Sathursiya, S., Perera, B.A.K.S. and Kavirathna, A.S., 2025. Integration of Lean Kaizen model to enhance material efficiency in construction projects: A literature review. In: Waidyasekara, K.G.A.S., Jayasena, H.S., Wimalaratne, P.L.I. and Tennakoon, G.A. (eds). *Proceedings of the 13th World Construction Symposium*, 15-16 August 2025, Sri Lanka. pp. 895-908. DOI: https://doi.org/10.31705/WCS.2025.67. Available from: https://ciobwcs.com/papers/

INTEGRATION OF LEAN KAIZEN MODEL TO ENHANCE MATERIAL EFFICIENCY IN CONSTRUCTION PROJECTS: A LITERATURE REVIEW

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ABSTRACT

The construction industry, being a major consumer of materials, has increasingly prioritised optimising resource usage, thereby highlighting the importance of Material Efficiency (ME). Meanwhile, lean construction has emerged, promoting value maximisation and waste minimisation, with the Kaizen technique gaining attention for enhancing processes and reducing waste. This study aims to investigate the applicability of the Kaizen model to enhance the ME in construction projects. A comprehensive literature review was conducted, with the content analysis approach employed to analyse the data. The findings indicate that Kaizen can effectively address ME challenges in the construction sector by overcoming associated barriers. Key challenges to ME include a lack of training and awareness, high costs, excessive regulations, and inadequate technological integration, which can be mitigated through Kaizen techniques such as Poka-Yoke, Gemba walks, Jidoka, and 5S. Furthermore, integrating Kaizen with ME is hindered by cultural barriers, insufficient training and involvement, and limited resource availability. To address these challenges, the study recommends implementing industry-wide training and awareness initiatives, strengthening collaboration among project stakeholders, and introducing government incentives and regulatory support for projects prioritising ME and Kaizen practices. This research contributes to theoretical knowledge by bridging the gap in integrating Kaizen to enhance ME in construction and provides practical insights for facilitating its effective adoption through the mitigation of identified barriers.

Keywords: *Kaizen; Lean Construction; Material Efficiency.*

1. INTRODUCTION

The construction industry significantly influences a country's economic development (Ajayi & Oyedele, 2015). It is a major consumer of natural resources and a waste generator, utilising nearly 40% of global energy and contributing to 36% of CO2 emissions (United Nations Environment Programme, 2024). With the growing demand for raw materials driven by population growth, prioritising Material Efficiency (ME) in

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the construction industry is essential to achieving sustainable development (Safa et al, 2014). ME in construction involves optimising resource use to minimise waste, reduce costs, and environmental impact (Almakayeel et al, 2023). In addition, it focuses on improving the lifecycle performance and recyclability of materials (Kabirifar et al., 2020). As resource scarcity and environmental concerns have risen, the importance of ME has grown significantly (Peng et al., 2023). Higher ME levels result in less waste, lower expenses, and improved sustainability (Almusaed et al., 2024). Meanwhile, Babalola et al. (2019) revealed that lean construction techniques have also been linked to quality improvements, productivity gains, and waste reduction.

Lean construction models enhance efficiency and productivity by eliminating non-value-added activities, standardising procedures, and promoting continuous improvement (Ikuma et al., 2011). Karlsson and Tagesson (2021) highlighted the adaptation of lean manufacturing principles to construction, focusing on continuous improvement, waste reduction, and value enhancement. Tools such as the Last Planner System (LPS), Kaizen, Kanban, Integrated Project Delivery (IPD), and 3D BIM are employed to optimise production systems and boost ME (Babalola et al., 2019). The Kaizen model, originating from lean manufacturing, supports ME improvement through small, incremental changes and waste elimination at every project stage (Omotayo et al., 2018). In addition, Okpala et al. (2024) revealed that the Kaizen fosters cooperation among all parties and long-term sustainability of ME gains, supported by systems like total quality management, just-in-time (JIT), total productive maintenance, and small group work. ME is thus continuously assessed and enhanced throughout the project lifecycle with Kaizen's principles (Androniceanu et al., 2023).

