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Key Strategies to overcome barriers in Lean Construction implementation

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ABSTRACT

Implementation of Lean Construction practices within the Malaysian construction industry has improved since the introduction of lean in Malaysia. The implementation of lean construction focused on improving the workflow, improving scheduling, reducing cost, and reducing waste of construction material. However, multiple studies have proven barriers are affecting the implementation of lean construction. Thus, the purpose of this study is to provide recommendations to overcome the barriers that hinder the implementation of lean construction. A mixed methodology was used in this study, involving two stages of data collection with a particular focus on identifying barriers and proposing strategies to overcome them. The first stage was collecting data through a structured questionnaire distributed to Grade G7 contractors operating within the Klang Valley. The instrument was designed to identify the barriers affecting the implementation of Lean Construction and recommendation to overcome it. The collected responses were subsequently analysed using descriptive statistical methods. The second stage, 5 construction industry practitioner were interviewed through semi-structured interview to obtain recommendation to overcome the identified barriers affecting the implementation of Lean Construction. As a result of this study, multiple recommendations were introduced to overcome barriers affecting the implementation of lean construction such as combination of strategic and practical measures is essential. Enhancing continuous training, awareness programme, strong leadership and commitment from top management are among the recommendations introduced in this study. These recommendations are essential to further improve lean implementation in Malaysia construction industry.

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1. INTRODUCTION

In Malaysia, multiple construction techniques have been developed and implemented throughout various construction projects. Each construction technique serves its own purpose such as to improve the efficiency of construction as well as improve cost budgeting. These construction techniques are important as the construction industry in Malaysia is crucial to the Nation's economy. The Malaysian construction industry shows a moderate growth trend in the recent years as investment in construction industry increased (Dehdasht et al., 2021). The construction industry has proven to be one of the major economic contributors to various countries. In China, new infrastructure investment encourages technological innovation, improves productivity, enhances industrial structures and ultimately improve the economic growth of the country (Du et al., 2022). Thus, multiple construction techniques have been introduced to Malaysia's construction industry to improve the efficiency of construction as well as improve the nation's economic growth.

In today's time, lean construction is one of the many construction techniques introduced in Malaysia. Lean construction has been proven to be not only beneficial in terms of cost of construction, but it can also reduce construction waste and improve construction efficiency. Lean philosophy is to approach in a different direction to maximise the value while also reducing waste, increasing construction efficiency and improve the client's satisfaction (Marhani et al., 2013). The introduction of lean construction aligns with the Malaysia's policy in promoting green technology as its main benefit is reducing waste. Today, Malaysia's construction sector is focused on achieving sustainable development goals, which implementation of various green initiatives such as the Green Building Index (Zakaria et al., 2024). However, lean construction implementation rate has remained low even if it was proven to be a green technology.

1.1 Lean construction

Lean is a method used in various industries to gain common benefits such as reducing waste while improving the efficiency of the product. Lean was originally introduced by Toyota Motor Company to improve the efficiency of product making (Habib et al., 2023). Using lean introduced by Toyota, it was perfected by Henry Ford, who invented the assembly line for the Model T in the early 1900s (Demirkesen, 2021). However, as one introduced lean while the other perfected lean. Neither uses the same lean tools to improve their manufacturing. In the case of Toyota, the chief of Toyota, Taiichi Ohno, introduced the Toyota Production System (TPS) which focuses on reduction of seven wastes to improve the satisfaction of customer value (Yamamoto & Milstead, 2019). While in the case of Ford, it introduces a Daily Management System or DM which promotes visual workflow management, local accountability, and daily problem solving (Zarbo et al., 2015). As years passed, lean has developed various types of lean tools that have been implemented in multiple industries such as car manufacturing, the food industry as well as construction industry. Lean tools such as Last Planner System, Information Integrated Project Delivery, Building Modelling, 5s, and Kaizen Events have been introduced in which many were created by combining various tools (Banna, 2023). Thus, lean tools are also used in the construction industry.

