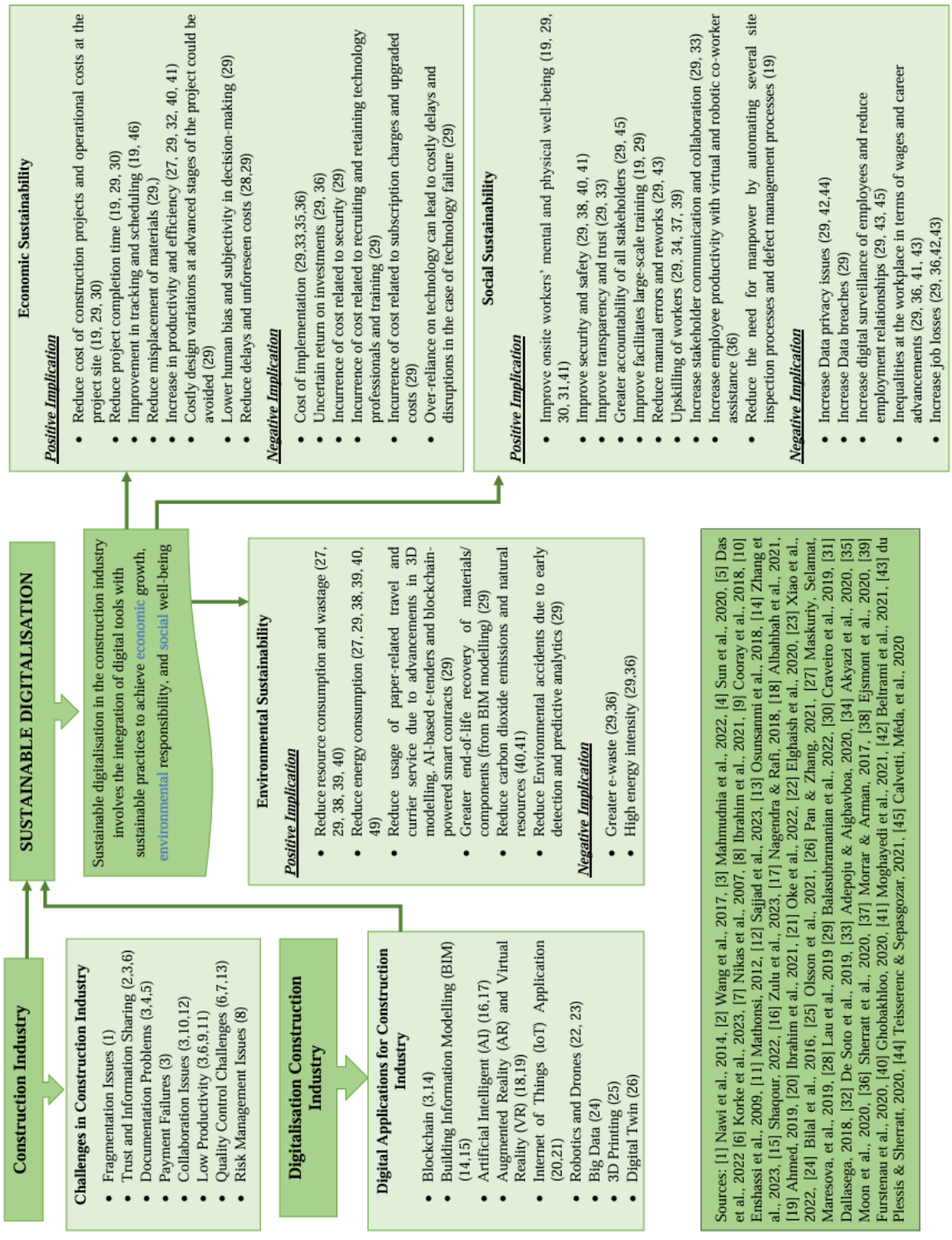

Figure 1: Summary of Literature Findings

5. CONCLUSIONS

In summary, this study delves into the challenges inherent in CI practices, explores the benefits and challenges of digitalisation in CI, and highlights the positive and negative implications of CI practices aligned with sustainable perspectives. By synthesising existing literature, this research contributes significantly to understanding how to sustainably digitalise CI. The analysis initially elucidates the hurdles faced within CI practices, providing a comprehensive review of the multifaceted challenges confronting the construction industry. Subsequently, the discussion navigates through the landscape of digitalisation in CI, elucidating both its advantages and challenges. Furthermore, the study examines how CI practices intersect with sustainability concerns, elucidating the nuanced impacts on economic, environmental, and social dimensions.

One of the primary contributions of this research lies in its thorough review of the challenges within CI practices and its exploration of digitalisation's effects on sustainability. By filling gaps in existing literature, this study provides a valuable resource for industry practitioners and researchers seeking to enhance sustainability within CI. Moving forward, industry practitioners must prioritise sustainable digitalisation within CI. This entails identifying strategies and frameworks to integrate digital technologies while ensuring alignment with sustainable principles. The findings of this research underscore the importance of proactive measures to navigate the complexities of digitalisation while promoting sustainability goals. Considering the study's outcomes, several recommendations emerge. Firstly, industry practitioners are encouraged to elevate the importance of sustainable digitalisation within their organisations, allocating resources and attention accordingly. Additionally, further research is warranted to conduct detailed surveys and practical analyses to inform the implementation of sustainable digitalisation strategies within CI practices on a global scale. Ultimately, by embracing the findings of this study and prioritising sustainable digitalisation within CI, industry stakeholders can pave the way for a more resilient, efficient, and environmentally responsible construction sector. The study is limited by the scope of the literature reviewed, potentially excluding recent research and emerging trends in digitalisation and sustainability in the construction industry. It may exhibit geographical bias due to reliance on region-specific sources, affecting the generalisability of findings across different countries. Additionally, the review broadly covers digitalisation but lacks an in-depth analysis of specific technologies such as BIM, IoT, AI, and blockchain, each of which has unique advantages, challenges, and sustainability implications that require more focused examination.

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