The current construction industry faces significant challenges in material wastage and inefficiency (Kabirifar et al., 2020). Meanwhile, Kaizen techniques help to improve productivity and efficiency by identifying and eliminating waste (Cherrafi et al., 2019). Sundararajan and Terkar (2022) discuss how applying Lean-Kaizen principles in the manufacturing sector enhances overall productivity by increasing system efficiency and improving worker satisfaction. In the context of the construction sector, effective material management plays a crucial role in enhancing overall productivity and promoting sustainability (Rodríguez et al., 2022). Accordingly, the application of Kaizen principles has the potential to contribute to the overall productivity of construction projects by mitigating various challenges (Babalola et al., 2019). Therefore, the integration of ME with the Kaizen model could promote resource efficiency in construction projects (Androniceanu et al., 2023). Consequently, there is an industry need for effective integration of the Kaizen model of lean construction to enhance ME in construction. Numerous scholars have explored the implementation of lean concepts within the construction industry (Albalkhy & Sweis, 2020; Babalola et al., 2019), the application of the Kaizen model in lean construction (Omotayo et al., 2018; Syaputra & Aisyah, 2022), and ME in construction projects (Peng et al., 2023). Previous studies have also addressed Kaizen-based solutions for improving energy efficiency (Androniceanu et al., 2023) and enhancing production efficiency in the manufacturing sector (Sundararajan & Terkar, 2022). Furthermore, research has examined the implementation of the Kaizen model to improve performance in housing projects (Ikuma et al., 2011).

However, despite this extensive body of research, no studies have specifically investigated the use of the Kaizen model to enhance ME in construction projects. Moreover, there is a lack of in-depth analysis assessing how Kaizen techniques could

address ME challenges and the barriers to implementing Kaizen with ME in construction. Therefore, this study aims to fill this gap by investigating the applicability of the Kaizen model to enhance ME in construction projects, drawing upon existing literature. Its objectives are to investigate the key challenges of current ME practices in the construction industry, to assess how the techniques of Kaizen can be used to overcome ME challenges in construction projects, and to investigate the barriers of integrating Kaizen with ME in construction.

2. RESEARCH METHODOLOGY

A robust literature review process strengthens knowledge advancement by integrating insights from various empirical studies and developing a structured theoretical foundation (Kraus et al., 2022). Standalone literature reviews enable researchers to critically assess existing scholarship, uncover gaps, and propose directions for future research (Snyder, 2019). In particular, a narrative literature review method offers a detailed synthesis of previously published findings, presented in a descriptive format (Juntunen & Lehenkari, 2021). Accordingly, this study adopts a narrative literature review approach to investigate the applicability of the Kaizen model to enhance ME in construction projects. The literature search was conducted across three academic databases: (i) Google Scholar, (ii) Web of Science, and (iii) Scopus. The search strategy focused on key terms such as "Kaizen", "lean construction", "challenges" and "material efficiency". In selecting the sources, priority was given to journal articles and conference papers published within the past fifteen years to ensure contemporary relevance. Figure 1 illustrates the overall research process adopted in this study.

