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Awareness and Adoption of Lean Construction Tools to Enhance Safety in Construction Projects

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ABSTRACT

Occupational accidents are wasteful and inefficient in the construction process, and lean construction is a promising concept that has been extensively discussed in the construction industry to enhance safety. The emergence of lean construction is a positive approach that can establish best practices and make the construction sector more profitable whilst delivering the most extreme value. The application of the lean construction concept in the industry is still considered new and fresh, and its application by the construction firms in the country is highly scarce. Therefore, this research aimed to ascertain the lean construction concepts, specifically to improve safety and their implementation in construction projects. Survey questionnaires were given to construction professionals to gauge their awareness and application of lean construction concepts to improve safety in construction projects. The findings revealed that most respondents were *unfamiliar with the terminologies used in the studied lean tools and concepts. Their answers showed that some ideas within these concepts were applied in their projects.*

Keywords: *Lean construction; safety; construction project*

INTRODUCTION

Malaysia aims to establish a strong economic growth by 2020, and the construction industry has observed an increased contribution to Malaysia's economy (Hamid et al., 2019). The Malaysian construction industry has been vital in enhancing the community's lifestyle, generating wealth for the country and contributing to the economic development (Razak, 2020). However, despite the relatively positive economic growth, the National Institute of Occupational Safety and Health (NIOSH) reported concerns about the rising number of fatal construction site accidents in the Malaysian construction industry (Thye, 2018). According to Azmy and Mohd Zain (2016), thousands of construction workers worldwide sustain injuries each year while working in construction sites. Despite the growing awareness of the rising number of casualties, there has been no improvement in construction safety worldwide (Fang et al., 2020). The lack of good safety conditions has become a major issue because this sector is known to have a high rate of accidents compared to other industries (Bajjou et al., 2017).

Work-related incidents and casualties are deemed as a significant cause of construction wastage, which is costly (Marhani, 2021). When these issues remain uncontrolled, they will be disruptive due to multiple cost-related issues, such as workers' compensation, high emergency healthcare costs, rehabilitation plans, high administrative costs, and reduced productivity (Kamar et al., 2019). The number of construction accident cases in Malaysia, as reported to the Social Security Organisation (SOCSO), has been rapidly increasing, with 143 deaths and 8,191 accidents in 2018 and 120 deaths and 7,870 accidents in 2017 (Danial, 2019). The Malaysian construction industry accidents rate is still soaring rapidly, reflecting the need to improve on-site safety measures to avoid more casualties. Although preventive measures have been regulated, some construction professionals are still reluctant to prioritize the importance of safety management on site. Those construction players do not accentuate safety due to the lack of knowledge of the staggering cost of an accident (Marhani et al., 2021). Balkhy et al. (2021) emphasized that the lack of understanding of lean construction practice caused many organizations to be unwilling to comprehend it in detail and to apply it to their projects.

Bajjou et al. (2017) studied the effects of lean practice on safety performance and the result showed that lean thinking could improve workers' on-site productivity and safety. Marhani (2021) further highlighted that the introduction of lean construction significantly reduces or minimises unnecessary accidents. Several studies have explored the lean concept and further suggested that the lean construction techniques on construction sites may boost safety in the workplace (Awada et al., 2016; Bajjou et al., 2017; Wu et al., 2019). Nonetheless, many studies (Panwar et al., 2018; Zhang & Chen, 2016) have reported that the effects of lean construction depend primarily on the team learning and development of understanding such that it can mediate the impact of lean tools on poor performance. Thus, this research aimed to study the lean construction concept, including tools, and how it has been applied in the construction industry to improve safety. The concepts of lean thinking can be effectively applied to the construction industry since the other industries applying lean principles achieve productivity improvements.

