Lean construction and project performance in the Australian construction industry

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Abstract. The construction industry is plagued by poor project performance and the adoption of lean construction is seen as a way to address this issue. Therefore, this research aims to assess the implementation of lean construction and its relationships with project performance in the Australian construction industry. Just in time, last planner system, Six Sigma, and 5S management are the four lean construction tools investigated in the research. Data were collected using a questionnaire survey from construction practitioners in Sydney, Australia. Results show that the implementation of these four tools is adequate, although some lean activities need to be implemented at a higher level. Lean construction also has strong correlations with many project performance indicators, demonstrating its value to the construction industry that is in a dire need of improvement. Finally, this research also recommends specific areas for improvements.

1. Introduction

The construction industry is notorious for its inefficiency, which results in low productivity, frequent delays, budget overruns and poor quality. Infrastructure Australia [1] reported that the productivity of the Australian construction sector on an hours-worked basis declined by 2.5% between 2017 and 2018, while the average global construction productivity grew by 1%. Another study conducted by KPMG [2] revealed that 89% of respondents working in Australian construction companies reported poor project performance, particularly delays and cost overruns.

Understandably, there have been many attempts to tackle these issues which have been plaguing the Australian construction industry. One of these attempts is the adoption of the lean management philosophy which originated from the car manufacturer Toyota. This management concept is based on five foundations: value, value stream, flow, pull and pursuit perfection [3].

In the construction industry, this philosophy has been adopted and adapted to many management tools and systems. Research has been done to assess the impact of implementing lean management on cost and time performances (for example, see Bashir et al. [4]). However, despite its rising popularity, the level of lean management implementation in construction projects in Australia and its impact on performance still need further investigation as most research was conducted in other countries. In order to fill this research gap, this research aims to assess the implementation levels of four lean management tools, namely, Just in Time (JIT), Last Planner System (LPS), Six Sigma and 5S Management, and their impact of construction project performance.
2. Literature review
The lean approach was pioneered by Toyota in the form of Toyota Production System. It became popular among western manufacturers due to a book titled “The Machine that Change the World” by Womack, Jones and Ross [5]. Since then, many major businesses globally have been trying to implement lean management to streamline the production process and achieve optimisation in the use of resources [6]. Lean management concept is underpinned by five core foundations [3]:
- Value: a company should comprehensively understand what a product’s value means in customers’ eyes.
- Value stream: the value that has been determined should be carried over to the production stage and all departments in the company.
- Pull or waste elimination: the concept of production is only produced if there is a demand.
- Flow or reorganising stream: corporation should improve its production flow so that there is no delay or interruption in delivering the product to customers.
- Pursue perfection: synonymous with the Kaizen concept in Japan which means continuous improvement.

The lean management concept was introduced to the construction industry by Koskela in 1991 at the first conference of the International Group of Lean Construction [7]. Since then, lean construction has evolved into diverse management techniques in the construction industry, aiming to eliminate waste, improve productivity and efficiency, and maximise value [8]. Implementation of lean construction is still relatively new compared to orthodox management practices. Lack of awareness of lean construction is still a major challenge [9] and some studies even argue that the lean construction concept is still in the early stage of development [10, 11].

Regardless of that, lean construction has slightly different foundations as compared to the original lean management for the manufacturing sector due to the nature of the production process. The principles of lean construction can be summarized into 6 points: reducing variability, reducing cycle time, simplicity, benchmarking, increasing output flexibility, and increasing process transparency [4]. Other researchers [12, 13] considered production flow and waste elimination as the core principles of lean construction.

In terms of tools to apply lean construction, it is common for organisations to apply more than one specific tool [7, 14-16]. Karim and Arif-Uz-Zaman [6] also revealed that the result of implementing these tools vary across organisations. As a result, construction companies only adopt suitable tools that align with their target, culture, and ability [4]. The following sections describe common tools used to implement lean construction.