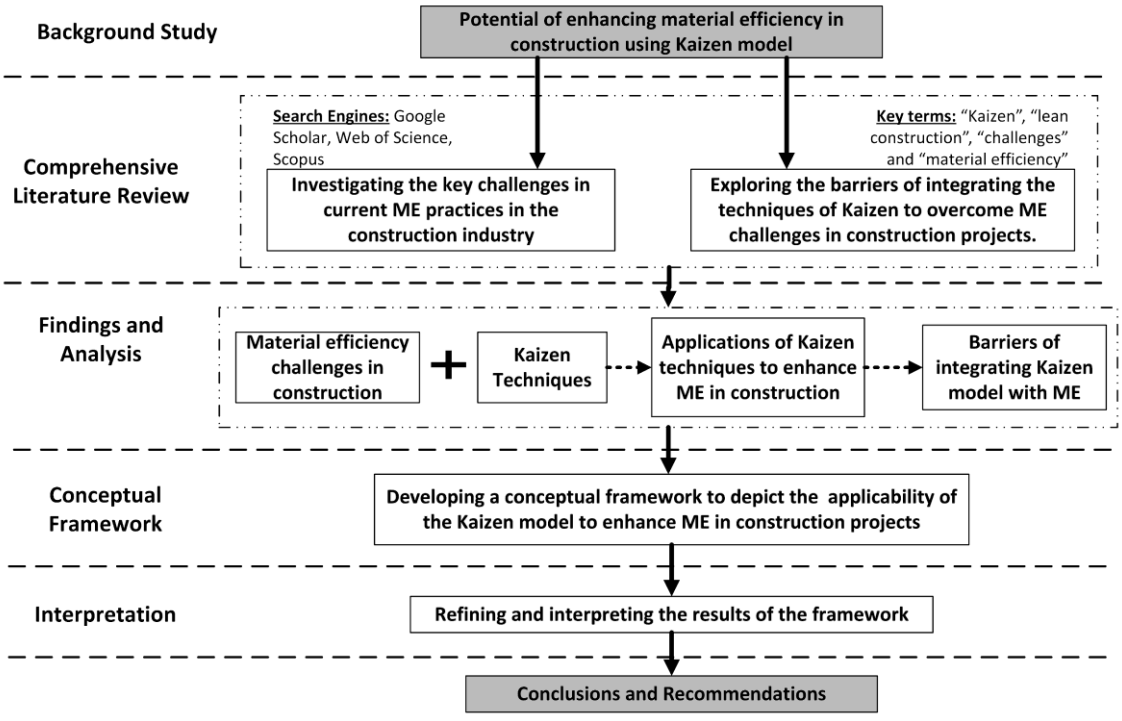

Figure 1: Research process

As presented in Figure 1, the research process commenced with a background study to establish a foundational understanding of the importance of improving ME in the

construction sector and the potential role of Kaizen techniques. Following this, a comprehensive literature review was undertaken to critically examine the existing knowledge on ME challenges in construction, Kaizen techniques, and integration barriers. The data collected were analysed using manual content analysis, a method particularly suited for categorising qualitative data and ensuring contextual sensitivity (Bengtsson, 2016). Manual coding allowed the findings to be systematically classified under major themes and sub-themes, enhancing the clarity and depth of the analysis. This approach is widely recognised for its ability to derive meaningful patterns from narrative data where statistical analysis is not feasible (Stemler, 2015). Thus, content analysis supported the structured exploration of how Kaizen can contribute to overcoming ME challenges in construction projects.

3. FINDINGS

This section explores the key challenges faced by the construction industry in improving ME, along with Kaizen techniques, and their applications to enhance ME in construction. Further, it identifies the barriers to integrating ME with the Kaizen model.

3.1 MATERIAL EFFICIENCY IN THE CONSTRUCTION INDUSTRY

The concept of ME optimises material utilisation in manufacturing processes, minimising waste and environmental impact while addressing material extraction and replenishment to promote sustainability (Ajayi & Oyedele, 2015). Broadly, ME can be defined as the ability to use materials in a way that maximises their functional utility while minimising the input of raw materials, energy, and waste generation (Kabirifar et al., 2020).

3.1.1 Challenges of ME in Construction

The construction industry faces numerous challenges and barriers in improving ME, which are critical for enhancing sustainability and reducing environmental impacts (De Sa & Korinek, 2021). Table 1 summarises notable challenges to implementing ME in the construction industry, identified by various past studies.