The implementation of Lean Construction (LC) in Malaysia has the potential to significantly enhance project performance through improved efficiency, reduced waste, and better value delivery, as evidenced in numerous studies (Abdelhamid et al., 2008; Koskela, 1992; Ballard & Howell, 2003). By adopting LC principles such as continuous improvement, collaborative planning, and value maximisation, construction

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projects can achieve higher productivity levels, minimise cost overruns, and improve overall quality outcomes, which are particularly relevant in addressing inefficiencies within the Malaysian construction industry. Furthermore, LC encourages stronger stakeholder integration and more reliable workflow management, contributing to timely project delivery and enhanced client satisfaction. However, despite these promising benefits, the implementation of LC in Malaysia remains limited due to various barriers, including resistance to change, lack of awareness and expertise, insufficient training, and the fragmented nature of the industry, all of which continue to hinder its widespread adoption.

1.2 Barriers in lean construction implementation

Lean construction has been proven to contribute major benefits towards various construction projects. This implementation managed to not only reduce waste but improved the construction productivity. Nevertheless, the implementation rate is still unsatisfactory. Many barriers have been identified in previous studies to be capable of overcoming. A barrier that is commonly known in various types of new developments is the lack of awareness among practitioners. Awareness in lean construction remained low as shown in previous studies. The level of awareness remains low in terms of awareness of lean techniques based on the previous study (Musa et al., 2023). Awareness of lean in construction remained low due to differences in the background of workers, different working experience and gap in level of education (Faizal et al., 2023). This barrier in lean construction is due to lack of understanding of lean principles and techniques (Likita et al., 2022). An understanding of lean is important to ensure effectiveness when implementing. Thus, more awareness efforts and knowledge distribution need to be made.

Other barriers that have been known effecting adaptation of lean construction is the limitations of financial resource. In many other industries in the world, limitation in financial and resources are one of the main issues preventing a successful project. In lean construction, it has remained as one of many limitations preventing a success lean implementation. While Lean practices are intended to generate long-term cost savings, their initial adoption often requires substantial investment in training, system development, process restructuring, and technology integration, which demand both financial capability and organisational preparedness. Due to increased costs associated with hiring experts and organising training sessions, many managers opted out of adopting lean (Jain & Rathore, 2016). Insufficient funding remains a barrier to the effort to adopt lean (Moradi & Sormunen, 2023). Small and Medium Enterprises (SMEs) also face comparable challenges, including financial, human, and technical constraints when attempting to adopt Lean practices(Anuar et al., 2023). In a study conducted in the United Kingdom, lack of funds has posed a significant challenge for small industries to successfully implement lean (Maware et al., 2022). These showed that funding is important to successfully adapt lean not only in the construction industry but also in many other industries. As a result, limited financial capacity, shortage of skilled personnel, and lack of technological support continue to restrict organisations from fully implementing Lean Construction.

Lastly, to successfully implement lean requires the support from all involved parties including top management. Leadership are important as many hard and crucial decisions need to be made and this requires full support from management. Lean construction implementation is low due to new techniques not having have enough support from management (Albalkhy & Sweis, 2021; and Marhani et al., 2013). Overall, these barriers are interrelated and collectively hinder the successful adoption of Lean Construction. Addressing them requires a comprehensive approach involving organisational change, capacity building, and strong

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leadership commitment. Understanding these barriers is essential for developing effective strategies to improve implementation and enhance project performance.

2. METHODOLOGY

This study employed a two-stage mixed-methods approach using a sequential explanatory design to obtain comprehensive data. The quantitative phase was conducted first, followed by a qualitative phase to further explain and enrich the initial findings. This approach provided a deeper understanding of the barriers to Lean Construction implementation. The quantitative phase involved a questionnaire survey distributed to G7 contractors in Malaysia, focusing on the Klang Valley area. Purposive sampling was used to select respondents with relevant construction experience. G7 contractors were selected because they are classified by the Construction Industry Development Board (CIDB) as the highest-grade contractors, indicating substantial experience in large-scale and high-value projects. After reviewing registered G7 contractors through the CIDB website, Raosoft software was used to calculate the required sample size. Based on a research population of 6021 obtained from registered contractor in CIDB, a sample size of 160 respondents was recommended, as shown in Figure 1.