LEAN CONSTRUCTION TOOLS TOWARDS SAFETY IMPROVEMENT

Lean construction can be seen as a continuous improvement in the construction process to reduce resource waste while increasing the value of the project to the customer (Marhani et al., 2018). In the lean concept, poor safety is considered waste and occupational injuries in construction projects contribute to wastage, which significantly impacts social and economic expenses (Marhani et al., 2019). Thus, enhanced safety performance, such as reduced injury and fatality rates, is an example of waste reduction since accidents will generally reduce the productivity and efficiency of a process, leading to non-value-added events (Hasmori et al., 2020). Therefore, from a lean viewpoint, being aware of any risks or uncertainties is a part of safety management as it is seen as a vulnerability that should be managed accordingly (Enshassi et al., 2021).

The instruments or tools are needed to change the current procedure to implement the lean construction approach, which can also be considered a lean construction agent (Babalola et al., 2019). Several studies and reviews have been undertaken to explore the lean tools and techniques that have been developed. According to Ansah et al. (2016), Bajjou et al. (2017), as well as Singh and Kumar (2021), the most developed lean construction tools are the Last Planner System, Visual Management, 5S Process and error-proofing. These tools were used in this study to identify the implementation and their significance in improving safety in construction work. Table 1 shows a list of nineteen (19) determinants arising from four (4) concepts and criteria of lean construction tools used in this study.

Last Planner System

The Last Planner System (LPS) was first developed to enhance the quality and reliability of workflow (Samad et al., 2017). Bajjou et al. (2017) further highlighted that LPS was aimed to replace the conventional planning strategy to ensure the full effectiveness of the construction process by eliminating waste sources in the construction system through collective cooperation among all construction project stakeholders. Hence, this technique gathers responsibilities at the operational level, which organises duties to enhance work process (Daniel et al., 2019). This method is grouped into four levels of planning: master planning, phase planning, look-ahead planning, and weekly planning (Babalola et al., 2019).

The master planning is the set of all tasks, steps and work sequences constructed using critical path method (CPM) calculations and sets milestones that will be executed on site. The safest working methods are reinforced to ensure that planning is completed in the best circumstances of safety possible. Furthermore, the usage of building information modelling (BIM) will be advantageous to establish milestones and structure the project so that it can be best visualised during master planning (Aslam et al., 2020). Phase planning generates a detailed schedule covering each project phase, such as foundations, structural frame, and finishing (Bajjou et al., 2017). It gathers the activities for which the last planner can engage for the next three or four months and the methods of work will be thoroughly reviewed and reconsidered (Dakhli et al., 2016).

Look-ahead planning is where the work plan is systematically updated when necessary to keep track of the schedule and to avoid incidents due to a lack of control at the construction site (Bajjou & Chafi, 2018). This is accomplished by breaking down activities into the level of operations, designing operations, and making tasks ready by removing task constraints (Bhatla, 2016). The last method under LPS known as the weekly planning is a detailed weekly schedule containing specification of on-site tasks that are clearly presented in a weekly work plan meeting. At this stage, the tasks for the following week are planned and assigned to project participants based on their abilities to carry them out (Bajjou et al., 2017).

Visual Management

Visual Management (VM) is a method to communicate information in all construction projects by applying the correct visual tools at the right time for the right situation. It is crucial in every construction site as they are able to pass information throughout the site without having to physically communicate with each of the employees on the construction project (Abdelkhalek et al., 2019). Various researchers have emphasized that VM is able to boost transparency in construction sites, minimize information processing time and errors, as well as encourage self-management. The most typical VM tools used are signs, labelling, colour coding and boards being displayed all over the construction site to transfer certain messages and information needed to prevent safety accidents (Tezel & Aziz, 2017b). Abdelkhalek et al. (2019) mentioned that VM was categorized into four types: visual indicators, visual signals, visual controls, and visual guarantees.

Visual indicators include a safety board demonstrating health and safety equipment, a safety control board, indication of first aid kit location and others (Abdelkhalek et al., 2019). Secondly, visual control shows deviations and assists individuals to perceive how they carry out their responsibilities. A few examples of visual controls are caution signs to indicate hazardous areas, road lines to ensure safe walkways, hazardous areas surrounded by noticeable fencing, barricade, and colour coding on-site safety and general rules (Tezel et al., 2015; Tezel & Aziz, 2017b).