Table 1: Challenges of ME in construction

Challenge Category	Main Challenges	Authors (in code)														
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Operational and Management	Poor material handling and storage	•						•			•			•		
	Lack of skilled labour leading to waste and rework					•									•	
	Inadequate site management practices													•		•
Design and Planning	Poor planning, scheduling and coordination		•		•								•			
	Design inefficiencies											•				•

Challenge Category	Main Challenges	Authors (in code)														
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Technological	Lack of effective material procurement planning													•	•	
	Lack of technological integration			•		•						•				
	Lack of access to advanced technologies						•		•						•	
	Obsolete construction technologies											•			•	
Regulatory	Insufficient regulations			•			•	•								
	Lack of government incentives												•		•	
Supply chain related	Lack of availability of sustainable materials								•		•					•
	Poor relationships with suppliers				•					•				•		
	Scarcity of materials		•												•	
Knowledge and Cultural	Insufficient training and awareness on ME practices				•					•						
	Resistance to change												•			•
Financial Constraints	High initial cost in implementing ME solutions	•						•					•			
	Lack of financial support and incentives											•			•	

A:(Abdullah et al, 2024), B:(Ajayi & Oyedele, 2015), C:(Almakayeel, 2023), D:(Bhatia et al, 2020), E:(Brändström et al, 2024), F:(De Sa & Korinek, 2021), G:(Drenth, 2023), H:(Ongechi & Mandala, 2021), I:(De Pinto, 2023), J:(Safa et al, 2014), K:(Mehr & Omran, 2013), L:(Allwood et al., 2013), M:(Sogaxa & Simpeh, 2022), N:(Rodríguez et al., 2022), O:(Pauliuk et al., 2021)

According to Table 1, while planning and management challenges, such as design inefficiencies and poor material handling, are evident, deeper systemic issues like inadequate training and insufficient regulations also critically undermine ME efforts (Almakayeel, 2023). In addition, technological and financial challenges also hinder effective material management in construction projects. Overall, these challenges reflect not only operational shortcomings but also a broader need for cultural and institutional change to embed ME practices within the construction sector.

3.2 KAIZEN AND ITS TECHNIQUES

Lean, originating from the Toyota Production System, is a systematic approach to continuous improvement by eliminating waste and enhancing value (Albalkhy & Sweis, 2020). Lean Construction, first proposed by Koskela, enhances value by eliminating waste and fostering trust and open communication within organisations (Ikuma et al., 2011). The concept of Kaizen, described in lean, was rooted in Japanese philosophy and emphasises continuous improvement through small, incremental changes (Singh & Singh, 2013). It is focused on continuous quality improvement that involves all stakeholders in identifying problems and collaboratively implementing solutions (Jamadar et al., 2021). This concept centres on eliminating non-value-added activities through small, incremental changes to enhance productivity, quality, and efficiency (Cherrafi et al., 2019).

Kaizen techniques focus on continuous, incremental improvements in manufacturing processes, emphasising accountability, value-added analysis, and setting achievable cost-reduction targets within work cells (Sundararajan & Terkar, 2022). These techniques are considered attractive performance improvement methods in practice, as their application costs are low (Okpala et al., 2024). In this study, ten specific Kaizen techniques were identified based on their frequency of mention in the existing literature and their relevance to improving material efficiency in construction. Table 2 presents a summary of the main Kaizen techniques along with their respective sources.

Table 2: Techniques of Kaizen

Techniques of Kaizen	Authors (in code)									
	A	B	C	D	E	F	G	H	I	J
Value stream mapping (VSM)	●	●			●		●	●	●	●
Just In Time (JIT)	●	●			●	●	●		●	
Gemba	●	●		●	●				●	
Plan Do Check Act (PDCA)	●		●				●		●	●
5S					●		●	●	●	●
Muda	●	●			●	●	●			
Poka-yoke	●	●			●		●			
5 Whys		●					●			
Jidoka		●					●			
Andon		●					●			

A:(Cherrafi et al., 2019), B:(Galzignato, 2018), C:(Al-Hyari et al., 2019), D:(Kumar et al., 2015), E:(Androniceanu et al., 2023), F:(Jamadar et al., 2021), G:(Okpala et al., 2024), H:(Önay & Seçkiner, 2024), I:(Podlesny, 2024), J:(Syaputra & Siti Aisyah, 2022)

In the context of construction, Kaizen techniques focus on structured events designed to optimise processes, enhance productivity, standardise workflows, and reduce lead times (Ikuma et al., 2011). As per Table 2, the most highlighted techniques include Gemba, JIT and VSM as they are consistently recognised for their effectiveness in lean construction practices. PDCA and 5S are also considered crucial techniques for identifying and solving problems, ensuring continuous improvement.