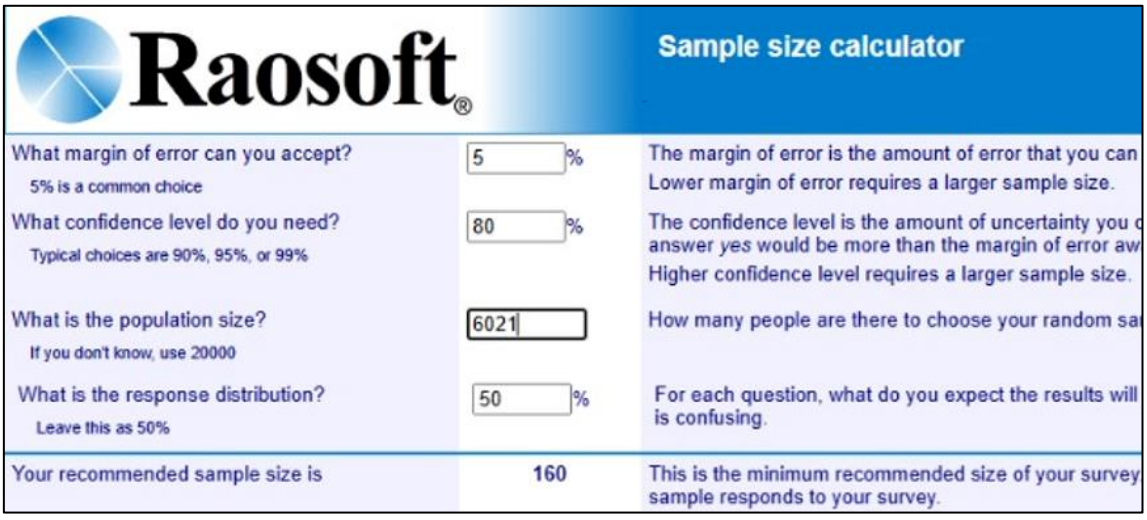


Fig. 1. Sample size calculator

A five-point Likert scale was employed to measure respondents' levels of agreement in identifying the barriers to lean construction (LC) implementation in Malaysia. The quantitative data were analysed using statistical software (e.g., SPSS), applying descriptive statistics and ranking analysis to determine the most significant barriers.

Subsequently, based on the findings obtained from the questionnaire survey, semi-structured interviews were conducted with selected participants. Several potential interviewees were invited to provide their insights into strategies to overcome the identified barriers. Given their extensive on-site experience, their perspectives were considered valuable in formulating effective approaches to address these barriers. Out of

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several invitations to potential interviewees, 5 respondents agreed to be interviewed to provide necessary opinions and hindsight to overcome the barriers affecting the lean construction implementation. Interview questions were developed to guide them during the interview session and lastly, provide the necessary information for the method to overcome identified barriers in lean construction implementation.

3. RESULTS AND FINDINGS

3.1 Demographic background

Table 1. Respondents' position in company

Position in company	Frequency	Percent (%)
Architect	18	16%
Engineer	17	15%
Quantity Surveyor	21	17%
Project Coordinator	17	15%
Project Director	14	13%
Project Manager	15	14%
Site Supervisor	11	10%
Total	113	100%

As shown in Table 1, 113 respondents have responded to the survey which is around 71% from the original target of 160 respondent. Out of 113 respondents, the largest group of respondents were Quantity Surveyors, which comprises 21 individuals (17%). This was followed by Architects with 18 respondents (16%) ranked as the second highest respondent from the questionnaire. Next, both the Engineers and Project Coordinators each accounted for 17 respondents (15%), while Project Managers represented 15 respondents (14%). The second lowest number of respondents is the Project Directors which consists of 14 respondents (13%). Lastly, the smallest group, Site Supervisors, made up 11 respondents (10%). All respondents are from G7 contractors with different positions in the company.

Table 2. Respondents' years of service

Years of service	Frequency	Percent (%)
1-5 years	45	40%
6-10 years`	42	37%
More than 10 years	26	23%
Total	113	100%

The results of data analysis are shown in Table 2, 45 individuals or up to 40% of the respondents have experience of working from 1 year and up to 5 years. This result also shows that the second highest number of respondents have years of experience from 6 years and up to 10 years. This group consists of 42 respondents (37%). Lastly, the lowest respondents group comprised of 26 respondents (23%) with working experience of more than 10 years.