Visual signals are utilized to incite a reaction to workers on site and decipher the environment that may change human's conduct to avoid errors.

In general, they are eye-catching for some fundamental focuses, for example warning lights or traffic lights (Abdelkhalek et al., 2019). Visual guarantees are to ensure that the work carried out on site is done properly by integrating devices such as a security camera. This will allow the site to be monitored closely and avoid any errors from worsen any further (Abdelkhalek et al., 2019; Tezel & Aziz, 2017a).

5S Process

5S Process is one of the most effective tools for lean manufacturing because it is the basis for effective lean implementation (Gambetese & Pestana, 2014). The 5S process allows more convenient circulation by organising material and equipment in the right places (Bajjou et al., 2017). By removing clutter, improving space utilisation, and introducing standards, the workplace is visually improved (Brady, 2014). The 5S programme is comprised of a series of activities referred to the five housekeeping practices that are part of the daily routine of every Japanese household: *Seiri* (Sort); *Seiton* (set in order); *Seiso* (shine); *Seiketsu* (standardise); and *Shitsuke* (sustain) (Enshassi & Zaiter, 2014; Tezel & Aziz, 2017a). These activities aim to cut down workplace waste, which can lead to errors, injuries, and defective products (Awada et al., 2016).

Sort focuses in eliminating the unnecessary items from the workplace. The item which is occasionally used is moved to a more organized storage area and the item which is completely unnecessary will be disposed (Hiwale, 2018). The red tag or label is commonly employed to help identify unwanted items, and all unneeded materials and equipment are disposed properly (Pons, 2016). The benefits of this process include saving space; safer workplace; comfortable working environment; and easily detecting the place/ equipment/ material damage early.

Set in order is arranging necessary things in their places through the utilization of ergonomic standards and guaranteeing that each thing has a spot (Kuklare & Hedaoo, 2017). Activities included are labelling items, using colour for quick identification, storing similar items together and storing different items together, painting floors, putting names and numbers on everything, and using rack and shadow boards for tools. The main objective is to develop the economical use of space, to keep the storage of goods neat and orderly, and to facilitate the process of locating and obtaining goods in the future (Sorooshian et al., 2012).

Shine focuses on the cleaning, including the daily cleanliness of apparatuses, machines and other gears, and guaranteeing that everything is returned to the designated place for a better work area (Kuklare & Hedaoo, 2017). Clean and organized work area acts as a motivation factor for the employees so that they will enjoy their work in a clean, healthy and safe environment which raises confidence (Enshassi & Zaiter, 2014).

Standardise refers to the process of ensuring that the first three stages of 5S become standardised to establish common standards and ways of working (Kuklare & Hedaoo, 2017). Good work standards have to be maintained so that the employees can play great roles in it, and know that their responsibilities and housekeeping duties are performed in their regular routine (Gupta & Jain, 2014). Often, standardise employs the use of visual aids. The standardisation is required to be followed by employees to guarantee the required quality and standards (Sorooshian et al., 2012).

The last process under 5S is sustain, which is to incorporate the 5S in the company's core and missions (Enshassi & Zaiter, 2014). 5S should be embedded as part of a culture in the project and should require shared responsibilities of all project team. It is considered to be the toughest to implement because it is difficult to sustain the activities performed for a longer period of time. Therefore, it is important to carry out regular audits, training and disciplining to ensure proper 5S practice, so that to avoid errors that may result in safety issues, low productivity, running costs, and many more (Kuklare & Hedaoo, 2017).

Error Proofing

The error-proofing process uses mechanical or electronic systems to identify and prevent the likelihood of errors in the production process in real time. If irregularities exist, such tools may be used to interrupt the operation in an automatic way. The error-proofing technique is aligned with safety regulations advocated by Occupational Safety and Health Administration (OSHA) to attain standardised safety requirements in the construction industry (Tommelein, 2018). In fact, the error proofing device is a tool that enables on-site workers to communicate to ensure that the work is self-regulating, self-ordering, self-improving and self-explaining (Bajjou et al., 2017).