3.3 ENHANCING THE MATERIAL EFFICIENCY IN CONSTRUCTION PROJECTS BY INTEGRATING THE KAIZEN TECHNIQUES

Integrating the Kaizen model with ME in construction projects is important as it supports sustainable practices and waste reduction (Önay & Seçkiner, 2024). Sustainable construction prioritises reducing environmental impacts and conserving resources, which relates to ME (Almakayeel et al, 2023). Hence, the synergy between Kaizen and ME can significantly contribute to advancing efficiency in construction practices (Podlesny, 2024). Table 3 summarises the applications of Kaizen techniques in overcoming ME challenges in construction projects.

Table 3: Integrating Kaizen techniques to enhance ME in construction

Main Challenges	Kaizen Techniques	Applications of Kaizen techniques in enhancing ME
Poor material handling and storage	Poka-yoke	Organise tools and materials to reduce time wasted and avoid damage.
Lack of skilled labour leading to waste and rework	5 Whys	Use visual guides or safety triggers to avoid wrong material usage.
Inadequate site management practices	Gemba	Use iterative planning to constantly refine scheduling and procurement strategies.
Poor planning, scheduling and coordination	Jidoka	Identify root causes of procurement delays or design rework.
Design inefficiencies	PDCA	Include real-time observations in site supervision.
Lack of effective material procurement planning	5S	Conduct pilot tests and gradually integrate new technologies in cycles.
Lack of technological integration	Muda	Use real-time digital dashboards to alert teams of tech failures or resource overuse.
Lack of access to advanced technologies	Andon	Create feedback loops between construction professionals and policymakers through pilot projects.
Obsolete construction technologies	VSM	Eliminate waste from over-ordering or long transport routes.
Insufficient regulations	JIT	Track material delivery issues in real time with visual boards.
Lack of government incentives		Create structured, visual environments that improve learning habits.
Lack of availability of sustainable materials		Implement small-scale training and improvement trials to reduce resistance.
Poor relationships with suppliers		Identify and cut unnecessary costs through waste elimination.
Scarcity of materials		
Insufficient training and awareness on ME practices		
Resistance to change		
High initial cost in implementing ME solutions		

Main Challenges	Kaizen Techniques	Applications of Kaizen techniques in enhancing ME
Lack of financial support and incentives		
Authors: (Omotayo et al., 2018), (Cherrafi et al., 2019), (Ikuma et al., 2011), (Jamadar et al., 2021), (Androniceanu et al., 2023), (Arya & Jain, 2014), (Syaputra & Aisyah, 2022), (Önay & Seçkiner, 2024), (Barbosa et al., 2023), (Kumar et al., 2015), (Podlesny, 2024), (Al-Hyari et al., 2019)		

As summarised in Table 3, various Kaizen techniques can be applied to address ME challenges in construction. For instance, the 5S technique directly contributes to enhancing ME by improving the organisation of material storage and handling areas. By systematically sorting and arranging materials, maintaining cleanliness, and standardising storage practices, 5S reduces the time wasted in searching for materials, minimises the risk of material damage, and prevents unnecessary reordering due to misplaced stock (Önay & Seçkiner, 2024). Jamadar et al. (2021) reported that implementing 5S in construction sites not only improved workspace organisation but also led to measurable reductions in material wastage, thereby enhancing overall ME. This demonstrates how the practical application of Kaizen techniques can achieve significant improvements in construction resource management.

Accordingly, lean construction methods, when implemented correctly, hold great potential for reducing waste and resource consumption, thus enhancing the sustainability of building projects (Ikuma et al., 2011). The integration of Kaizen approaches further augments the construction process, particularly by improving lead times and workflow efficiency (Barbosa et al., 2023). This highlights the critical role of lean and continuous improvement models in driving more efficient and productive construction practices. To encourage continuous improvement in construction, professionals must gain a comprehensive understanding of Kaizen concepts (Omotayo et al., 2018). The integration of Kaizen techniques offers significant opportunities to improve ME and sustainability in construction projects. Nevertheless, the construction industry faces several obstacles in adopting the Kaizen model (Albalkhy & Sweis, 2020).