2.1. Just in time (JIT)
JIT emphasises the concepts of having the right items, the right quality and the right quantity [17]. This management tool focuses on improving production flow by tidying up inventory and utilised the inventory system best practice to control material and equipment stockpiles. Rather than excessively stockpiling materials and products to anticipate unforeseen conditions, JIT focuses on improving the quality of the products and reducing the material buffer. With a significant reduction in the storage cost and material stockpile, this tool helps to reduce production cost while also improving the quality of delivered products. However, due to a tight buffer on materials and a strictly regularised programme, JIT is prone to sudden disruptions from the supply chain [17], which will wipe out all benefits of its implementation.

In the construction industry, researchers [7,17,18] agreed that to achieve the philosophy of JIT, construction projects should start by improving the workflow by organising the construction site layout, material and equipment storage, and having a good inventory system to track the stockpile. Hence, the implementation of JIT concept mainly focuses on construction site management and logistics.

Pheng and Hui [17] conducted a case study to assess how JIT can be utilised to organise site layout in a residential building project in Singapore and found that the project had a better outcome than those that did not implement JIT. Another study by Pheng and Chuan [18] investigated the supply management
of precast concrete components. The study highlighted that JIT could reduce storage cost and time buffer of work packages. However, there is still a reluctance to implement the strict JIT concept, i.e., delivering materials on the day when they are required to be installed, due to the risk of delivery delay and other unexpected scenarios, such as weather conditions. JIT implementation, therefore, should be adjusted to accommodate uncertainties in the construction process.

2.2. Last planner system (LPS)
LPS was firstly introduced in an attempt to set a realistic expectation of the completion of a construction project [19]. To set realistic planning and uninterrupted workflow, LPS introduces collaborative planning that involves all project team members to ensure smooth workflow and reduce miscommunication between trades [20]. LPS is typically based on four planning stages: the master plan, six-week look-ahead plan, weekly work plan, and percent plan complete [4, 19, 20].

The master plan consists of a high-level project schedule, which is developed based on key project milestones. Milestones are planned using the reverse scheduling technique, in which each milestone is derived from the successor milestone [19, 20]. The look-ahead plan is an intermediate level of planning that consists of work items within six to eight weeks of work schedule [19]. The number of weeks varies, depending on the reliability of the planning system and the lead times for acquiring information and resources [3]. The weekly work plan is a detailed schedule derived from the look-ahead plans. At this stage, an examination of prerequisites items for each assignment can be conducted to ensure the feasibility of executing assignments [21]. Finally, percent plan complete acts as a benchmarking tool to measure the percentage of completed assignments within the total assignment planned on the weekly work plan [3]. The reasons for failing to complete assignments are recorded to evaluate and improve the weekly work plan. Research found that the use of LPS can reduce the unpredictability of the construction schedule, minimise miscommunication between stakeholders, and improve construction safety [10, 11, 16].

It is also worth mentioning that the master plan and look-ahead plan are common planning tools in construction projects [7, 8, 9]. However, LPS enforces different approaches to developing these planning tools. Instead of relying only on past performance and data, the LPS method also takes consideration the feedback given by executors and direct stakeholders on construction site, e.g., foremen and trades [3, 7, 9, 27]. Their feedback then further enforces the detailed planning for each work package in the weekly work plan.

The main concept of percent work complete is to actively measure deviations between the targets set up in the planning tools (master plan, look-ahead plan, and weekly work plan) and the execution of each task [3, 8, 27]. By doing so, immediate corrective actions can be taken to prevent any further deviation and help to improve the accuracy of further work stages planning.

2.3. Six sigma
Six Sigma is a structured management tool that aims to reduce variations that occur during the production process [22]. With the reduction in variations, the outcome of the production process can be predicted and defects can be anticipated. The term Six Sigma originally came from statistics, where one sigma represents a single standard deviation of the expected outcome. When products deviate within the range of six sigma, they have an extremely low deviation rate [23]. A number of researchers [22-24] argued that the Six Sigma concept strives for a quality of having no more than 3.4 defects per million products. The nature of the construction industry makes it difficult to achieve that level of defect rate. Instead, Six Sigma in the construction industry is more about the concept of reducing waste and defects as much as possible [25].

