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Awareness of Lean Construction Concepts in the Construction Industry of the UAE

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Abstract

Question: Could a lack of awareness be the main obstacle to the adoption of Lean construction in the U.A.E.?

Purpose: This research aims to investigate the extent of familiarity with lean construction principles and tools among engineers in the construction industry of the U.A.E and determine whether this lack of awareness is the major barrier to the implementation of lean construction practices in the U.A.E.

Research Method: The paper employs a comprehensive literature review, quantitative surveys, and a qualitative case study among the engineers in the construction industry of the U.A.E.

Findings: The study found that while many engineers were unfamiliar with the specific terminologies of LC concepts, they demonstrated an understanding of the underlying principles. This suggests that lack of awareness may not be a significant barrier, especially considering the increasing awareness among recent graduates. Additionally, when implementing LC into a firm, challenges such as resistance to change and lack of motivation were identified as more prominent barriers than lack of awareness.

Limitations: The paper is based on 136 survey respondents and a single case study in a consultancy firm in the U.A.E, and future studies should seek to build on and refine the findings presented here.

Implications: While the engineers in the study exhibited awareness, it would be presumptuous to generalize this finding to the entire industry.

Value for authors: The study underscores that challenges in LC adoption can vary based on multiple factors therefore it is important to thoroughly assess the root causes of the barriers rather than opting for generic solutions.

Keywords: Lean construction, Lean practices, Lean tools, Barriers, Awareness.

Paper type: Full Paper

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Introduction

The construction sector in the UAE stands as a key pillar of the nation's economy, driving significant income and fostering economic growth. The UAE construction market is projected to be valued at USD 41 billion in 2024, with an anticipated growth to USD 50.40 billion by 2029, representing a compound annual growth rate (CAGR) of 4.26% during the forecast period spanning from 2024 to 2029 ("UAE construction market insights," n.d.). Despite these figures, the industry continues to rely on traditional management practices (Mbe 2016), leading to inefficiencies and reduced productivity compared to other sectors (Nawi, Baluch, and Bahauddin 2014).

The construction industry has long been characterized by inefficiencies, waste, and fragmented processes (Teo & Loosemore, 2001). As projects grew in complexity and scale, the need for innovative approaches to enhance productivity and deliver value became increasingly apparent. This backdrop led to the emergence of Lean Construction (Koskela et al., 2002). Although various interpretations of Lean Construction exist, a universally accepted definition remains elusive (Mossman, 2018). This paper defines Lean Construction as "a way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value," as defined by Lauri Koskela, Greg Howell, Glenn Ballard, and Iris Tommelein in 2002 (Koskela et al., 2002).

Lean Construction traces its roots to the Lean Manufacturing movement, which originated in the mid-20th century with the Toyota Production System (TPS) (Gao & Low, 2014; Arunagiri and Gnanavelbabu 2014). This system was developed to streamline manufacturing processes by reducing waste, improving quality, and enhancing efficiency (Le and Nguyen 2021; Amunzu, 2020; Oehmen and Rebentisch 2010). Lean principles emphasize the importance of customer value and the relentless pursuit of waste elimination. In the manufacturing context, this meant refining workflows, minimizing excess inventory, and fostering a culture of continuous improvement (Ferrazzi & Alberto, 2023).

The adaptation of lean principles to construction began in the 1990s, driven by a recognition that traditional construction practices often led to significant waste, including time delays, material overuse, and labour inefficiencies (Koskela et al., 2002). Two concurrent development paths marked the early evolution of Lean Construction. The first path began in the late 1980s and early 1990s when Dr. Lauri Koskela, a construction academic, questioned the industry's chronic inability to deliver projects on time, within budget, and to the desired quality. He attributed this persistent issue to the lack of a comprehensive theory of production in construction and proposed the Transformation-Flow-Value (TFV) theory (Ballard, 1994). This theory emphasized the importance of understanding construction as a complex process involving the transformation of materials, the flow of information, and the creation of value for stakeholders (Ballard, 1994). Simultaneously, the second path was pioneered by Prof. Greg Howell and Dr. Glenn Ballard, who sought to develop a management system that could provide reliable workflow on construction sites (Kim, 2014). Ballard and Howell's analyses of project plan failures indicated that normally only about 50% of the tasks on weekly work plans are completed by the end of the plan week. They posited that constructors could mitigate many of the issues causing these failures through "active management of variability, starting with the structuring of the project (temporary production system) and continuing through its

operation and improvement (G. Ballard & Howell, 2003). Their work led to the creation of the Last Planner System® (LPS), which focuses on collaborative planning and commitment-based scheduling (Abdelhamid & Copeland, 2022). By engaging all stakeholders in the planning process, LPS aims to enhance accountability and ensure that work is completed efficiently and on schedule (Kim, 2014; AlSehaimi, Fazenda, and Koskela 2014; Ballard & Tommelein, 2021; Warid and Hamani 2022). These two foundational efforts established the basis for Lean Construction, which has since evolved across multiple areas, incorporating a wide range of tools and methodologies (Mossman et al., 2015; Abdelhamid & Copeland, 2022).

As Lean Construction gained traction, various tools and techniques were developed to facilitate its implementation. Some of the commonly used tools and their benefits are discussed in this paper. Concurrent Engineering fosters interdisciplinary collaboration from the beginning of the design process by reducing development time and costs, enhancing product quality, and stimulating innovation (Koufteros, Vonderembse, and Doll 2000). Daily Huddle Meetings provide a platform for daily progress updates, problem identification, and planning, bolstering communication, collaboration, problem-solving, and teamwork (Donnelly et al. 2016). The 5S workplace organization method fosters a clean, efficient, and safe work environment enhancing productivity and reducing waste (Michalska and Szewieczek 2007; Randhawa and Ahuja 2017). Just-In-Time (JIT) and Kanban (Pull System) methodologies ensure the timely delivery of materials, reducing waste, improving lead times, and enhancing flexibility (Aktürk and Erhun 1999; Akintoye 1995; Golhar and Stamm 1991; Huang and Kusiak 1996). Visual Management employs visual aids to enhance communication, transparency, accountability, facilitating problem identification and resolution (Koskela, Tezel, and Tzortzopoulos 2018). Continuous Flow systems strive for uninterrupted work processes, improving efficiency and customer satisfaction (Avelar, Meiriño, and Tortorella 2019). Similarly, Six Sigma methodologies utilize data-driven approaches to identify and eliminate defects, improving quality and profitability (Qayyum et al. 2016).

Furthermore, the study highlights various problem-solving techniques such as Failure Mode and Effects Analysis (FMEA), Root Cause Analysis, and the 5 Whys, aiding in problem prevention and effective solutions (Ardeshir, Mohajeri, and Amiri 2016; Sarkar, Mukhopadhyay, and Ghosh 2013; Lindhard 2014). Techniques like Poka-Yoke (Error Proofing) and Jidoka/Autonomation prevent defects and stop processes automatically upon defect detection (Poka-Yoke, n.d.; Romero et al. 2019). Additionally, tools like Value Stream Mapping, Bottleneck Analysis, and Pareto Analysis facilitate process improvement by identifying waste, inefficiencies, and critical areas for intervention (Nallusamy and Saravanan 2016; Panahi et al. 2023; Karuppusami and Gandhinathan 2006). In general LC and its associated tools facilitate workflow predictability, reduces rework, enhances quality, fosters innovation, minimizes waste, improves teamwork, and much more (Buehlmann and Fricke 2016).