3.3.1 Barriers to the Integration of the Kaizen Model with Material Efficiency

Integrating ME with Kaizen methodologies faces several barriers that hinder effective implementation (Caldera et al., 2019). Understanding these obstacles is crucial for successfully implementing Kaizen in the construction industry. Table 4 summarises some main barriers identified in previous research.

Table 4: Barriers to the integration of Kaizen with ME

ME and Kaizen Integration Barriers	Authors								
	A	B	C	D	E	F	G	H	I
Cultural Barriers		●	●	●	●	●			●
Lack of Training and Involvement	●		●	●	●			●	●

ME and Kaizen Integration Barriers	Authors								
	A	B	C	D	E	F	G	H	I
Limited resources	●	●	●	●	●		●		
Leadership Commitment						●		●	●
Poor Administration							●	●	●
Financial Constraints					●				●
Limited Understanding of Kaizen Principles	●	●							
Regulatory Challenges						●			
Need for Continuous Evaluation						●			
Uncontrolled Inventory									●

A:(Arya & Jain, 2014), B:(Caldera et al., 2019), C:(Cherrafi et al., 2019), D:(Gaikwad & Sunnapwar, 2019), E:(Kabzhassarova et al., 2021), F:(Karlsson & Tagesson, 2021), G:(Kurdve & Bellgran, 2020), H:(Singh & Singh, 2023), I:(Syaputra & Siti Aisyah, 2022)

It is evident from Table 4 that integrating ME with Kaizen is a challenging endeavour. The most common barriers identified include cultural barriers, lack of training and involvement and insufficient resources. Previous studies have highlighted these challenges as the most prominent compared to less significant barriers such as financial constraints, regulatory challenges, and the need for continuous evaluation. For instance, the cultural barriers, including resistance to change and traditional mindsets, largely hinder the implementation of Kaizen techniques in ME practices (Kabzhassarova et al., 2021). To fully attain the benefits of Kaizen, stakeholder participation and effective management are vital (Pauliuk et al., 2021). Al-Hyari et al. (2019) emphasise that a cooperative approach involving all stakeholders is necessary for the successful implementation of Kaizen in construction projects.

4. CONCEPTUAL FRAMEWORK

A conceptual framework serves as a structured guide for exploring the research problem, often developed through a critical review of relevant literature (Juntunen & Lehenkari, 2021). It outlines key factors and relationships in the research scope and can be presented either narratively or visually using flowcharts, mind maps or diagrams (Gaikwad & Sunnapwar, 2019). In line with this, Figure 2 presents the conceptual framework developed to examine the applicability of the Kaizen model in improving ME in construction projects.