Six Sigma consists of five main elements, namely, define, measure, analyse, improve, and control. ‘Define’ is about identifying problems, client’s expectations, and key factors affecting the production process [26]. The ‘Define’ stage starts in the beginning of the project cycle and involves discussion and brainstorming among stakeholders to ensure they have the same view on expected project outcomes [22, 26]. The desired outcomes are then linked with quantifiable measurements that include performance
indicators in the ‘Measure’ process. This allows performance levels to be monitored regularly and ensures those outcomes are carried on to the production stage [22]. ‘Analyse’ focuses on finding solutions to improve the current state of the project [25, 26]. ‘Analyse’ process also includes monitoring and controlling any reworks and defects, and also finding any possible preventive actions [22]. ‘Improve’ is about implementing any solutions and innovations to improve the current production process. It should be highlighted that Six-Sigma also strongly recommends a collaborative approach throughout the process which allows any team member to suggest ideas and recommendations for the sake of improvement [24] Lastly, ‘Control’ is about maintaining the current gain and improvement [15]. Banawi and Bilec [15] explained that to strongly maintain the current level of improvement and gain, leadership and management of an organisation should have a strong commitment towards continuous improvement. This includes providing any necessary training, induction, and organisation cultural changes [25].

In construction, Six Sigma has the potential to reduce variations, improve quality control, and reduce defects and reworks [15, 26]. Banawi and Bilec [15] conducted a study on Six-Sigma implementation in pile caps installation project. The study found that Six-Sigma implementation prevents defects and rework by diagnosing processes that can potentially produce defective products. Additionally, Han et al. [26] confirmed the benefit of Six-Sigma application to reduce production variability.

2.4. 5S management

5S Management concept was introduced by Takashi Osada in 1980 as a main key to a total quality environment that improves the physical environment and mental processes in workplaces [28]. 5S Management is systemic housekeeping in the workplace and focuses on cleanliness, organisations, standardisation of the workplace which leads to better safety, productivity, creativity, and continuous improvement [4, 7, 16]. In construction, 5S management is usually used for site management and layout planning. This includes classifying material and equipment (seiri), tidying up (seiton), maintaining the cleanliness (seiso) of the site, removing (seiketsu) unnecessary stuff and waste, and providing necessary training and induction to sustain the best-practice (shitsuke) [7, 9, 20]. Research has indicated that 5S management can improve productivity and safety in the construction industry [7, 9, 11, 16].

Pheng and Ang [28] conducted a case study in which 5S Management was implemented in a residential building project in Singapore. The study found that despite not achieving the total elimination of waste, 5S Management tool helped the project declutter and improve the accessibility of the site which resulted in safety improvement. These findings are also aligned with Enshassi et al. [9] and Maradzano et al. [16].

3. Research methodology

The research aims to assess the implementation level of lean construction tools and to establish relationships between lean construction implementation and project performance in Australia. It was hypothesised that there should be positive associations between lean construction and project performance. Since the research is deductive in nature, quantitative methodology was adopted and an online questionnaire survey was used to collect data from construction practitioners in the Australian construction industry.

The questionnaire consists of three sections. The first section was designed to capture demographic data of respondents, such as organisation’s role, organisation size, ISO 9001:2015 certification in the organisation, respondent’s highest qualifications, and years of experience. The second section has 17 items and was used to assess the implementation level of four lean construction tools discussed in the literature review. The five-point Likert scale format, ranging from strongly disagree to strongly agree was utilised to capture respondents’ perceptions of the implementation of lean construction tools in projects they were currently working on. The same Likert scale format is used in the third section to measure the respondents’ perceptions of nine project performance indicators, including material waste, rework, storage cost, time performance, productivity, management process, quality performance, client satisfaction, and potential repeat works from the client.
The online questionnaire was distributed to construction practitioners in Sydney, Australia, through social media, construction forum and personal messages. In this early stage of the research, 33 responses were collected, but nine responses had to be discarded due to incomplete responses, bringing the total valid responses to 24. More data will be collected in the next phase of the research.

4. Analysis and discussion
Table 1 presents the profile of the 24 respondents. Many of the respondents worked in medium size companies (50%). The majority of the respondents (75%) had an undergraduate or a postgraduate degree and more than 70% of them had worked six years or more in the construction industry.