Despite these advantages, LC remains relatively uncommon in the construction industry of the UAE (Hamouri, and Hamouri 2017; Musharavati 2023). This signifies that there are several barriers to the emergence of LC. Among those barriers the lack of awareness of LC concept plays a very significant role. Research conducted across various projects, timelines, and countries consistently indicates that the understanding of LC among individuals is notably low (Lean Construction Institute, n.d.; Abdullah, Razak, and

Mohammad 2009; Alinaitwe 2009; Tezel and Nielsen 2013; Aziz and Hafez 2013; Sarhan 2014; Bashir et al. 2015; Olamilokun 2015; Bajjou and Chafi 2018; Musa et al. 2023; Nwaki, Eze, and Awodele, n.d.; Hyarat, Montalbán-Domingo, and Pellicer 2024). Building upon these findings, the paper attempts to investigate whether the lack of awareness of LC concept persists among engineers in the construction industry of the UAE. Additionally, it seeks to explore if this lack of awareness will be the most challenging barrier to tackle while introducing LC into a firm. This study is particularly crucial in an era where sustainable construction practices are increasingly prioritized, underscoring the necessity for innovative approaches to tackle industry challenges.

Methods

The study encompasses a comprehensive literature review examining the implementation of LC in the construction industry through various Lean tools and the barriers hindering its adoption. From this review, the paper identified the primary barrier to Lean is the lack of awareness regarding LC concepts and its implementations ((Lean Construction Institute, n.d.; Abdullah, Razak, and Mohammad 2009; Alinaitwe 2009; Tezel and Nielsen 2013; Aziz and Hafez 2013; Sarhan 2014; Bashir et al. 2015; Olamilokun 2015; Bajjou and Chafi 2018; Musa et al. 2023; Nwaki, Eze, and Awodele, n.d.; Hyarat, Montalbán-Domingo, and Pellicer 2024). Thus, the study aims to delve deeper into whether this lack of awareness persists in the current context of U.A.E. This was done through surveys, case studies and interviews with various objectives as shown in Figure 1.

As the first step of research a quantitative survey was done among engineers including contractors, consultants, and business owners in the U.A.E. This survey was to understand if the engineers were well acquainted with LC or if they had limited or no understanding of it. The survey was divided into two parts. The first part comprised questions regarding respondent's highest level of education, years of experience, and their awareness of the term "Lean Construction". Then an analysis was done to investigate if there was any relation between awareness of LC with the level of education and years of experience of the respondents. The second part of the survey was only for respondents who selected the response "Yes, I am well acquainted with the concept" and "Yes, I have heard of the term but have limited understanding" to the question "Have you ever heard of the term "Lean Construction". In this section the respondents were asked if they were aware of the different LC tools like "Six sigma", "Last planner system", "Value stream mapping", etc. The questionnaire was kept so precise and no additional information was given regarding the context or background of each of these tools. This was done based on the assumption that if the respondents could understand the terminologies, it would help to better understand their level of proficiency in that subject.

Following the completion of the initial survey, the same group was invited to participate in a second survey. This subsequent questionnaire contained the same LC tools specified in the first survey, but along with their definitions. The questionnaire was structured to analyze whether respondents, even if unfamiliar with the specific terminologies of LC tools, might still possess some level of awareness. It also examines if the respondents had directly or indirectly implemented these tools in their firms. This approach would offer insights into whether the perceived lack of understanding of LC

concepts stems from a genuine absence of knowledge or is it just a lack of familiarity with the fancy terminologies used.

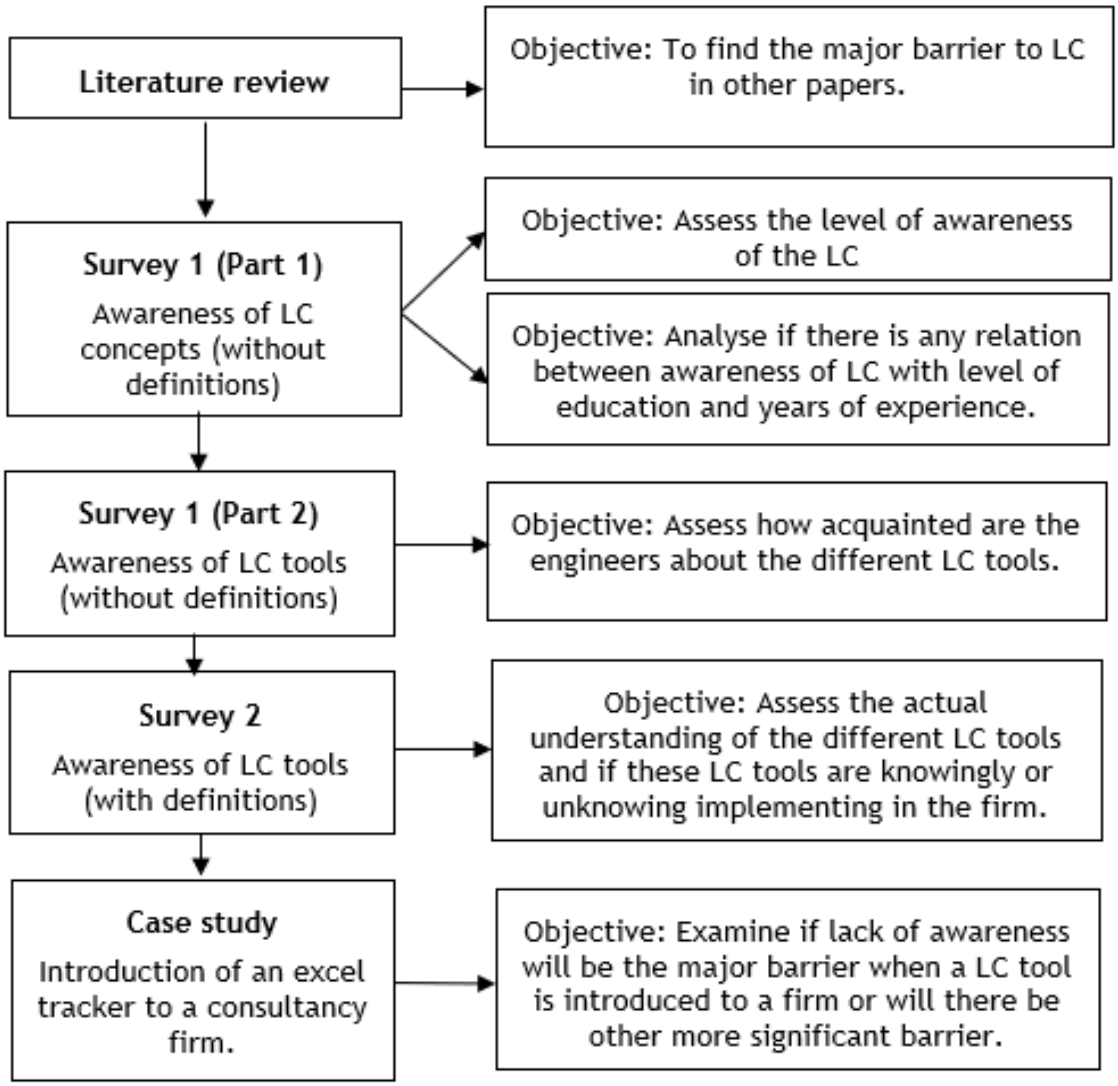

Figure 1: Flowchart of methods and objective of each method.

Finally, a case study was conducted to analyze whether the major barrier encountered in implementing LC within a firm was indeed the lack of awareness or if other factors presented greater challenges. The case study involved introducing an excel progress tracker (inspired by the lean tools Kanban and Value stream mapping (VSM)) to a consultancy firm. Just like how VSM provides a visual representation of the flow of people, materials, and information in a firm, the progress tracker served as a detailed list of inspections to be conducted according to a predetermined schedule. It outlined the sequence of inspections, prioritizing which tasks needed to be completed first and what should follow next (Gellad and Day 2016). The list of inspections was transferred into an Excel sheet, where all engineers can collaborate to update the status of all inspections on a daily basis. Each task is marked as "to be done," "approved," or "rejected," with different colors representing each status. This approach draws inspiration from the Kanban board, fostering collaboration among multiple stakeholders by consolidating various activities' statuses into a unified platform (Huang and Kusiak 1996).

The tracker is expected to help identify any delays or bottlenecks, the status of each activity, measure the productivity of individual engineers, and understand the overall progress of the project. Introducing a new system to the firm will provide practical insights into the barriers that a new implementation can encounter. Therefore, this case study is expected to thoroughly analyze whether lack of awareness represented the primary obstacle to LC adoption in the construction industry of U.A.E or is it just one of the barriers.