Error proofing employs devices or tools that can be attached to hazardous areas, such as siren alarm, and in the case of failure, such devices will go off and all the work will immediately be halted (Tommelein, 2018). However, all the switches for the siren alarm should be accessible to all workers to provide safety during emergencies (Ballard et al., 2002). This has proven to be effective as it can reduce the circulation of accidents on site by integrating devices.

Table 1
List of Determinants of Lean Construction Tools

Tools	Determinants
Last Planner System	Tasks on site are explicitly outlined in sequence Utilise BIM as a communication tool to establish milestones and structure the project Detailed schedule is generated covering each project phase Keep track of the schedule to avoid incidents due to a lack of control at the construction site Detailed specifications of tasks on site are clearly presented in the weekly work plan meeting
Visual Management	Signs, labels, and colour coding are available in the construction site Safety and health instruction boards are available on the construction site Caution signs and noticeable fencing to indicate hazardous areas The use of warning light or traffic light to grab attention for some essential point Security cameras are available around the construction site
5S	All unneeded materials and equipment are disposed properly All materials and equipment are labelled and put in the right places The workplace (construction site) is kept clean and organised Establish and standardise rules to sustain the 5S process There are regular audits and training to ensure proper 5S practice
Error Proofing	Siren alarm devices are available in the construction site All switches for siren alarm devices are known and accessible Remote-control devices are used to ensure easier execution of work Zones where errors are likely to occur are indicated

Furthermore, to accomplish the usage of this tool in a construction site, high-risk zones ought to be distinguished (Sadri et al., 2011). This method also prompts the usage of machines or devices, for instance, a device that stops operating at an identified time or stops pumping when tanks are full (Abdelkhalek et al., 2019). By identifying the location of errors, the project manager might focus on investigating and addressing the problem as well as implementing a mistake-proofing mechanism to prevent further incidents. Additionally, an example of error proofing is by using a remote device to ensure better work procedure, including an electrical trolley hoist and a few workers (Sadri et al., 2011).

METHODOLOGY

This research focused on the implementation of lean construction in construction projects for safety improvement. The quantitative research was conducted with the respondents comprising G7 contractors, particularly in Kuching, Sarawak, and registered under the Construction Industry Development Board (CIDB) Malaysia. The list of contractors' firms was obtained from the Centralised Information Management System (CIMS) available on the CIDB websites. From the CIMS, there were 477 contractor companies identified, making the total population in this study. The sample size of 214 respondents was determined by using a sample size calculator with a 5% margin error and a 95% confidence level. The respondents were selected randomly from several professional groups, ranging from the safety managers, construction managers, site managers, and project managers attached with the contractors' organisations. The survey was hosted online for six weeks via Google form, and eighty-four responses were received.

The questionnaire was divided into three parts: Sections A, B, and C. Section A presents the respondents' background, such as designation, experience in the construction industry, and type of project involved. All these data were nominal scales. Section B presents questions related to the understanding of the lean construction concept. Section C contains a number of questions related to the level of implementation of lean construction in their projects. The respondents were asked to rate their responses by using the Likert scale to indicate the level of understanding and implementation of lean construction. The data analysis was carried out by using SPSS Software by applying the frequency and descriptive analysis method to present the mean and standard deviation values. The data obtained were presented in the form of tables for easy understanding.

RESULTS AND DISCUSSION

Section 1: Respondents' background

Table 2 shows that the majority of respondents are safety officers in the construction projects, followed by project managers with 28.57% and 25.00%, respectively. Regarding the respondents' experience in construction projects, most of them were considered at the middle, and senior level with working experiences of more than five years. Moreover, most of the respondents were involved in projects ranging from residential, commercial and public buildings, such as schools, hospitals and mosques since the construction products in Malaysia mainly consist of building works.