Table 3. Respondents' level of implementation of lean construction

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Level of implementation of lean construction	Frequency	Percent (%)
Always	10	9%
Often	15	13%
Occasionally	11	10%
Rarely	16	14%
Never	61	54%
Total	113	100%

As shown in Table 3, the level of Lean Construction implementation among respondents is categorised into five Likert-scale levels: Always, Often, Occasionally, Rarely, and Never. The findings indicate that the majority of respondents which consisted of 61 individuals (54%), reported that they never implement Lean Construction techniques in their projects. While more than half of the respondents reported never implementing lean construction techniques in their projects, around 16 respondents (14%) stated that they rarely do so. In contrast, 10 respondents (9%) indicated that they always apply Lean practices, and 15 respondents (13%) reported that they often implement them. Lastly, 11 respondents (10%) occasionally use Lean Construction techniques. Overall, the results suggest that most respondents either rarely or never adopt Lean Construction, indicating that the level of implementation within the Malaysian construction industry remains relatively low.

3.2 Barriers in lean construction implementation

Table 4: Barriers in lean construction implementation

Key barriers in lean construction implementation	Std. Deviation	Mean	Rank
Lack of management commitment and support.	0.589	4.33	1
Financial and resource constraints prevent proper implementation.	0.560	4.27	2
Tight project schedules make Lean Construction challenging to implement.	0.532	4.25	3
Lack of awareness about Lean Construction principles and benefits.	0.739	4.19	4
Difficulty integrating Lean practices with existing systems.	0.586	4.18	5

From the data analysis table, the main barrier affecting lean construction implementation is the lack of management commitment and support. The results show that lack of management commitment and support ranked first with the highest mean value of 4.33 and has a low standard deviation result of 0.589. This result indicates that significant limits in successful implementation are due to the top management not committing to and supporting the implementation effort. Top management plays a critical role in Lean Construction adoption, and insufficient leadership will likely affect the implementation process on the project. Other than that, the low standard deviation results suggested that this issue is recognised within the industry. Thus, to overcome these barriers, it is crucial that leadership must play their roles to improve the lean construction implementation effort.

The second rank is the financial and resource constraints with a recorded mean value of 4.27 and a standard deviation of 0.560. Limited financial capacity, manpower and resources will hinder the effort to implement lean construction especially hindering the training and new development that can be used by the management to increase the rate of implementation. By providing new development, training courses, and guidelines, it can improve the awareness and knowledge among construction practitioners in Malaysia. Any new development on lean tools to further improve the lean implementation results will face restrictions due to the lack of financial resources.

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Next, the third most significant barrier is tight project schedules. This barrier is ranked third with a mean value of 4.25 and a standard deviation of 0.532 as it indicates that time pressures and fast-track project delivery environments will create difficulties in applying lean practices in various projects. Thus, to utilise and improve lean practices in construction projects, a proper well plan and structured scheduling as well as improved coordination are critical to achieving the intended benefits of the Lean construction implementation. As a result, as shown in the analysis table, constrains in scheduling are operational challenges and effecting the implementation of lean construction.

The lack of awareness of Lean Construction principles and benefits ranked fourth, with a mean score of 4.19 and a standard deviation of 0.739. In this barrier, the relatively high mean indicates that limited understanding and awareness remain key barriers to effective implementation. This result may be corelated with the third-ranked barriers, such as a lack of financial hinder the effectiveness of awareness campaigns and training courses. This is results is further supported by the standard deviation, which shows some variability in responses. The variation suggests differences in respondents' opinions, exposure, experience, and familiarity with lean concepts across the industry. While some respondents demonstrated lower levels of understanding, others recognised the importance of Lean Construction and identified lack of awareness as a significant challenge. Overall, this highlights the inconsistency in Lean knowledge among industry practitioners.

The difficulty in integrating Lean practices with existing systems was ranked fifth among the five key barriers to Lean Construction implementation. This is results is supported by a 4.18 mean value and a standard deviation of 0.586. Nevertheless, the relatively high mean also indicates that respondents generally agree that system integration is a significant barrier to successful Lean implementation, which must be overcome to improve the implementation rate. Next, this finding also highlights the challenges of aligning Lean approaches with traditional project management systems and fragmented project delivery methods. Lastly, it is suggested that such integration issues can negatively impact the site coordination, as well as disrupt information flow, and hinder process standardisation, which as a result, greatly reduces the overall effectiveness of Lean Construction practices.

Overall, the result of these findings from this study have shown that managerial, financial, and project-related constraints are the most significant barriers hindering the implementation effort of Lean Construction. Other factors such as organisational knowledge and system integration also contribute to the barriers in implementing lean construction, although to a lesser degree. These results establish a clear prioritisation of barriers, allowing industry stakeholders to concentrate their efforts on addressing the most critical factors that limit the effective adoption of Lean Construction practices.

