Editorial: Innovation and lean practices for sustainable construction project management; emerging technologies, strategies and challenges

The construction sector, representing a significant portion of the global economy, has been pivotal in delivering successful complex projects like skyscrapers and undersea tunnels (McKinsey, 2020). Despite its scale and achievements, the industry has struggled with limited productivity gains and inefficiencies, including frequent cost and time overruns and a considerable environmental impact due to high resource and energy consumption (Rodriguez Trejo *et al.*, 2024; Sheikhkhoshkar *et al.*, 2023). Over the previous decades, many strategies, innovations, technologies, methodologies and tools have been developed and applied to address these challenges. In this regard, methodologies such as lean construction have been adopted, drawing from lean manufacturing principles to improve process efficiency by reducing waste and maximizing value (Dauda *et al.*, 2024). This approach has led to more rapid, cost-effective and higher-quality project deliveries, fostering a culture of teamwork and enhancing client satisfaction by mitigating common project issues (González *et al.*, 2022). Moreover, lean project delivery models like integrated project delivery (IPD) and alliancing are reshaping the construction industry by fostering stakeholder collaboration. This approach aligns with lean principles, focusing on reducing waste and enhancing efficiency, while tackling common issues such as budget overruns and delays. The shift towards a more integrated and cooperative project management method promises to deliver projects more effectively, meeting time and budget constraints while ensuring quality (Elghaish *et al.*, 2022; Rashidian *et al.*, 2024).

On another front, the advent of Industry 4.0 technologies such as building information modeling (BIM), blockchain, virtual reality (VR) and augmented reality (AR), robotics and artificial intelligence (AI) is set to revolutionize the construction industry by addressing its longstanding challenges (Dawood *et al.*, 2022; Rahimian *et al.*, 2021). BIM revolutionizes construction by digitizing project management through a collaborative 3D model. Enriched with detailed information, this model serves throughout a building's lifecycle, improving planning, design, construction and operation. BIM enhances efficiency, reduces errors and fosters better collaboration among stakeholders, making it an indispensable tool in modern construction practices (Sompolgrunk *et al.*, 2023). Blockchain technology introduces transparency and security in transactions and documentation (Singh *et al.*, 2023). VR and AR provide immersive experiences for visualizing projects before they are built, enhancing decision-making and training (Adebowale and Agumba, 2024). Robotics and AI bring automation and smart analytics, respectively, optimizing construction processes, reducing errors and improving safety (Abioye *et al.*, 2021; Oke *et al.*, 2024). Together, these technologies contribute to solving critical issues in construction, such as cost overruns, project delays and safety concerns, leading to more efficient, sustainable and cost-effective construction practices.

This issue, "Innovation and Lean Practices for Sustainable Construction Project Management," presents 12 landmark papers. Together, they offer an in-depth examination of the latest advancements, lean methodologies and the transformative impact of digital technologies within construction management. Each paper serves as a critical piece,

Smart and Sustainable Built Environment
Vol. 13 No. 3, 2024
pp. 473-478

2046-6099
DOI 10.1108/SASBE-05-2024-406

contributing to a broader understanding of how innovative practices are integrated within architecture, engineering and construction (AEC), thereby reshaping the industry.

Adebowale and Agumba (2024) argue that despite the construction industry's significant role in economic growth, it lags in productivity growth compared to other sectors. This situation has prompted stakeholders to explore emerging technologies for enhancements. In this study, the authors employed a content analysis through a systematic literature review to highlight augmented reality (AR) applications critical for improving contractors' productivity. Their findings suggest that AR can enhance construction productivity through applications in assembly, training and education, monitoring and control, interdisciplinary functions, health and safety and design information.