Table 2
Respondents' Designation, Experience and Project Involved

Category	Classification	Frequency	Percentage (%)
Designation	Safety Officer	24	28.57
	Site Engineer	18	21.43
	Construction Manager	11	13.10
	Contract Manager	10	11.90
	Project Manager	21	25.00
Working Experience	< 5 years	21	25.00
	5 – 10 years	33	39.29
	> 10 years	30	35.71
Project Type	Residential Building	31	36.90
	Commercial Building	18	21.43
	Infrastructure	10	11.90
	Public Building	25	29.76

Section 2: Understanding on Lean Construction

Table 3 shows the mean scores for the respondents' understanding on lean construction. It is essential to collect this information in order to evaluate the level of understanding and familiarity with lean construction among the construction players. The respondents were surveyed on their

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thoughts on five key variables. Most respondents gave a mean score of at least 3.0, with scores ranging from 3.06 to 3.26. Out of all variables, the majority of respondents (mean = 3.26) agreed on the argument that lean construction is a production system that aims to maximise value while minimising waste. It was then followed by the respondents' agreement that lean construction is able to deliver projects on time by eliminating waste, with an overall mean of 3.23. Nevertheless, it was critical to note that the respondents' familiarity and knowledge with the lean construction concept received the lowest score, thus indicating that the respondents had a basic understanding of lean construction but were unfamiliar with the terminology. Consequently, the implementation of lean construction concept is still unpopular in the Malaysian construction industry despite having professionals who are knowledgeable in the current construction development. Hence, there has to be an adequate level of awareness and understanding among construction professionals for the effective implementation of lean construction.

Table 3
Respondents' Understanding on Lean Construction

Variables	N	Mean	Std. Deviation
Familiarity with the lean construction concept	84	3.06	.812
Aim to maximize value and minimize waste	84	3.26	.946
Achieve balanced use of labours, materials, and resources	84	3.17	.709
Deliver projects on time by eliminating waste	84	3.23	.896
Motivate people by reorganising the workplace to be more efficient	84	3.20	.833

Section 3: Implementation of Lean Construction Concept towards safety improvement

Table 4 reveals the degree of lean construction tool implementation as assessed by respondents based on the safety measures practised in their construction sites. The lean construction tools for improving safety were classified into four groups: Last Planner System, Visual Management, 5S Process, error-proofing, and the interpretation based on their determinants. As for the last planner system, most respondents (mean score = 4.23) agreed on a master planning, with the tasks on site being explicitly outlined in sequence. This was usually done via critical path method (CPM) calculations widely used in construction projects to set milestones. It was followed with phase planning application where the detailed schedule was generated for each project phase, such as sub-structure, super-structure, finishes and external works, with a mean score of 3.79. However, the survey indicated that there was a minimal use of BIM to establish milestones and structure the project on construction sites as assessed by the respondents, with a mean value of 2.73. This coincided with the findings from previous researchers that argued that the integration of BIM technology has not been fully conducted in construction projects.

In terms of Visual Management, most construction sites used this tool more frequently to improve safety as assessed by the respondents with the mean above 4. This coincides with the argument from previous researchers that VM is crucial as it improves efficiency. The highest determinant was the availability of a safety and health instruction board, with the mean value of 4.44. This was categorised under visual indicator that intended to pass crucial information from management to operational level. On the other hand, the results showed that the usage of security cameras as a visual management tool was evaluated at a low level by the respondents with a mean value of 2.18, indicating that their usage was quite limited in the construction sites. This does not conform with the suggestion to integrate the installation of security cameras around the construction projects to ensure transparency of the site conditions to increase service efficiency and safety and to reduce errors.