3.3 Strategies to overcome barriers in lean construction implementation

Demographic Background of The Interview Participants

After contacting several respondents from the survey questionnaire, only 5 respondents have agreed to participate in the interview session. The interviewees were then asked about their preference on the approach of the interview such as the date, time and method of interview whether via face to face or via online or phone call. After several discussions were held between interviewees and interviewer, 3 interviewees have opted to be interviewed face to face at their respective companies, while 2 interviewees agreed to be interviewed via telephone.

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Table 5. Interviewees' profile

Participants' reference	Organization	Position	Remarks	Interview approach
P1	Contractor	Contract Executive	Gadang Engineering (M) Sdn Bhd	Face to face
P2	Contractor	Assistant Contract Manager	Signature International	Face to face
P3	Contractor	Senior Quantity Surveyor	Binary Construction	Telephone
P4	Contractor	Project Executive	Kayangan Kemas	Telephone
P5	Contractor	Quantity Surveyor	Regional Utilities Sdn Bhd	Face to face

Based on Table 5, all respondents who agreed to be interviewed are from a contractor company located in Klang Valley. Respondents P1 and P3 are from a construction company specialise in infrastructure work. While Respondent P2 is from a construction company specialising in interior works. Respondent P4 specialises in high-rise residential buildings, and Respondents P5 specialises in water utilities and solar work.

Strategies to Overcome Barriers in Lean Construction Implementation

A total of five key barriers were identified from the questionnaire survey findings as significantly hindering the implementation of Lean Construction namely, lack of management commitment and support, financial and resource constraints prevent proper implementation, tight project schedules make Lean Construction challenging to implement, lack of awareness about Lean Construction principles and benefits, and difficulty integrating Lean practices with existing systems. Subsequently, the interviewees were invited to provide their expert opinions on potential strategies to address and overcome these challenges.

Analysis of Barrier 1: Lack of Management Commitment and Support

To overcome the barrier of insufficient management commitment in Lean Construction, a multi-faceted approach involving active leadership, strategic communication, and consistent oversight is required. Research findings suggest that the foundation of a successful Lean transition lies in leadership management, where top-level directors must go beyond formal endorsement to demonstrate "commitment through action." This includes active participation in Lean meetings and the strategic allocation of resources, as their physical presence and financial backing signal the project's priority to the rest of the workforce. Hence, Respondent P2 suggests that leadership must actively participate in decision-making to address the lack of management commitment and support.

"I noticed that when directors do not attend Lean meetings, staff assume it is not important. Leadership must actively participate and allocate proper resources to show real commitment." Respondent P2.

Complementing this leadership is the need for clear communication and structural accountability. Management must ensure that the purpose and benefits of Lean are transparently communicated across all organisational levels to align company expectations. Respondent P1 emphasised that management commitment must be communicated between all parties to set company or project expectations. By integrating Lean initiatives directly into Key Performance Indicators (KPIs), the organisation transforms

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Lean from a vague concept into a measurable, sustained strategy that ensures long-term accountability. Finally, regular reviews and periodic monitoring serve as the enforcement mechanism for these strategies.

"If management only approves policies but does not monitor progress, Lean becomes ineffective. Regular reviews and accountability mechanisms are necessary." Respondent P3.

Respondent P3 explained that when management reviews Lean progress often, joins coordination meetings, and asks for performance updates, it shows that Lean practices matter at every project level. Through consistent performance updates and participation in coordination meetings, management fosters a culture of discipline and responsibility, ensuring that Lean practices are effectively implemented and maintained throughout the project lifecycle.

Analysis of Barrier 2: Financial and Resource Constraints Prevent Proper Implementation

To overcome financial and resource constraints, the research highlights three strategic initiatives centred on proactive planning and education. First, allocating a budget during the early planning or tender stages. Most respondents agree that by allocating budget in early planning can overcome the financial and resource constraints suffered in majority projects. This effort is essential to shift the perception of Lean from an "additional cost" to a long-term investment. By earmarking funds for training and system improvements, companies can significantly reduce material waste and rework, ensuring that resource implementation is properly executed without risking cost overruns. This initiative is supported by Respondent P1 which stated,

"Many companies see Lean as an additional cost. However, allocating a small budget for training and system improvement at the beginning can reduce long-term waste." Respondent P1.