Dauda *et al.* (2024) discuss how small- and medium-sized enterprises (SMEs) within the construction sector are highly vulnerable to disruptions caused by political and economic decisions or pandemics. In this study, adopting a qualitative method, they evaluate the current processes of participating SMEs against Liker's 14 Toyota Production System (TPS) management principles. They assessed the operations of selected SMEs providing engineering design and consultancy services against the TPS lean tool. They aim to juxtapose SME operations and processes with TPS to ascertain the level of their operations' conformity to the established TPS lean thinking tool. The analysis revealed that focusing on short-term goals, immediate profit and duplication of effort due to insufficient collaboration currently creates waste in participating SMEs' operations. Hence, implementing TPS as a lean tool was recommended, and a framework based on the TPS lean tool was developed to improve SMEs' operations.

Disney *et al.* (2024) discuss that BIM is mostly limited to the design phase, where two parallel processes exist: creating 2D drawings and BIM. Toward the end of the design process, BIM becomes obsolete as the focus shifts to producing static 2D drawings, which leads to a lack of trust in BIM. They highlighted that in Scandinavia, a concept known as *Total BIM* has emerged, an "all-in" approach where BIM serves as the single source of information throughout the project. The Total BIM concept relies on the strong interdependencies between commonly found isolated BIM uses. Disney *et al.* (2024) conducted a qualitative approach to investigate the overall concept of a total BIM project and its holistic approach to supporting implementation and strategy work connected to BIM. They identify four main success factors: production-oriented BIM as the main contractual and legally binding construction document, cloud-based model management, user-friendly on-site mobile BIM software and strong leadership.

Ghanbaripour *et al.* (2024) emphasize the importance of evaluating project delivery success in construction projects to aid organizational growth and continuous improvement. Despite the critical role of such evaluations, there is still a lack of consensus on universal success criteria, complicating assessments for practitioners and scholars. The study introduces a systematic project delivery success model (3D integration model) tested within the Australian construction industry to provide a consistent evaluation method applicable across various projects. Employing a mixed-method research approach, the study analyzed 40 construction projects from an Australian project management consultancy. The analysis involved calculating project delivery success scores, conducting qualitative performance assessments and validating findings with the organization's head. Results confirmed the 3D integration model's accuracy and reliability across projects of different scales and characteristics. The model highlights value, speed and impact as critical performance indicators, suggesting that project managers prioritize these areas to enhance project delivery outcomes.

Nikmehr *et al.* (2024) explore methods to improve recycled concrete aggregate (RCA) quality for their potential use as a substitute for natural aggregates in concrete, which is crucial due to the weakening effect of the old paste on RCAs. Their study evaluates methods for reinforcing RCAs, cleaning the old paste and enhancing RCA-based concrete quality through environmental, cost and technical lenses. Techniques include accelerated carbonation, bio

deposition, various soaking methods, coating with geopolymer slurry for reinforcement and cleaning methods like acid, water and thermal treatments. Additionally, using RCAs in saturated surface dry conditions and adding fibers or pozzolana are explored for quality enhancement without RCA modification. This study prioritizes adding fibers, pozzolana and geopolymer slurry coating as the most effective techniques based on environmental, economic and technical criteria while identifying future research directions.

Rashidian *et al.* (2024) examine the use of IPD, BIM and lean construction (LC) in enhancing collaboration and efficiency in construction projects. Despite the growing adoption and recognition of these methods, there is a noted gap in the literature for a maturity model (MM) that comprehensively benchmarks progress in integrating BIM, IPD and LC. This study highlights the absence of a unified MM through a systematic literature review and thematic analysis. It explores the interrelationships and common themes of these methods among existing MMs. The analysis identifies five key themes: customer satisfaction, waste minimization, lean practices and cultural and legal aspects that underline the collaboration among BIM, IPD and LC. The study also evaluates current MMs' common characteristics, strengths and limitations, laying the groundwork for developing future MMs that can holistically measure the integration of BIM, IPD and LC within organizations.