Findings

Survey 1 (Part 1) - Awareness of LC concepts among engineers of U.A.E construction industry.

The first survey garnered responses from 136 participants with diverse levels of experience and education. Among these respondents, 49% (67) indicated that they were not familiar with the term "Lean Construction" while 38% (52) stated that they had heard of the term but had limited understanding. Only 12% (17) responded affirmatively, stating that they were well acquainted with the concept. These findings corroborate the assumption regarding the lack of awareness of LC among engineers. Furthermore, the study examined whether there was any correlation between respondent's level of education and years of experience concerning LC concepts. Chart 1 and Chart 2 illustrate a comparison of respondent's survey responses relative to their educational attainment and years of experience.

Survey 1 (Part 2) - Awareness of LC tools among engineers of U.A.E construction industry.

The second part of survey 1 was to be answered by only the respondents who gave positive response about their awareness of LC in the first part. Therefore only 69 out of 136 respondents qualified for the second survey. In this section the responded was asked about their awareness of various LC tools. The results are shown in chart 3. Even from this it is visible that many of the LC tools are unknown to people and majority of the respondents gave a negative response to most of the LC tools. This again signifies that there is a persisting lack of awareness of several lean tools in the industry. However, upon closer analysis of the responses, it was found that terms with straightforward English terminology, such as "work structuring", "daily huddle meeting", "check sheet", etc. received more positive recognition. Conversely, terms like "kanban", "kaizen", "muda walk", "jidoka", etc. which are not commonly used English words, garnered less familiarity. This raised the question of whether the respondents were genuinely unfamiliar with the Lean concepts or if the complexity of the terminology played a role. To address this uncertainty, a second survey was conducted with the same group and same LC tools but this time providing descriptions of each of the tools.

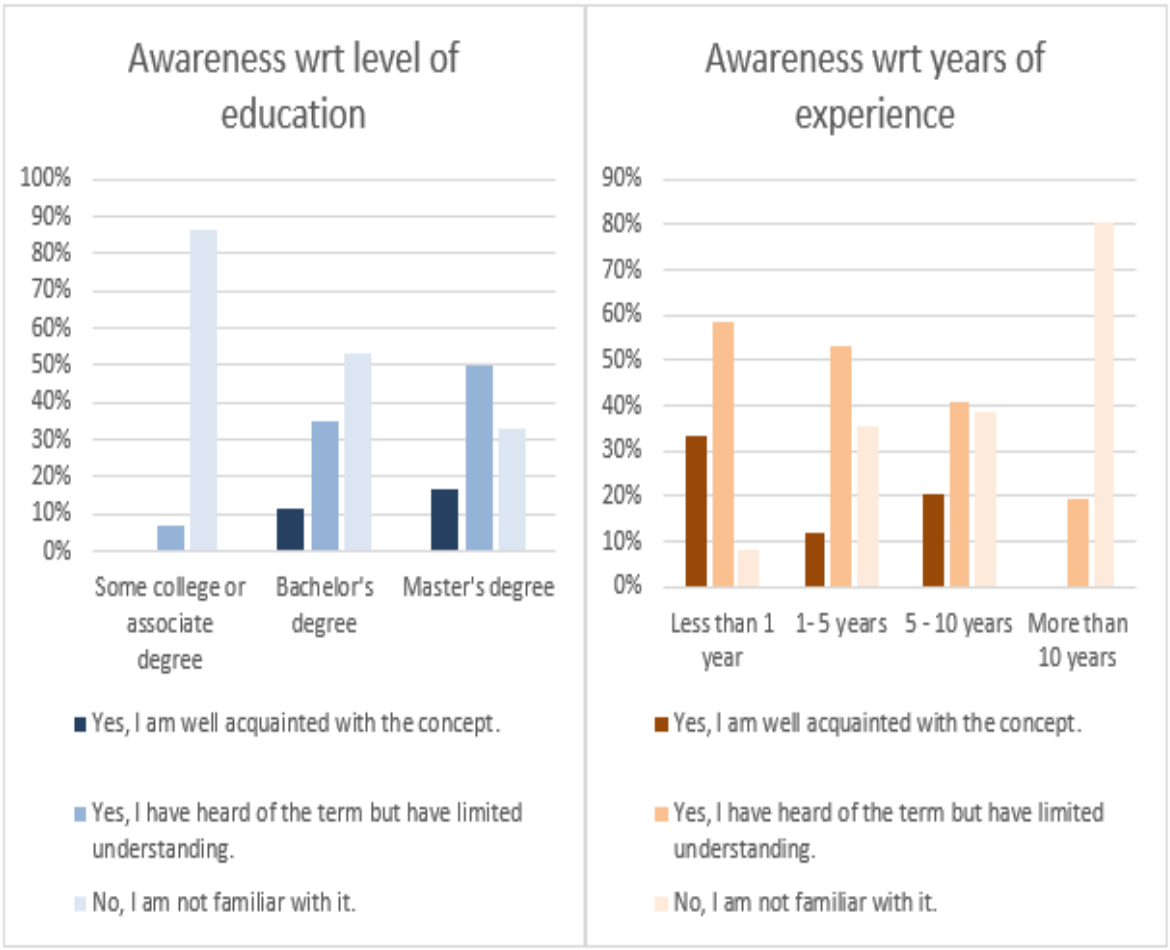

Figure 2. Chart 1- denoting awareness w.r.t to Level of education (left) and Chart 2- denoting awareness w.r.t to Years of experience (right).

Survey 2 - Awareness of LC tools (with definitions) among engineers of U.A.E construction industry.

About 101 responses were gathered for the second survey and the results are shown in Chart 4. As expected, there was a noticeable shift between the response with majority of the respondents choosing the option “Yes, I am well acquainted with the concept and have used it or seen people using it” to most of the tools. However, some tools like kaizen, six sigma, poka-yoke, and 5S received negative responses, suggesting unfamiliarity even after providing descriptions. This could imply that there is lack of familiarity with some of the LC tools, or the descriptions provided for the tools were not clear enough for the respondents to comprehend the concept. Despite some respondents showing unfamiliarity with few LC tools, the majority expressed awareness of the underlying principles and practical utilization of LC tools in the industry. Therefore, this concludes that lack of awareness of LC concepts is not the actual issue, but rather the lack of familiarity with the terminologies. Hence, it suggests that introducing LC into the industry may not require significant effort in terms of creating awareness as most of the engineers already possess the basic knowledge of LC concepts.