Next, fostering a clear understanding of the Return on Investment (ROI) is crucial to influence clients and contractors to consider adopting lean in construction projects. By introducing ROI of Lean-to construction practitioners, all party will understand the benefits of implementing lean in construction projects. More resources will be allocated to ensure the effectiveness of lean implementation on site because of understanding the ROI of lean. Finally, introducing Lean tools, starting with simple applications on ongoing sites, serve as a proof of concept. While Lean is most effective when integrated from a project's inception, demonstrating its impact mid-project encourages practitioners to adopt more structured and advanced systems. It can encourage construction practitioners to consider implementing lean on future projects after seeing the effect of implementing lean on projects.

Analysis of Barrier 3: Tight Project Schedules Make Lean Construction Challenging to Implement

To tackle the challenges of tight project scheduling, Lean principles must be deeply embedded into the initial project phases and supported by consistent communication. First, integrating Lean tools, such as the Last Planner System, directly into the planning phase will increase the effectiveness of lean implementation throughout the project duration. It enhances workflow predictability and reduces delays as implementation of lean will shift the scheduling to a more advanced, easy-to-work schedule.

"Schedule pressure makes teams focus only on completion, not process improvement. Lean should be integrated during planning phase." Respondent P2.

This highlights that Lean should not be viewed as additional work but should be aligned with existing scheduling tools to ensure practices are not ignored when timelines become compressed. By including lean

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in early planning, it can reduce and overcome the tight project schedules as lean has been proven to reduce the risk of delay. Furthermore, in terms of establishing regular coordination meetings between site teams, management, stakeholders, and other essential parties. This regular meeting or "look-ahead" planning is important for the upcoming two to six weeks, which allows stakeholders to align tasks and resolve potential resource or staffing issues before they escalate, improving schedule reliability and the management of tight deadlines.

Analysis Of Barrier 4: Lack of Awareness About Lean Construction Principles and Benefits

To improve the adoption of Lean principles, most interviewees emphasise the need for comprehensive training and awareness programmes. This programme can be a workshop and sharing sessions with a clear objective such as to clear up common misunderstandings or demonstrate that Lean is more than just a cost-cutting measure.

"Many staff misunderstand Lean as just cost-cutting. Training and awareness programmes are necessary." Respondent P1.

Next, integrating these principles into Continuous Professional Development (CPD) programmes further ensures a structured, long-term learning framework that elevates Lean techniques to a permanent professional standard. CPD is crucial for professional roles such as quantity surveyors and project managers as they need CPD points to maintain and enhance professional skills, staying competitive, and advancing career. Additionally, practical first-hand demonstrations on-site allow staff to witness the immediate benefits of Lean tools. These benefits such as reduced rework and streamlined workflows are important to encourage lean implementation towards future development.

Analysis of Barrier 5: Difficulty Integrating Lean Practices with Existing Systems

Recommendation for the last barrier is lean principles can be integrated with existing construction systems. By introducing Lean tools such as pull-driven or just-in-time methods to construction projects, all parties can evaluate their compatibility with current operations with lean tools. It will allow staff to adapt progressively, maintaining stability and reducing resistance to change. To further support this integration, using techniques like process mapping can identify areas for improvement without disrupting overall workflows. Additionally, implementing digital project management software allows teams to monitor progress while improving coordination more effectively. This achievement can be achieved by integrating Lean tracking within existing digital platforms. Lastly, the involvement of the site team in the redesign process is crucial. Site teams are more knowledgeable as they manage daily operations. The participation of site teams also fosters a sense of ownership and ensures that Lean practices are both practical and realistic for on-site conditions.

3.4 Comparison with previous study

As a result of this research, the barriers identified are quite similar to previous research which was conducted in various locations such as lack of management commitment and support as well as awareness. Jadhav et al. (2015) indicated that the barriers to the implementation of lean tools, JIT production also experienced lack of management support in improving lean implementation. Lodgaard et al. (2016) mentioned that the lack of management support is not a top barrier. However, the top barrier in lean

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implementation is lack of knowledge on lean which can be simplified as lack of awareness on lean. These results show that in various research, the barriers that are faced in lean implementation are quite similar.

Thus, it is essential that this research constructed a framework in overcoming these barriers in future lean implementation.