Ogunmakinde *et al.* (2024) argue that establishing a more sustainable built environment is an increasing global concern for the construction industry. Despite the intrinsic and extrinsic obstacles stakeholders face, significant efforts are required to transition smoothly to sustainable construction (SC) practices. This study utilized systematic reviews and a meta-analysis (PRISMA) approach to identify influential obstacles to SC in developing nations. The findings identified construction professional training and education, clients' attitudes and awareness, the culture and capacity of construction industries, government regulations and policies and the economy as the main obstacles to SC in developing countries. The key barriers identified from the meta-analysis include inadequate training and education among construction professionals, poor execution of sustainability ethics, negative public attitudes toward sustainability, a lack of awareness and understanding, absence of precise data and integrated study and inappropriate priorities regarding sustainability.

Oke *et al.* (2024), conducting a quantitative approach, presented the results of assessing the barriers that can hinder the deployment of robotics and automation systems in developing countries, using the Nigerian construction industry as a case study. This study highlights the top five barriers: the fragmented nature of the construction process, resistance by workers and unions, hesitation to adopt innovation, lack of capacity and expertise and lack of support from top-level managers. Through factor analysis, the barriers identified were categorized into four principal clusters: industry, human, economic and technical.

Efforts to guide planners and control teams in assessing project performance and control have been extensive in academic and industrial circles. However, these efforts have often neglected a deeper examination of the concepts behind the numerous control metrics developed and implemented. Addressing this oversight, Sheikhkhoshkar *et al.* (2024) aim to compile and scrutinize a comprehensive list of control metrics and their functionalities within the construction industry. A multi-step analytical procedure was adopted. Initially, a comprehensive inventory of control metrics and their roles in the construction industry was compiled. This was followed by a quantitative analysis employing social network analysis (SNA) to identify the most critical functionalities. The analysis indicated variability in the significance of control metrics' functionalities (CMF) based on the metric types (lagging and leading) and control levels. The key functionalities identified include project progress and performance management, assessment of look-ahead level performance, evaluation of workflow reliability and stability, examination of the make-ready process, constraint management and quality measurement of construction flow.

Tantiyaswasdikul (2024), conducting systematic reviews and meta-analyses, explores design thinking's (DT) role as a methodology and tool in promoting innovation within the sustainable built environment. This study aims to create a novel model that combines DT and future thinking strategies, paving the way for a cohesive DT and foresight concept for subsequent research and practical uses. The findings of this study highlight the difficulty of predicting the impacts of DT on sustainable built environment innovation. It suggests that innovations bringing new solutions to new contexts tend to gain significant attention, as citation metrics show. The review also points out a research void in merging foresight with DT for sustainability, leading to the development of a foresight DT model to direct future studies and facilitate DT's application in sustainable practices.

Singh and Kumar (2024) examine strategic factors affecting blockchain technology's role in sustainable development goals (SDGs) and environmental, social and governance (ESG) principles within infrastructure projects, especially in emerging economies. Employing a three-stage methodology – initial identification of 13 strategic factors via literature review and expert interviews, further data collection from nine experts and analysis through interpretive structural modeling (ISM) and cross-impact matrix multiplication (MICMAC) – the study pinpoints three critical, independent factors for effective blockchain adoption: data security, identity management and supply chain management. Applying ISM and MICMAC, Singh and Kumar (2024) highlight these factors' hierarchical interplay and dependencies, emphasizing their importance for blockchain implementation in SDG and ESG-focused infrastructure efforts.

Van der Heijden (2024) presents a critical review of public governance within the framework of Construction 4.0, targeting researchers, policymakers and practitioners. This study systematically assesses the academic discourse on this topic using the Preferred Reporting Items for Systematic Reviews and meta-analysis guidelines for source selection. Van der Heijden (2024) uncovers eight key themes central to public governance's role in Construction 4.0, including policy, infrastructure, skill development, digital inclusion, collaboration, data privacy, environmental and societal impacts and the influence of Construction 4.0 on governance. This review underscores a noticeable gap between the theoretical importance of public governance in Construction 4.0 and the limited empirical research on its practical application. This study emphasizes the need for more thorough examinations of governance strategies and their effectiveness in this situation.

Mina Najafi, Moslem Sheikhkhoshkar and Farzad Rahimian

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