Table 1. Profile of the respondents.

| Profile                  | Category                | %  |
|--------------------------|-------------------------|----|
| Organisation size        | Self-employed           | 8  |
|                          | Micro (1-4)             | 8  |
|                          | Small (5-19)            | 17 |
|                          | Medium (20-199)         | 50 |
|                          | Large (200 or more)     | 17 |
| ISO 9001:2015 certification | Yes                    | 21 |
|                          | No                      | 37 |
|                          | Don’t know              | 42 |
| Highest qualification    | Certificate III/IV      | 4  |
|                          | Diploma/Associate degree| 17 |
|                          | Bachelor                | 42 |
|                          | Master                  | 29 |
|                          | PhD                     | 4  |
|                          | Other                   | 4  |
| Years of experience      | 1-5                     | 29 |
|                          | 6-10                    | 25 |
|                          | 11-15                   | 25 |
|                          | 16-20                   | 17 |
|                          | More than 20            | 4  |

Table 2 presents the levels of lean construction implementation. JIT seems to be the most common lean construction tool to be implemented in the Australian construction industry, while 5S is the least common. Nearly all the mean scores are below 4, indicating that their implementation can be improved further. It is concerning to see that deviation between plan and progress is not measured and monitored regularly. Standards and rules on housekeeping and site management as well as training to enforce site management best practices are also lacking. Finally, there is a need for stronger management commitment to continuous improvements.
Table 2. Lean construction implementation.

| Profile                  | Category                                      | Mean  Overall mean |
|--------------------------|-----------------------------------------------|-------------------|
| Just in time             | Defined area for storing material and equipment| 3.75  3.78        |
|                          | A classification storage system for easy access| 3.50             |
|                          | Inventory system                              | 4.08             |
| Last planner system      | Work collaboratively to develop the schedule for each work phase | 3.83  3.54        |
|                          | Look ahead planning throughout project duration| 3.96             |
|                          | Measure and monitor deviation between plan and progress | 2.75             |
|                          | Immediate corrective action                   | 3.63             |
| Six Sigma                | Discussion in the beginning of the project to ensure each team member is on the same page | 3.96  3.61        |
|                          | Clear goals and performance indicators         | 3.96             |
|                          | Control and monitor defects and reworks        | 3.46             |
|                          | Any team member can suggest improvements       | 3.58             |
|                          | Strong management commitment and leadership to continuous improvements | 3.08             |
| 5S management            | Monitor, audit and sort materials, equipment and tools on site | 3.96  3.53        |
|                          | Remove unnecessary stuff and waste from the site| 3.83             |
|                          | Regular housekeeping and cleaning              | 3.96             |
|                          | Consistent standards and rules applied on housekeeping and site management | 2.92             |
|                          | Training to enforce the application of site management best practices | 3.00             |

Note: For the mean score, 1 = strongly disagree and 5 = strongly agree

4.1. Just in time and project performance
Spearman’s correlation was conducted to establish relationships between just in time and project performance indicators. The significant correlations ($p<0.05$) are presented in Table 3. The main aim of JIT is to improve production flow by tidying up the inventory on construction site [18]. Understandably, JIT can reduce storage cost and improve the efficiency of management process. Effective inventory system used in JIT also contributes to on-time delivery of work packages, probably due to improved production flow. This also improves the quality of work as reflected by the reduced number of reworks. Finally, positive time and quality performances can lead to high level of client satisfaction, which opens the way for repeat works or future partnership with the client.

Table 3. Significant correlations between just in time and project performance.

| JIT element                                      | Project performance                                      | Correlation | Significance |
|--------------------------------------------------|----------------------------------------------------------|-------------|--------------|
| Defined area for storing material and equipment   | Effective management process                              | 0.633       | 0.001        |
|                                                  | High client satisfaction                                  | 0.490       | 0.018        |
|                                                  | Reduced reworks                                           | 0.601       | 0.002        |
|                                                  | Reduced material and equipment storage cost               | 0.549       | 0.007        |
|                                                  | Future partnership potential with client                   | 0.538       | 0.008        |
| A classification storage system for easy access  | Reduced reworks                                           | 0.592       | 0.003        |
|                                                  | Effective management process                              | 0.440       | 0.036        |
| Inventory system                                 | On-time work package delivery                             | 0.451       | 0.031        |
4.2. Last planner system and project performance