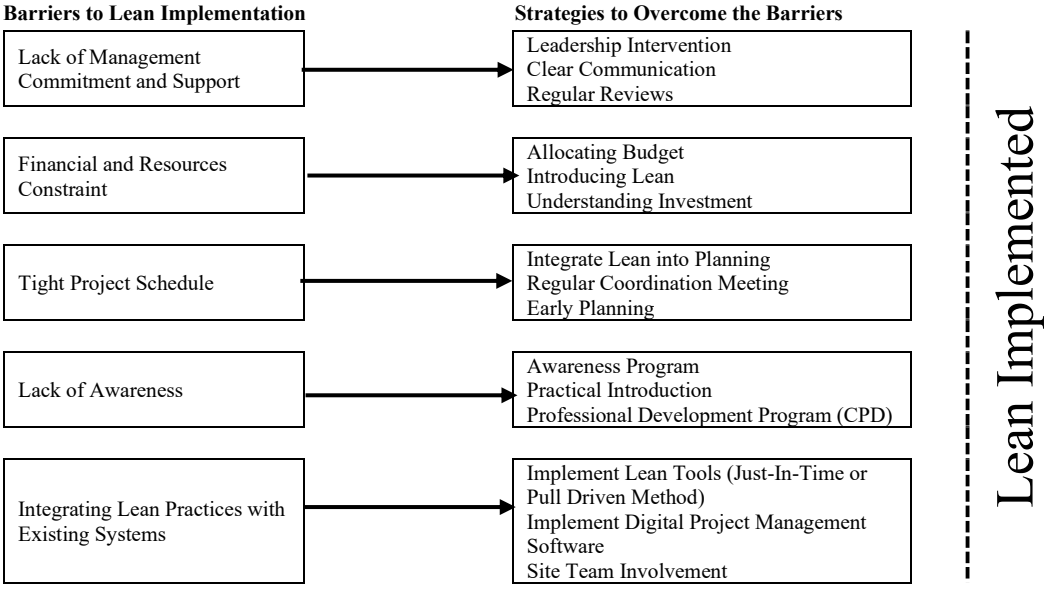


Fig. 2. Framework strategies to overcome key barriers in lean construction implementation

4. CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

In conclusion, the findings show that Lean Construction implementation among G7 contractors in the Klang Valley remains relatively low, with most respondents rarely or never applied Lean practices in their projects. The study identified several key barriers to implementation, including limited management commitment, financial and resource constraints, tight project schedules, low awareness, and difficulties integrating Lean practices with existing systems. These barriers suggest that the challenges are not only technical, but also organisational and cultural. Since Lean Construction offers recognized benefits, such as improved construction efficiency and reduced waste, these barriers must be addressed strategically. Improving implementation requires a holistic approach that includes stronger leadership involvement, enhanced training and awareness, better resource planning, and early integration of Lean principles into project planning. By addressing these issues, Malaysia's construction industry can strengthen Lean adoption, improve project performance, increase productivity, and achieve more sustainable outcomes. As a result of the development of the framework, future research can focus on the effect of implementation of the framework to understand the benefits and limitations of the framework. This will open for new opportunities to further enhance the framework to develop a more proper and effective framework in lean implementation.

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6. CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders. The authors testify that all authors have contributed significantly to the work, and legitimacy of the data and its interpretation for data availability/supplementary materials. This manuscript has not been submitted for publication, nor has it been published in whole or in part elsewhere.

7. AUTHORS' CONTRIBUTIONS

Imilia Husna Dilah: Conceptualisation, methodology, formal analysis, investigation and writing-original draft; **Wan Norizan Binti Wan Ismail**: Conceptualisation, methodology, and formal analysis and validation; **Siti Sarah Mat Isa**: Conceptualisation, supervision, and formal analysis; **Muhammad Adam Shaharuddin**: Conceptualisation, methodology, writing- review and editing, and validation.

8. DATA AVAILABILITY/SUPPLEMENTARY MATERIALS

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

9. ETHICS STATEMENT

This study was reviewed and approved by the Institutional Ethics Committee of Universiti Teknologi MARA (Approval No: REC/04/2025 (PG/MR/220)). All procedures involving human participants were in fulfilment of the ethical standards of the 1964 Helsinki Declaration. Informed consent was obtained from all participants, and data anonymity was strictly maintained throughout the study.

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