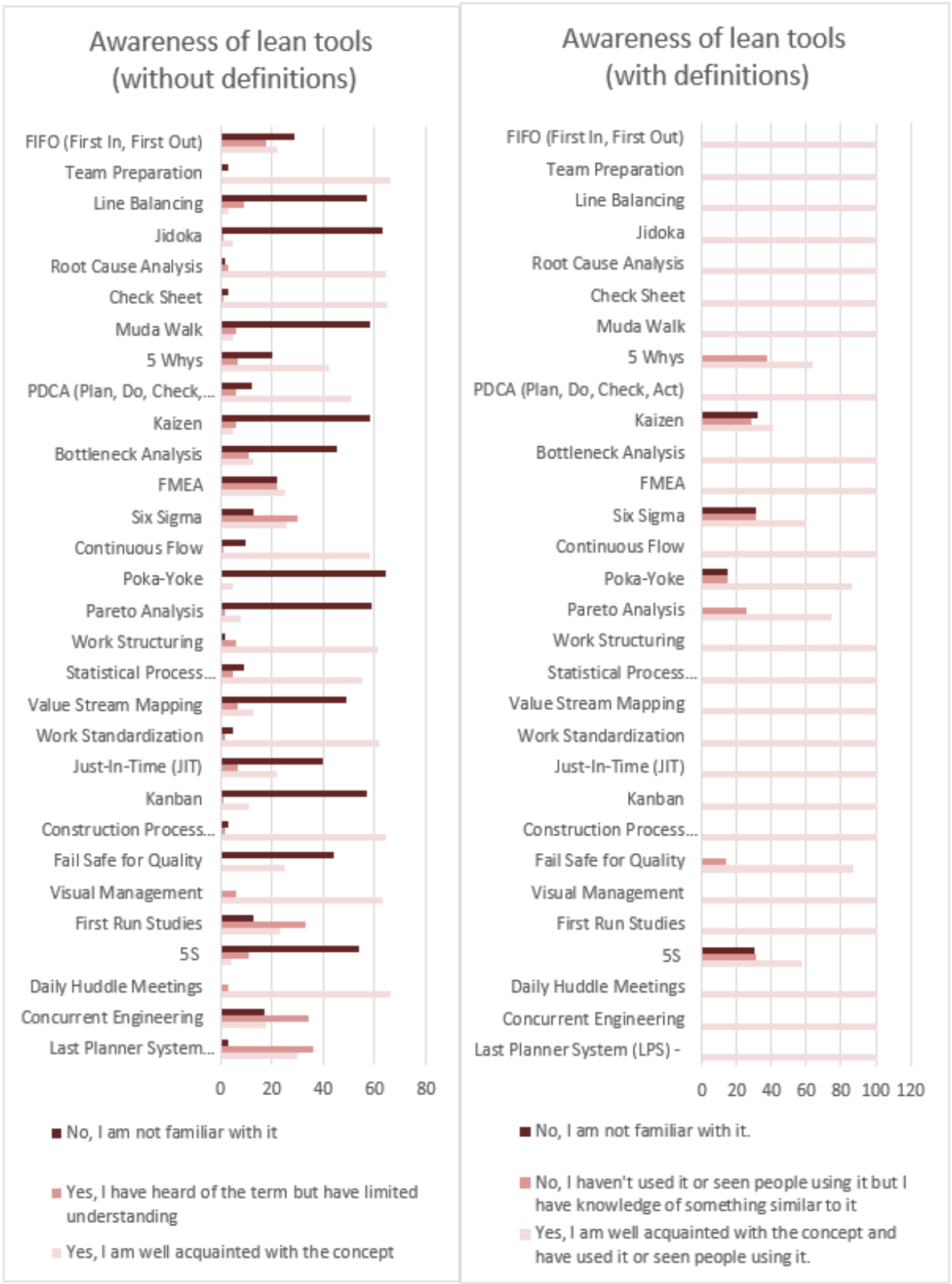

Figure 3. Chart 3- Awareness among engineers on various lean tools without description (left) and Chart 4- Awareness among engineers on various lean tools after adding description.

Case study – Implementation of an inspection progress tracker in a consultancy firm.

The inferences from both the quantitative surveys finally lead to the assumptions that there is not really a lack of awareness of LC among engineers but only lack of awareness of few terminologies. Moreover, irrespective of knowingly the terminologies 90% of the engineers who responded to the survey stated that they have been implementing several lean tools in their day-to-day life. This underscores the idea that lack of awareness is not a significant obstacle to implementing LC practices in the construction industry of the U.A.E., as it is easier to teach concepts that people already have some knowledge of. But to increase the credibility of the conclusion the research includes a case study to investigate further if LC was to be implemented into a firm, will lack of awareness be the primary barrier. Therefore, this research includes a case study depicting the challenges that arose when a lean tool was introduced into a consultancy firm.

A renowned consultancy working on a high-rise building project in the UAE was chosen for the case study. The consultancy had 8 site inspectors from the civil, electrical, and mechanical department working for that project. On investigation it was found that there was no system in the firm to track the productivity of individual employees and consider if the execution at site is as per the planning. Therefore, to control and monitor the site inspectors and work progress a tracker was introduced in the project. The progress tracker was a simple excel sheet containing the list of inspections to be done as per schedule. Each inspector was assigned a task to update this tracker with the date of completion and the status of the inspections. The purpose was to create a centralized system that enables analyzing delays between the scheduled and the actual inspection time, measure productivity of all the inspectors, and point out the critical activities and bottlenecks in the projects.

The tracker was designed by the Construction Manager (CM) and was sent to the inspectors giving them instructions on how to use it. However, no updates were seen on the tracker even after days of launching it. Initially it was assumed that the inspectors did not understand how to use the tracker, signifying a lack of awareness. A follow-up was done with the inspectors to inquire if further assistance or clarification is required. All the inspectors indicated that they understood how to use the tracker but cited a lack of time due to their busy schedules as the key reason for not updating it promptly. The inspectors assured us that they would update it soon, but even after days there were no real improvements from their side. Therefore, the CM reached out to the Senior Residential Engineer (SRE) regarding this tracker, highlighting its benefits and the need for it in the firm. Additionally, SRE's attention was brought to the negligence of the site supervisors in updating the tracker despite several reminders. As a result, the SRE personally sent an official email to all the inspectors, mandating the update of the progress tracker regularly. Noticeable progress was observed following the intervention from the SRE. The inspectors began updating the tracker, leading to improved control over the site inspections. However, this progress was short-lived. Within a week, some inspectors fell behind in updating the progress tracker, and by the end of the following week, the tracker's update came to a complete halt resulting in the failure of lean implementation.

A follow-up interview with the inspectors was conducted again. Inspectors acknowledged the benefits of the tracker, however once again confirmed busy schedules

and workload as the main reason for not being able to update the tracker regularly. Inspectors who initially stopped using the tracker said that it was challenging to manage an additional task alongside their existing responsibilities, such as inspections, drawing reviews, commenting on work, and site walks. Moreover, the inspectors were not going to get paid extra for the additional task and the only reason they started using the tracker was because of the orders from the SRE. Therefore, upon realizing that the SRE was not continuously supervising them, they discontinued updating the tracker. Also, some inspectors noted that if everyone did not consistently update it, the tracker would not fulfill its purpose. Thus, it would be a waste of time if only a few inspectors continued to update the tracker while others didn't.

This case study underscores that the failure of the work progress tracker was not primarily due to a lack of awareness among the engineers regarding its use and benefits. Instead, the main obstacle was their reluctance to take initiative beyond their job descriptions. Additionally, the involvement of top management was also found to be a crucial factor in driving the implementation of LC practices. The research again reached the conclusion that while lack of awareness may pose a barrier, it cannot be considered the most significant obstacle to implementing LC in the construction industry.

Limitations and Recommendations for Future Research

This study had few limitations, including the applicability of the findings to the national level, due to potential sampling biases. Although the survey results indicated a level of awareness among participants, the sample size may not accurately represent the awareness level across the entire engineering population in the region. Additionally, the demographic information collected was limited to years of experience and level of education. Due to concerns regarding confidentiality and the challenge of obtaining responses from busy engineering professionals without adding bias or causing survey fatigue, only essential demographic questions were included. Future studies could expand the demographic scope by including variables such as age, gender, and institutional background to provide a more comprehensive understanding of factors influencing LC awareness.

While our findings suggest that a lack of awareness of LC concepts may not be prevalent, based on the results from Survey 2 and the case study, it is noteworthy that many respondents in Survey 1 reported lower levels of familiarity with LC tools. This is a limitation worth addressing in future research. One need to ensure that a lack of familiarity with LC terminology may imply a broader unawareness of related concepts, principles, and methodologies. For example, a respondent unfamiliar with the term "Last Planner System" (LPS) may not fully grasp its practical application, even if they believe they understand the principles behind it. Though the survey provided respondents with detailed descriptions of various LC tools, due to survey length constraints, there were limits to how much information could be shared. Future research could assess whether respondents who claimed to use LC tools in practice are indeed implementing recognized LC methods, as opposed to drawing conclusions solely from survey responses.

Conclusions

The paper examines the level of awareness of LC concepts among the engineers of the UAE's construction industry. The results suggests that while LC terminology requires more recognition, this cannot be regarded as an actual lack of awareness. This is because it was found that a large majority of engineers have been utilizing LC tools in their firms but in a different format. It is also noteworthy that LC is gradually gaining more recognition and is being taught in colleges and universities, as evidenced by higher awareness among recent graduates. This further indicates that even if there is a lack of awareness, it is gradually changing.