The significant correlations between last planner system and project performance are presented in Table 4. LPS is a useful tool to improve communication and coordination between stakeholders, and to set realistic targets for everyone involved [19, 20]. Regular control and monitoring processes in LPS are valuable to identify deviations early so that corrective action can be done to bring the project back on track [27]. As such, LPS is considered as an effective lean construction tool to improve productivity and quality in construction projects [20, 27].

This research found that LPS has positive associations with many project performance indicators. As expected, LPS is correlated positively with time performance indicators, such as productivity, effective management process, and on-time delivery of work packages, due to its focus on developing work schedules collaboratively, which improves communication and coordination among project stakeholders. Better communication and coordination through the implementation of LPS also can improve the quality of work, which is reflected by reduced reworks and product consistency. All this results in highly satisfied clients who are more likely to offer repeated works.

Table 4. Significant correlations between last planner system and project performance.

| LPS element                                         | Project performance                        | Correlation | Significance |
|----------------------------------------------------|--------------------------------------------|-------------|--------------|
| Work collaboratively to develop the schedule for each work phase | Effective management process               | 0.588       | 0.003        |
|                                                     | High client satisfaction                    | 0.522       | 0.011        |
|                                                     | Reduced reworks                            | 0.512       | 0.013        |
|                                                     | High productivity                          | 0.504       | 0.014        |
|                                                     | Product consistency                        | 0.440       | 0.035        |
|                                                     | On-time work package delivery               | 0.432       | 0.040        |
| Look ahead planning throughout project duration     | High client satisfaction                    | 0.636       | 0.001        |
|                                                     | Future partnership potential with client    | 0.568       | 0.005        |
|                                                     | Product consistency                        | 0.440       | 0.035        |
| Measure and monitor deviation between plan and progress | Future partnership potential with client    | 0.515       | 0.012        |
|                                                     | Effective management process                | 0.474       | 0.022        |
| Immediate corrective action                         | High client satisfaction                    | 0.550       | 0.007        |
|                                                     | Reduced material and equipment storage cost | 0.494       | 0.017        |

Looking back at Table 2, ‘measure and monitor deviation between plan and progress’ has a low level of implementation (2.75) even though it can improve management process and lead to better relationships with the clients. This is an area of improvement that construction organisations can focus on.

4.3. Six sigma and project performance

Spearman’s correlation analysis was performed to find the relationships between Six Sigma and project performance, and the significant results are presented in Table 5. As stated earlier, Six Sigma aims to reduce variations and continuously improve performance in construction processes. The results demonstrate that Six Sigma can indeed achieve these aims in the Australian construction sector. Six Sigma has the potential to reduce reworks and generate consistent products, which can also lead to reduced waste and storage cost. Fewer variations also mean less burden on the management process and higher productivity. Ultimately, the clients are satisfied and are willing to build long-term relationships with the construction organisations involved.

Table 2 shows that ‘management commitment and leadership to continuous improvements’ is an element of Six Sigma that can be further improved. This is important because management commitment is an underlying and support factor that drives change and motivate employees to embrace new ways of
doing things to improve performance. It is urgent for the Australian construction industry to improve its commitment to continuous improvements because this research has confirmed that it can reduce reworks, improve management process, and build positive relationships with clients.