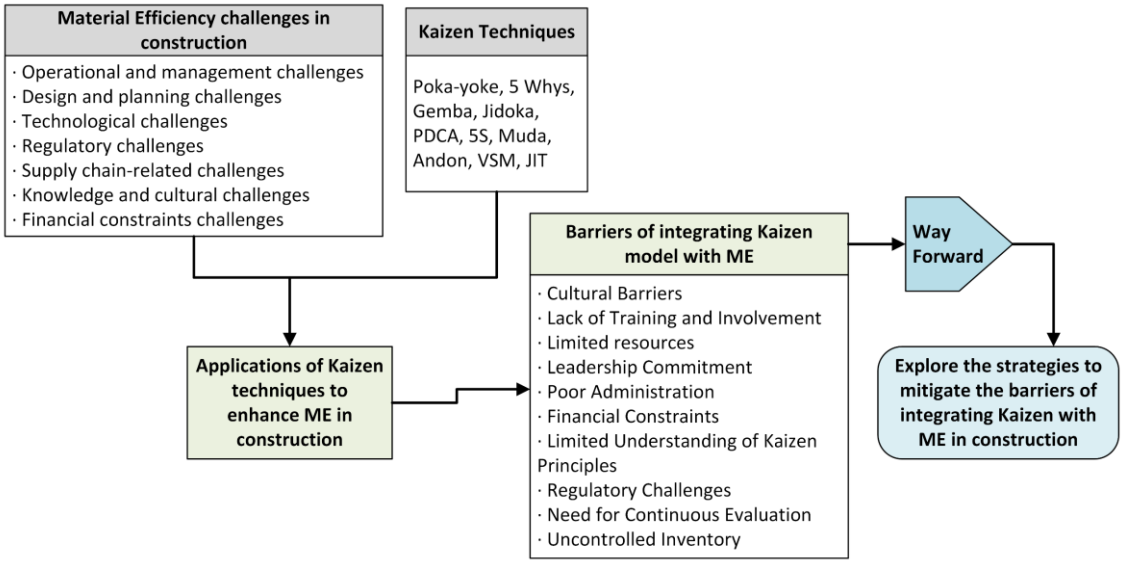

Figure 2: Conceptual framework

As illustrated in Figure 2, challenges related to ME in construction projects can be addressed through the implementation of the Kaizen concept, which emphasises continuous improvement via incremental changes. Figure 2 initially depicts the key ME challenges in construction alongside the Kaizen techniques applicable to address them. By integrating these two aspects, it demonstrates the applications of Kaizen techniques to mitigate ME-related issues. Following this integration, Figure 2 outlines the barriers to implementing Kaizen within ME practices. Finally, it presents the potential future directions as to explore the strategies to overcome the barriers associated with this integration. The application of Kaizen techniques helps to reduce errors in material handling, thereby contributing to waste minimisation and resource conservation (Cherrafi et al., 2019). Furthermore, the adoption of the Kaizen model supports the achievement of sustainability goals within the construction industry (Omotayo et al., 2018). However, integrating Kaizen into ME practices require careful consideration, as several barriers, including cultural barriers and limited understanding of Kaizen among stakeholders, may impede this process (Caldera et al., 2019; Kabzhassarova et al., 2021). Consequently, future research should focus on identifying and developing effective strategies to overcome these barriers and facilitate the successful application of Kaizen techniques to enhance ME in the construction sector.

5. CONCLUSION AND RECOMMENDATIONS

This study aims to investigate the applicability of the Kaizen model to enhance ME in construction projects based on existing literature. The findings suggest that the integration of the Kaizen techniques and ME holds significant potential for the construction industry, particularly in terms of reducing material waste and promoting sustainability. Moreover, it is highlighted that the importance of continuous improvement in construction processes, where the implementation of Kaizen can drive efficiencies and enhance the overall performance of construction projects. However, barriers such as cultural barriers, limited training and understanding, and poor administration need to be addressed to fully realise the benefits of this integration. Accordingly, it is recommended that industry-wide training and awareness programs be implemented, promote stronger collaboration

between all project stakeholders, from planners to suppliers, and offer government incentives and regulatory support for projects that prioritise ME and Kaizen techniques. This study contributes to theory by extending existing knowledge on lean construction by specifically investigating the applicability of the Kaizen model to enhance ME in construction projects, an area that has received limited focused attention in prior research. In terms of industrial contribution, this study highlights the importance of adopting Kaizen techniques to improve ME, identifies the key barriers hindering their integration in construction practices, and proposes actionable recommendations for industry stakeholders to enhance resource efficiency, sustainability, and overall project performance. Considering the limitations of this study, primarily its reliance on a literature review, there is potential bias in article selection and exclusion of non-English publications, which may not fully capture the relevant findings. Consequently, the generalisability of the results is limited. Nevertheless, despite these limitations, this study can serve as a benchmark for future in-depth research in this area.

Further studies are directed to explore the strategies to overcome the barriers to integrating Kaizen and ME in construction, encouraging its practical application. Methodologies such as case studies and surveys can be adopted to examine the real-world applications of Kaizen in ME practices and to capture stakeholder perceptions of this adoption. Additionally, comparative studies between developing and developed countries are recommended to understand how contextual factors influence the integration of Kaizen and ME in construction, thus guiding targeted implementation strategies globally.

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