In the case study where an LC tool was introduced into a consultancy firm lack of awareness was found to be a manageable barrier. Instead, other factors such as lack of motivation and resistance to change were found to be more prominent challenges. Therefore, if the implementation of the LC was to be successful in the case study the steps that needed to be undertaken would include top managers taking initiatives to LC (Watfa and Sawalha 2021) fostering employee motivation (Kennedy and Brewer 2012) and maintaining continuous monitoring and supervision (Aziz and Hafez 2013) instead of just focusing on creating awareness.

The study does not suggest that creating awareness is entirely unnecessary. Although the engineers in the selected group demonstrated awareness of LC concepts, it's important to note that this sample may not be representative of the entire industry. Moreover, when implementing LC on a larger scale, especially among laborers or while introducing more complex tools adequate awareness and training should be provided to all stakeholders (Ahmed and Sobuz 2019). Awareness is also crucial for managers and decision-makers to select the most suitable tools that align with the organization's objectives and challenges. Without sufficient awareness, there is a risk of selecting inappropriate tools or approaches, which can end up adding no value to the organization (Lekšić, Štefanić, and Veža 2020). Therefore, this research emphasizes the necessity for a comprehensive assessment of LC awareness across diverse sectors within the construction industry. Tailored training and awareness programs can then be devised to ensure the effective adoption of LC practices (Hyarat, Montalbán-Domingo, and Pellicer 2024).

Similarly, in-depth investigation of all common barriers is to be done before proposing solutions rather than making assumptions and investing in unwanted areas. It's crucial to understand that challenges for implementation of LC vary across stakeholders, project sizes, locations, and timelines (Sunder 2016). Therefore, it is necessary to thoroughly analysis individual barriers and its significance rather than proposing generic solutions. In conclusion the paper proposes that though LC holds a lot of potential to enhance the efficiency of the construction industry (Al-Aomar 2012). However, without proper implementation the benefits of LC will remain unattainable. Therefore, developments must be made for the effective implementation of LC by tackling the right barriers. This would contribute to overall improvement and the advancement of the UAE's construction sector in the coming future (Ahmed, Hossain, and Haq 2020).

References

Abdelhamid, T. S., & Copeland, K. (2022). Lean Construction Journal Editors' Note: 2022 Issue. *Lean Construction Journal 2022*. https://lean-construction-gcs.storage.googleapis.com/wp-content/uploads/2023/01/11161638/LCJ-22-000E.pdf

Abdullah, Shardy, Arman Abdul Razak, and Izran Sarrazin Mohammad, eds. 2009. Towards Producing Best Practice in the Malaysian Construction Industry: The Barriers in Implementing the Lean Construction Approach. International Conference on Construction Industry 2 (ICCI2). https://www.researchgate.net/publication/202165546_Towards_Producing_Best_Practice_in_the_Malaysian_Construction_Industry_The_Barriers_in_Implementing_the_Lean_Construction_Approach.

Ahmed, Shakil, and Md. Habibur Rahman Sobuz. 2019. "Challenges of Implementing Lean Construction in the Construction Industry in Bangladesh." Smart and Sustainable Built Environment 9 (2): 174–207. https://doi.org/10.1108/sasbe-02-2019-0018.

Ahmed, Shakil, Md. Mehrab Hossain, and Iffat Haq. 2020. "Implementation of Lean Construction in the Construction Industry in Bangladesh: Awareness, Benefits and Challenges." International Journal of Building Pathology and Adaptation 39 (2): 368–406. https://doi.org/10.1108/ijbpa-04-2019-0037.

Akintoye, Akintola. 1995. "Just-in-Time Application and Implementation for Building Material Management." Construction Management & Economics 13 (2): 105–13. https://doi.org/10.1080/01446199500000013.

Aktürk, M. Selïm, and Feryal Erhun. 1999. "An Overview of Design and Operational Issues of Kanban Systems." International Journal of Production Research 37 (17): 3859–81. https://doi.org/10.1080/002075499189808.

Al-Aomar, Raid (2012) Analysis of lean construction practices at Abu Dhabi construction industry. Lean Construction Journal 2012 pp 105-121 www.leanconstructionjournal.org

Alinaitwe, Henry Mwanaki. 2009. "Prioritising Lean Construction Barriers in Uganda's Construction Industry." Journal of Construction in Developing Countries 14 (1). http://web.usm.my/jcdc/vol14_1_2009/2_Henry%20%20(p.15-30).pdf.

AlSehaimi, Abdullah O., P Tzortzopoulos Fazenda, and Lauri Koskela. 2014. "Improving Construction Management Practice with the Last Planner System: A Case Study." Engineering Construction and Architectural Management 21 (1): 51–64. https://doi.org/10.1108/ecam-03-2012-0032.

Amunzu, I. C. (2020, January 22). *A qualitative case study of construction managers' understanding of lean thinking - ProQuest*. https://www.proquest.com/openview/de0ea712c63716c43b65129482f1c5a/1?pq-origsite=gscholar&cbl=51922&diss=y

Ardeshir, Abdollah, Mehdi Mohajeri, and Maghsoud Amiri. 2016. "Evaluation of Safety Risks in Construction Using Fuzzy Failure Mode and Effect Analysis (FFMEA)." Scientia Iranica 23 (6): 2546–56. https://doi.org/10.24200/sci.2016.2313.

Arunagiri, P., and A. Gnanavelbabu. 2014. "Identification of Major Lean Production Waste in Automobile Industries Using Weighted Average Method." Procedia Engineering 97 (January): 2167–75. https://doi.org/10.1016/j.proeng.2014.12.460.

Avelar, Wallace, Marcelo Jasmim Meiriño, and Guilherme Luz Tortorella. 2019. "The Practical Relationship Between Continuous Flow and Lean Construction in SMEs." ▫the ▫TQM Journal 32 (2): 362–80. https://doi.org/10.1108/tqm-05-2019-0129.

Aziz, Remon F., and Sherif M. Hafez. 2013. "Applying Lean Thinking in Construction and Performance Improvement." Alexandria Engineering Journal /Alexandria Engineering Journal 52 (4): 679–95. https://doi.org/10.1016/j.aej.2013.04.008.

Bajjou, Mohamed Saad, and Anas Chafi. 2018. "Lean Construction Implementation in the Moroccan Construction Industry." Journal of Engineering, Design and Technology 16 (4): 533–56. https://doi.org/10.1108/jedt-02-2018-0031.

Ballard, G. (2014). Competing construction management paradigms. *Berkeley*. https://www.academia.edu/811475/Competing_construction_management_paradigms

Ballard, G., & Howell, G. (2003). *Competing construction management paradigms*. https://www.semanticscholar.org/paper/Competing-Construction-Management-Paradigms-Ballard-Howell/57d1d35e76b95694c88f4f69ae2d5338cd6783c4

Ballard, G., & Tommelein, I. (2021). 2020 Current Process Benchmark for The Last Planner® System Of Project Planning and Control. *Lean Construction Journal*, *53-155*. https://www.proquest.com/docview/2617209302?sourcetype=Scholarly%20Journals

Ballard, H. G. (1994). The Last Planner. In *Northern California Construction Institute Monterey, Ca*. Northern California Construction Institute, Monterey, California, United States of America. Lean Construction Institute. https://leanconstruction.org.uk/wp-content/uploads/2018/09/LastPlanner.pdf

Bashir, Abubakar Muhammad, Subashini Suresh, David Oloke, David Proverbs, and Rod Gameson. 2015. "Overcoming the Challenges Facing Lean Construction Practice in the UK Contracting Organizations." International Journal of Architecture, Engineering and Construction/International Journal of Architecture, Engineering and Construction 4 (1). https://doi.org/10.7492/ijaec.2015.002.

Buehlmann, Urs, and Christian Fricke. 2016. "Benefits of Lean Transformation Efforts in Small- and Medium-sized Enterprises." Production & Manufacturing Research 4 (1): 114–32. https://doi.org/10.1080/21693277.2016.1212679.