Table 5. Significant correlations between Six Sigma and project performance.

| Six Sigma element                          | Project performance                          | Correlation | Significance |
|-------------------------------------------|---------------------------------------------|-------------|--------------|
| Clear goals and performance indicators    | Material waste reduction                     | 0.636       | 0.001        |
|                                          | High productivity                           | 0.505       | 0.014        |
|                                          | High client satisfaction                    | 0.473       | 0.023        |
|                                          | Reduced material and equipment storage cost | 0.446       | 0.033        |
| Control and monitor defects and reworks   | Material waste reduction                     | 0.515       | 0.012        |
|                                          | Product consistency                         | 0.424       | 0.044        |
|                                          | Effective management process                | 0.419       | 0.047        |
|                                          | Reduced material and equipment storage cost | 0.415       | 0.049        |
| Any team member can suggest improvements  | Future partnership potential with client     | 0.550       | 0.007        |
|                                          | High client satisfaction                    | 0.448       | 0.032        |
|                                          | Effective management process                | 0.420       | 0.046        |
| Strong management commitment and leadership to continuous improvements | Future partnership potential with client | 0.592 | 0.003 |
|                                          | Reduced reworks                            | 0.537       | 0.008        |
|                                          | Effective management process                | 0.494       | 0.016        |

4.4. 5S management and project performance

Lastly, Table 6 presents the significant relationships between 5S management and project performance. 5S management particularly focuses on housekeeping on site, which facilitates better safety, higher productivity, and increased creativity [4, 7, 16].

Table 6. Significant correlations between 5S management and project performance

| 5S element                              | Project performance                          | Correlation | Significance |
|-----------------------------------------|---------------------------------------------|-------------|--------------|
| Monitor, audit and sort materials, equipment and tools on site | Material waste reduction                     | 0.553       | 0.06         |
|                                          | Product consistency                         | 0.432       | 0.04         |
| Remove unnecessary stuff and waste from the site | Product consistency                     | 0.771       | < 0.001      |
|                                          | High client satisfaction                    | 0.455       | 0.029        |
|                                          | Material waste reduction                    | 0.583       | 0.003        |
| Regular housekeeping and cleaning       | Reduced reworks                            | 0.672       | < 0.001      |
|                                          | Effective management process                | 0.519       | 0.011        |
|                                          | High productivity                           | 0.589       | 0.003        |
|                                          | Reduced material and equipment storage cost | 0.442       | 0.034        |
|                                          | On-time work package delivery               | 0.431       | 0.04         |
| Consistent standards and rules applied on housekeeping and site management | Effective management process | 0.681 | < 0.001 |
|                                          | Reduced material and equipment storage cost | 0.491       | 0.017        |
|                                          | Future partnership potential                | 0.431       | 0.04         |
| Training to enforce the application of site management best practices | Future partnership potential | 0.692 | < 0.001 |
|                                          | Effective management process                | 0.570       | 0.005        |
|                                          | Reduced reworks                            | 0.476       | 0.022        |
The correlations show that 5S management has a strong potential to improve project performance in the Australian construction industry. Better housekeeping can lead to waste reduction and cost saving in material storage. Better housekeeping makes a site cleaner and free from clutters, which improve productivity and on-time delivery of work packages. Housekeeping also matters when it comes to quality of work as it facilitates product consistency and reduces reworks. As the other previous lean construction tools, 5S management also strongly correlates with high client satisfaction and positive relationships with clients.

Table 2 shows that ‘consistent standards and rules applied on housekeeping and site management’ and ‘training to enforce the application of site management best practices’ are lacking in the Australian construction industry. These two elements of 5S management are needed to standardise and sustain housekeeping practices in and across projects within a construction organisation.

5. Conclusions

This research has assessed the level of lean construction implementation and established the relationships between lean construction tools and project performance. The research found that the level of lean construction implementation is adequate, even though some lean activities can be improved considerably. This is important because lean construction is strongly associated with a wide range of project performance indicators, including productivity, waste reduction, on-time delivery of works, quality, and client satisfaction. This research has identified the following areas for improvements:

- Measuring and monitoring performance to capture deviations from expected performance early so that corrective actions can be implemented in a timely manner.
- Management commitment to continuous improvements, which is an important driver to change organisational culture and motivate employees to embrace new practices that improve performance.
- Having housekeeping standards and rules which can be applied across projects within a construction organisation.
- Communicating housekeeping standards and rules to employees and providing necessary training to allow the employees to implement those standards and rules.

This paper presents preliminary results of research on lean construction in the Australian construction industry. More representative data will still be collected to validate the results. Despite this limitation, the research has given an important snapshot that demonstrates the potentials of lean construction to improve project performance which has been falling in the Australian construction industry.

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