The third lean construction tool highlighted in this study was the 5S Process. Most of the responses were graded at a mean score above 3. Most respondents agreed that all materials and equipment in their construction sites were labelled and put in the right places (mean score = 3.39). These criteria reflect one of the concepts in 5S known as “set in order”, which can prevent site congestion and potentially reduce accidents. Moreover, the respondents also believed that all unneeded materials and equipment on the construction site were disposed of properly (mean score = 3.21). This represents the “sort” concept in 5S that leads to cleanliness, thus potentially reducing accidents by untidiness on site. The least score by respondents was on conducting regular audits and training to ensure proper 5S practice,

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Table 4
Implementation of Lean Construction

Tools/ Concept	Determinants	Mean	Std. Deviation
Last Planner System	Tasks on site are explicitly outlined in the weekly work plan	4.22	.647
	Detailed specifications of tasks on site are clearly presented in the weekly work plan meeting	3.64	.771
	Utilise BIM as a communication tool to establish milestones and structure the project	2.73	1.302
	Keep track of the schedule to avoid incidents due to a lack of control at the construction site	3.74	.778
	Detailed schedule is generated covering each project phase	3.79	.746
Visual Management	Signs, labels, and colour coding are available in the construction site	4.25	.758
	The use of warning light or traffic light to grab attention for some essential point	4.19	.630
	Caution signs and noticeable fencing to indicate hazardous areas	4.29	.737
	Security cameras are available around the construction site	2.18	.588
	Safety and health instruction boards are available	4.44	1.163
5S process	All materials and equipment are labelled and put in the right places	3.39	.761
	The workplace (construction site) is kept clean and organised	3.09	.652
	All unneeded materials and equipment are disposed properly	3.21	.678
	Establish and standardise rules to sustain the 5S process	3.07	.792
	There are regular audits and training to ensure proper 5S practice	2.89	.655
Error Proofing	Siren alarm devices are available in the construction site	2.92	1.099
	All switches for siren alarm devices are known and accessible	2.71	.952
	Remote-control devices are used to ensure easier execution of work	1.99	.963
	Zones where errors are likely to occur are indicated	3.63	.833

which fell under "sustain" process with the mean value of 2.89. This process is the toughest to be implemented because it is difficult to sustain the activities performed for a long period of time.

Lastly, the result that indicated the degree of implementation for error-proofing tools showed that most of the respondents agreed that there was a clear indication of possible error zone in the construction site with a mean score of 3.63. By monitoring error, the respected personnel such as project manager may investigate and resolve them, and build a mistake-proofing mechanism to prevent future problems. The least score graded by the respondents under this category was the use of remote-control devices to ensure easier execution of work (mean score = 1.98). This indicates that the use of this device is very low despite being significant in making task easier, and thus reducing the likelihood of accidents caused by manual handling.

CONCLUSION

This paper is intended to highlight the lean concept and its tools which can be adopted in the construction project to enhance safety. Even though the lean construction is still an unpopular term or technique among construction professionals in the industry, it has demonstrated a considerable number of advantages for improving the safety of construction sites. The findings of this paper represented the extent of the application and understanding of lean construction tools (Last Planner System (LPS), Visual Management (VM), 5S Process and Error Proofing) on safety in Sarawak's construction industry particularly. The results of the study showed that all respondents had moderate knowledge and understanding of lean construction concept. However, the use of lean construction tools has been adequately implemented by most of the respondents' organisations. Additionally, it is recommended for future researchers to use a case study to study how lean construction is being used on construction sites. This is to comprehend and further learn about a wider range of things from different points of view. At the same time, it will give future researchers the chance to compare the lean construction tools that are already being used on construction sites.

In conclusion, many organisations that adopt lean construction have shown significantly increased safety, efficiency, waste reduction, project value, and customer satisfaction. Therefore, the exposure to lean construction concept among construction players is important to enhance its implementation in construction projects, which effectively reduces safety issues and waste while remaining competitive in the industry. The result obtained will hence improve the awareness and implementation of the lean construction concept in the construction industry, thereby enhancing workplace safety.

CONTRIBUTIONS OF AUTHORS

The authors confirm the equal contribution in each part of this work. All authors reviewed and approved the final version of this work.

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CONFLICT OF INTERESTS

All authors declare that they have no conflicts of interest.

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