Donnelly, Lane F., Shirley S. Cherian, Kimberly B. Chua, Sam Thankachan, Laura A. Millecker, Alex G. Koroll, and George S. Bisset. 2016. "The Daily Readiness Huddle: A Process to Rapidly Identify Issues and Foster Improvement Through Problem-solving Accountability." Pediatric Radiology 47 (1): 22–30. https://doi.org/10.1007/s00247-016-3712-x.

Ferrazzi, M., & Alberto, P. S. (2023, October 5). *Lean manufacturing mitigates barriers to improve environmental performance: mapping current research and establish future research agenda*. https://www.politesi.polimi.it/handle/10589/209314

Gao, S., & Low, S. P. (2014). Lean Construction management. In *Springer eBooks*. https://doi.org/10.1007/978-981-287-014-8

Gao, Shang, and Sui Pheng Low. 2013. "The Toyota Way Model: An Alternative Framework for Lean Construction." Total Quality Management and Business Excellence/Total Quality Management & Business Excellence 25 (5–6): 664–82. https://doi.org/10.1080/14783363.2013.820022.

Gellad, Ziad F., and Theodore E. Day. 2016. "What Is Value Stream Mapping, and How Can It Help My Practice?" ▫the ▫American Journal of Gastroenterology 111 (4): 447–48. https://doi.org/10.1038/ajg.2016.38.

Golhar, Damodar Y., and Carol Lee Stamm. 1991. "The Just-in-time Philosophy: A Literature Review." International Journal of Production Research 29 (4): 657–76. https://doi.org/10.1080/00207549108930094.

Howell, G. (2014). REFORMING PROJECT MANAGEMENT: THE ROLE OF LEAN CONSTRUCTION. *www.academia.edu*.

https://www.academia.edu/7595001/REFORMING_PROJECT_MANAGEMENT_THE_ROLE_OF_LEAN_CONSTRUCTION

Huang, Chun-Che, and Andrew Kusiak. 1996. "Overview of Kanban Systems." International Journal of Computer Integrated Manufacturing 9 (3): 169–89. https://doi.org/10.1080/095119296131643.

Hyarat, Esraa, Laura Montalbán-Domingo, and Eugenio Pellicer. 2024. "Lean Constructions Barriers in Jordan's Building Sub-sector: A Comprehensive Knowledge Framework." Ain Shams Engineering Journal/Ain Shams Engineering Journal, February, 102703. https://doi.org/10.1016/j.asej.2024.102703.

Johnston, R., & Brennan, M. (1996). Planning or organizing: The implications of theories of activity for management of operations. *Omega*, *24*(4), 367–384. https://doi.org/10.1016/0305-0483(96)00016-3

Karuppusami, G., and R. Gandhinathan. 2006. "Pareto Analysis of Critical Success Factors of Total Quality Management." TQM Magazine/▫the ▫TQM Magazine 18 (4): 372–85. https://doi.org/10.1108/09544780610671048.

Kennedy, Frances A., and Peter C. Brewer. 2012. Motivating Employee Performance in Lean Environments: Respect, Empower, Support. https://doi.org/10.1002/9781119196808.ch5.

Kim, C. D. (2014). *An analysis of the last planner® system in a construction project - ProQuest*. https://www.proquest.com/openview/0a75f01fb77da9eda0a9f5e1b19f2235/1?pq-origsite=gscholar&cbl=18750

Koskela, L., Ballard, G., Howell, G., & Tommelein, I. D. (2002). *The foundations of lean construction*. https://www.semanticscholar.org/paper/The-foundations-of-lean-construction-Koskela-Ballard/79849ebb52ba74b46f3390bef9b620ede137841f

Koskela, Lauri, Algan Tezel, and Patricia Tzortzopoulos. 2018. "Why Visual Management?" 2018. https://iglc.net/Papers/Details/1548.

Koufteros, Xenophon, Mark A. Vonderembse, and William J. Doll. 2000. "Concurrent Engineering and Its Consequences." Journal of Operations Management 19 (1): 97–115. https://doi.org/10.1016/s0272-6963(00)00048-6.

Le, Phuoc Luong, and Nguyen Thi Duc Nguyen. 2021. "Prospect of Lean Practices Towards Construction Supply Chain Management Trends." International Journal of Lean Six Sigma 13 (3): 557–93. https://doi.org/10.1108/ijlss-06-2020-0071.

Lean Construction Institute. n.d. "Lean Construction: Prospects for the German Construction Industry - Northumbria Research Link." https://nrl.northumbria.ac.uk/id/eprint/1746/.

Lekšić, Ivan, Nedeljko Štefanić, and Ivica Veža. 2020. "The Impact of Using Different Lean Manufacturing Tools on Waste Reduction." Advances in Production Engineering & Management 15 (1): 81–92. https://doi.org/10.14743/apem2020.1.351.

Lindhard, Søren Munch. 2014. "Applying the 5 WHYs to Identify Root Causes to Non-completions in On-Site Construction." In Lecture Notes in Production Engineering, 51–61. https://doi.org/10.1007/978-3-319-04271-8_5.

Mbe, Jamil Kanafani BEng., Mba,. 2016. "Barriers to the Implementation of Lean Thinking in the Construction Industry – the Case of UAE." Xn--Universitt-Stuttgart-Jzb, May. https://www.academia.edu/25510363/Barriers_to_the_Implementation_of_Lean_Thinking_in_the_Construction_Industry_The_Case_of_UAE.

Michalska, and Szewieczek. 2007. "The 5S methodology as a tool for improving the organisation." Journal of Achievements in Materials and Manufacturing Engineering 24 (2). http://jamme.acmsse.h2.pl/papers_vol24_2/24247.pdf.

Mossman, A. (2018). What is lean Construction: Another Look - 2018. *www.academia.edu*. https://www.academia.edu/64792791/What_Is_Lean_Construction_Another_Look_2018

Mossman, A., Pasquire, C., & Ballard, G. (2015). Lean Project Delivery — innovation in integrated design & delivery. *www.academia.edu*. https://www.academia.edu/238424/Lean_Project_Delivery_innovation_in_integrated_design_and_delivery

Musa, Mohammed Mukhtar, İbrahim Saleh, Y. K. E. Ibrahim, and Mukhtar Adamu Dandajeh. 2023. "Assessment of Awareness and Barriers to the Application of Lean Construction Techniques in Kano State, Nigeria." Journal of Construction Business and Management 6 (1): 33–42. https://doi.org/10.15641/jcbm.6.1.1262.

Musharavati, Farayi. 2023. "Optimized Integration of Lean Construction, Building Information Modeling, and Facilities Management in Developing Countries: A Case of Qatar." Buildings 13 (12): 3051. https://doi.org/10.3390/buildings13123051.

Nallusamy, S., and Vadivel Saravanan. 2016. "Enhancement of Overall Output in a Small Scale Industry Through VSM, Line Balancing and Work Standardization." International Journal of Engineering Research in Africa 26 (October): 176–83. https://doi.org/10.4028/www.scientific.net/jera.26.176.

Nawi, Mohd Nasrun Mohd, Nazim Hussain Baluch, and Ahmad Yusni Bahauddin. 2014. "Impact of Fragmentation Issue in Construction Industry: An Overview." MATEC Web of Conferences 15 (January): 01009. https://doi.org/10.1051/matecconf/20141501009.

Nwaki, Wiliam, Emmanuel Eze, and Imoleayo Awodele. n.d. "Major Barriers Assessment of Lean Construction Application in Construction Projects Delivery." UI Scholars Hub. https://scholarhub.ui.ac.id/jid/vol4/iss1/6/.

Oehmen, Josef, and Eric Rebentisch. 2010. "Waste in Lean Product Development." July 1, 2010. https://dspace.mit.edu/handle/1721.1/79838.

Olamilokun, Olajide. 2015. "Investigating Facilitators and Barriers for Adopting Lean Construction Principles in the Nigerian Building Consulting Firms." November 30, 2015. https://ischolar.sscldl.in/index.php/IJIRD/article/view/143056.

Panahi, Roshan, Joseph Louis, Ankur Podder, Colby Swanson, and Shanti Pless. 2023. "Bottleneck Detection in Modular Construction Factories Using Computer Vision." Sensors 23 (8): 3982. https://doi.org/10.3390/s23083982.

"Poka-Yoke." n.d. Google Books. https://books.google.ae/books?hl=en&lr=&id=hR_8Ulz6d_oC&oi=fnd&pg=PR7&dq=poka+yoke+method&ots=k0QdQIuHdD&sig=8IrDvagia9DmzO-nf8yQSaGUCj4&redir_esc=y#v=onepage&q=poka%20yoke%20method&f=false.

Qayyum, Siddra, Fahim Ullah, Muhammad Jamaluddin Thaheem, and Hamza Farooq Gabriel. 2016. "Six Sigma in Construction: A Review of Critical Success Factors." International Journal of Lean Six Sigma 7 (2): 171–86. https://doi.org/10.1108/ijlss-11-2015-0045.

Randhawa, Jugraj Singh, and Inderpreet Singh Ahuja. 2017. "5S – a Quality Improvement Tool for Sustainable Performance: Literature Review and Directions." International Journal of Quality and Reliability Management/International Journal of Quality & Reliability Management 34 (3): 334–61. https://doi.org/10.1108/ijqrm-03-2015-0045

Rashid, D. G. H. (n.d.). *Lean Dissertation Writing Process (LDWP) - ProQuest*. https://www.proquest.com/openview/3379b2d0589874842b03e545c4c5c560/1?pq-origsite=gscholar&cbl=2026366&diss=y

Romero, David, Paolo Gaiardelli, Daryl Powell, Thorsten Wuest, and Matthias Thürer. 2019. "Rethinking Jidoka Systems Under Automation &Amp; Learning Perspectives in the

Digital Lean Manufacturing World." IFAC-PapersOnLine 52 (13): 899–903. https://doi.org/10.1016/j.ifacol.2019.11.309.

Sarhan, Saad. 2014. "Barriers to Implementing Lean Construction in the UK Construction Industry." Ulincoln, May. https://www.academia.edu/3079096/Barriers_to_Implementing_Lean_Construction_in_the_UK_Construction_Industry.

Sarkar, Shri Ashok, Arup Ranjan Mukhopadhyay, and Sadhan Kumar Ghosh. 2013. "Root Cause Analysis, Lean Six Sigma and Test of Hypothesis." ▫the ▫TQM Journal 25 (2): 170–85. https://doi.org/10.1108/17542731311299609.

Small, Edgar P., Khaled Al Hamouri, and Husameddin Al Hamouri. 2017. "Examination of Opportunities for Integration of Lean Principles in Construction in Dubai." Procedia Engineering 196 (January): 616–21. https://doi.org/10.1016/j.proeng.2017.08.049.

Sunder, M Vijaya. 2016. "Lean Six Sigma Project Management – a Stakeholder Management Perspective." ▫the ▫TQM Journal 28 (1): 132–50. https://doi.org/10.1108/tqm-09-2014-0070.

Teo, M. M. M., & Loosemore, M. (2001). A theory of waste behaviour in the construction industry. *Construction Management and Economics*, *19*(7), 741–751. https://doi.org/10.1080/01446190110067037

Tezel, Algan, and Yasemin Nielsen. 2013. "Lean Construction Conformance Among Construction Contractors in Turkey." Journal of Management in Engineering 29 (3): 236–50. https://doi.org/10.1061/(asce)me.1943-5479.0000145.

"UAE construction market insights." n.d. https://www.mordorintelligence.com/industry-reports/uae-construction-market.

Warid, O., and Hamani, K. (2022). Lean Construction in UAE: Implementation of Last Planner System®. Lean Construction Journal 2003 pp 01-20 (Submitted 26Jun2022; Accepted 12Feb2023) www.leanconstructionjournal.org

Watfa, Mohamed and Sawalha, Murad (2021) Critical Success Factors for Lean Construction: An Empirical Study in the UAE. Lean Construction Journal 2021 pp 01-17 (submitted 31Jan2021; Accepted 31Mar2021) www.leanconstructionjournal.org

Appendix 1

Questionnaire for Survey 1 (Part 1) - Awareness of LC concepts among engineers of U.A.E construction industry.

What is your highest level of education completed?	Some college or associate degree
	Bachelor's degree
	Master's degree
	Doctorate or professional degree
How many years of experience do you have working in the field of engineering?	Less than 1 year
	1- 5 years
	5 - 10 years
	More than 10 years
Have you ever heard of the term "Lean Construction	Yes, I am well acquainted with the concept.
	Yes, I have heard of the term but have limited understanding.
	No, I am not familiar with it.

Questionnaire for Survey 1 (Part 2) - Awareness of LC tools among engineers of U.A.E construction industry.

LC tools	**Yes, I am well acquainted with the concept.**	**Yes, I have heard of the term but have limited understanding.**	**No, I am not familiar with it.**
Have you ever heard of the term Last Planner System (LPS) -			
Have you ever heard of the term "Concurrent Engineering"			
Have you ever heard of the term "Daily Huddle Meetings"			
Have you ever heard of the term " 5S "			
Have you ever heard of the term "First Run Studies"			
Have you ever heard of the term "Visual Management"			
Have you ever heard of the term "Fail Safe for Quality"			
Have you ever heard of the term "Construction Process Analysis"			
Have you ever heard of the term "Kanban"			
Have you ever heard of the term "Just-In-Time (JIT)"			

Questionnaire for Survey 1 (Part 2) - Awareness of LC tools among engineers of U.A.E construction industry.

LC tools	Yes, I am well acquainted with the concept.	Yes, I have heard of the term but have limited understanding.	No, I am not familiar with it.
Have you ever heard of the term "Work Standardization"			
Have you ever heard of the term "Value Stream Mapping"			
Have you ever heard of the term "Statistical Process Control (SPC)"			
Have you ever heard of the term "Work Structuring"			
Have you ever heard of the term "Pareto Analysis"			
Have you ever heard of the term "Poka-Yoke"			
Have you ever heard of the term "Continuous Flow"			
Have you ever heard of the term "Six Sigma"			
Have you ever heard of the term "Failure Mode and Effects Analysis (FMEA)"			
Have you ever heard of the term "Bottleneck Analysis"			
Have you ever heard of the term "Kaizen"			
Have you ever heard of the term "PDCA (Plan, Do, Check, Act)"			
Have you ever heard of the term "5 Whys"			
Have you ever heard of the term "Muda Walk"			
Have you ever heard of the term "Check Sheet"			
Have you ever heard of the term "Root Cause Analysis"			
Have you ever heard of the term "Jidoka"			
Have you ever heard of the term "Line Balancing"			
Have you ever heard of the term "Team Preparation"			
Have you ever heard of the term "FIFO (First In, First Out)"			

Questionnaire for Survey 2 - Awareness of LC tools (with definitions) among engineers of U.A.E construction industry.

LC tools	Yes, I am well acquainted with the concept and have used it or seen people using it.	No, I haven't used it or seen people using it but I knowledge of something similar to it	No, I am not familiar with it.
Last Planner System (LPS)- It is a method used in construction to make projects run smoothly and on time. It involves setting big goals, breaking the project into smaller phases, and planning weekly tasks with the team. Daily meetings help track progress and solve problems quickly. The system measures how many tasks are completed on time and uses this information to improve future planning. Overall, it encourages teamwork and continuous improvement.			
Concurrent Engineering- A product development approach where different engineering disciplines work together concurrently from the beginning of the design process.			
Daily Huddle Meetings-Short, daily meetings where team members discuss progress, identify problems, and plan for the upcoming day.			
5S- It is a simple method to keep workplaces clean and organized. It involves five steps: **Sort** (get rid of unnecessary items), **Set in Order** (arrange things so they are easy to find), **Shine** (clean the area), **Standardize** (create routines to keep it organized), and **Sustain** (make these practices a habit). This system helps improve safety, efficiency, and overall work environment.			
First Run Studies-A process for analyzing and improving the performance of a new production process during its initial run.			
Visual Management- The use of visual aids, such as charts, graphs, and Kanban boards, to communicate information and track progress.			

LC tools	Yes, I am well acquainted with the concept and have used it or seen people using it.	No, I haven't used it or seen people using it but I knowledge of something similar to it	No, I am not familiar with it.
Fail Safe for Quality- It involves designing processes and systems to prevent errors or reduce their impact if they occur. For example, using sensors to detect misalignments in structural components or implementing automatic shutdowns for machinery if unsafe conditions are detected. This approach ensures that even if something goes wrong, it won't lead to significant defects or safety issues, maintaining high-quality standards throughout the project.			
Construction Process Analysis- It involves examining each step of a construction project to ensure efficiency, safety, and quality. It includes planning and design, where detailed plans are developed; pre-construction, which involves site preparation and finalizing details; procurement, where materials and services are acquired; construction, where the actual building work is carried out; and post-construction, which includes final inspections and project handover. This analysis helps identify potential problems early, streamline workflows, and ensure the project stays on schedule and within budget.			

LC tools	Yes, I am well acquainted with the concept and have used it or seen people using it.	No, I haven't used it or seen people using it but I knowledge of something similar to it	No, I am not familiar with it.
Kanban- It is a visual workflow management tool used to improve efficiency and productivity in construction projects. It involves using a Kanban board, which is divided into columns representing different stages (to do, doing, done) of the workflow. Tasks are represented by cards that move through these columns as work progresses. This system helps teams visualize their work, limit work in progress, and quickly identify bottlenecks. By focusing on actual demand and continuous improvement, Kanban ensures that resources are used efficiently and projects stay on track			
Just-In-Time-A production system that strives to produce only the parts needed, in the quantities needed, and at the time needed.			
Work Standardization- It involves documenting the best way to perform tasks to ensure consistency, efficiency, and quality. This process includes creating detailed instructions for each task, training workers to follow these instructions, and regularly reviewing and updating them. By standardizing work, construction projects can reduce variability, improve safety, and ensure that all team members are aligned in their methods, leading to more predictable and reliable outcomes			

LC tools	Yes, I am well acquainted with the concept and have used it or seen people using it.	No, I haven't used it or seen people using it but I knowledge of something similar to it	No, I am not familiar with it.
Value Stream Mapping- It is a lean tool that uses a flowchart to document every step in a process, from start to finish. It helps identify waste, reduce process cycle times, and improve overall efficiency. By mapping out the current state of a process, teams can visualize how materials and information flow, pinpoint bottlenecks, and design a more efficient future state. This tool is essential for continuous improvement, ensuring that resources are used effectively and customer value is maximized			
Statistical Process Control (SPC)- It involves collecting data from various stages of a process and using control charts to identify trends, patterns, and anomalies. By distinguishing between normal process variations and those that indicate a problem, SPC helps maintain consistent quality and improve process performance			
Work Structuring- This process includes defining standard procedures, ensuring tasks are performed in the best possible order, and continuously improving these methods. By focusing on the overall workflow and integrating various systems, work structuring helps reduce waste, improve productivity, and ensure that all parts of the project work together smoothly.			

LC tools	Yes, I am well acquainted with the concept and have used it or seen people using it.	No, I haven't used it or seen people using it but I knowledge of something similar to it	No, I am not familiar with it.
Pareto Analysis- A method for identifying the most important problems to address. Also known as the 80/20 rule, which states that 80% of the problems come from 20% of the causes. To conduct a Pareto Analysis, start by listing all the problems you need to address and determine their root causes. Assign a score to each problem based on its impact, then group the problems by their causes. Add up the scores for each group to identify which causes have the most significant impact. Focus on addressing the highest-scoring problems first to achieve the greatest improvements in efficiency and quality.			
Poka-Yoke (Error Proofing)- Techniques used to prevent mistakes from being made in a process.			
Continuous Flow- It involves ensuring that every part of the building process moves smoothly from one step to the next without delays. The goal is to maintain a steady pace of work, where each task flows seamlessly into the next. This approach helps reduce waiting times, minimize waste, and improve overall efficiency by ensuring that resources are used effectively and that the project progresses predictably			

LC tools	Yes, I am well acquainted with the concept and have used it or seen people using it.	No, I haven't used it or seen people using it but I knowledge of something similar to it	No, I am not familiar with it.
Six Sigma - It is a data-driven methodology aimed at improving the quality and efficiency of processes by reducing defects and variability. It uses a structured approach known as DMAIC, which stands for Define, Measure, Analyze, Improve, and Control. To implement Six Sigma, start by **defining** the problem and setting goals. Next, **measure** the current process performance to establish a baseline. Then, **analyze** the data to identify root causes of defects. After that, **improve** the process by implementing solutions to eliminate these causes. Finally, **control** the new process to ensure that improvements are sustained.			
Failure Mode and Effects Analysis (FMEA)- It is a method used to identify and prevent potential failures in processes, products, or systems. It involves several steps: assembling a cross-functional team, defining the scope, listing potential failure modes, evaluating their effects and causes, and assessing the current controls. Each failure mode is then rated based on its severity, likelihood of occurrence, and detectability. These ratings are used to calculate a Risk Priority Number (RPN), which helps prioritize which issues to address first. By focusing on the most critical risks, FMEA helps improve quality, reliability, and safety			
Bottleneck Analysis- A method for identifying and eliminating bottlenecks (high lead time/delay) in a process.			

LC tools	Yes, I am well acquainted with the concept and have used it or seen people using it.	No, I haven't used it or seen people using it but I knowledge of something similar to it	No, I am not familiar with it.
Kaizen- A Japanese philosophy of continuous improvement. It is a lean tool focused on continuous improvement through small, incremental changes. It involves everyone in the organization, from top management to frontline workers, in identifying areas for improvement and implementing solutions. The process typically follows these steps: identify a problem, analyze the process, develop and implement a solution, study the results, and standardize the improvement. By making small, daily changes, Kaizen helps improve quality, productivity, safety, and workplace culture over time			
PDCA (Plan, Do, Check, Act)- It is a four-step method for continuous improvement. It starts with **Plan**, where you identify an improvement opportunity and plan a change. In **Do**, you implement the plan on a small scale. **Check** involves monitoring and evaluating the results. Finally, in **Act**, you implement successful changes on a larger scale or refine the plan and repeat the cycle.			
5 Whys- A problem-solving technique that involves asking "why" five times to get to the root cause of a problem.			
Muda Walk- A process of walking through a workplace to identify waste (muda) in the Lean sense. Muda can be anything that does not add value to the product or service.			
Check Sheet- A check sheet is a structured form used for collecting and analyzing data in real time at the location where the data is generated. It can capture both quantitative and qualitative information and is used to identify and eliminate wastes.			

LC tools	Yes, I am well acquainted with the concept and have used it or seen people using it.	No, I haven't used it or seen people using it but I knowledge of something similar to it	No, I am not familiar with it.
Root Cause Analysis- It is a systematic method used to identify the underlying causes of problems to prevent their recurrence. The process involves defining the problem, collecting relevant data, ...			
Jidoka/Autonomation- A principle in Lean manufacturing that means "autonomation" and refers to designing machines and processes to stop automatically when a defect is detected.			
Synchronized/Line Balancing- It involves distributing tasks evenly across different workstations or crews to ensure a smooth workflow and minimize delays. This is particularly useful in projects with repetitive activities, such as building floors in high-rise buildings or laying pipelines. By balancing the workload, construction managers can optimize resource use, reduce idle time, and ensure that each phase of the project progresses efficiently			
Team Preparation- The process of preparing a team to work effectively together. This includes activities such as setting goals, clarifying roles, and communicating expectations.			
FIFO (First In, First Out)- An inventory management system that ensures that the items that were added to inventory first are also the first ones to be used or sold.			