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Lean Construction Tools

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Abstract

Production management is at the center of lean construction (LC) and keeps running from the project initiation through project handover to maintenance. Several powerful lean production techniques and tools have been developed over the past decade to manage construction projects. Some of these are procedural, some are conceptual, and some are embedded in programming. Besides, while some of these tools are simple, complexities revolves around others, for instance, the last planner system (LPS) is considered complex. This different set of tools is very effective in the hands of managers stimulated by the lean project conceptualization and management. It has been indicated that Danish contractors had increased productivity by 20%, minimized project duration by 10%, expanded efficiency by 20%, and enhanced profitability 20% - 40% on projects where lean principles are adopted. However, no list would be conclusive and accurate for long because innovation is in progress and new techniques and tools emerge constantly. In this study, we identify suitable lean construction tools based on their applicability and ability to control delays in Malaysian construction projects. This study provides construction managements with suitable lean construction tools to build a realistic and rational lean application guide.

Keywords

Lean Construction, Lean Tools, Construction Project, Lean Production, Applicability

1. Introduction

Production management is at the center of lean construction (LC) and keeps running from the project initiation through project handover to maintenance. Lean Production Management (LPM) is keen to managing and reducing uncertainty and variability in project plans execution. Numerous powerful lean production techniques and tools have been developed over the past decade to manage construction projects. Some of these are procedural, some are conceptual, and some are embedded in programming. While some of these tools are simple, complexities revolve around others, for instance, the last planner system (LPS) is considered complex (Ballard et al., 2000). This different set of tools is very effective in the hands of managers enlivened through project conceptualization and management. Bertelsen et al. (2001) indicated that Danish contractors had increased productivity by 20%, minimized project duration by 10%, expanded efficiency by 20%, and enhanced profitability 20% - 40% on projects where lean principles are adopted. However, no list would be conclusive and accurate for long because innovation is in progress and new techniques and tools emerge constantly.

The recognition of the uncertainty on construction projects as a result of the how projects are managed, rather than blaming on external sources is an initial step for lean project delivery system (LPDS) and subsequently reducing uncertainty and waste in processes. Project management must utilize and deploy tools, skills, knowledge, techniques and available resources to facilitate projects to be able to complete projects on time (Glenn, 2007; Sorooshian et al., 2010; Norzima et al., 2011; Saladis and Kerzner, 2011; Sorooshian, 2014).

Several techniques and tools have been developed and used in the lean project implementation guideline LPDS. This is due to the recognition by construction companies of the possibilities of an effective lean project development process in reducing time to complete new projects (Bashford et al., 2005; Abdelhamid et al., 2008; Sacks et al., 2010; Marhani et al., 2013; Sarhan and Fox 2013; Muhammad et al., 2013; Nikakhtar et al., 2015), environmental sustainability, design and supply chain management integration, engineering hours, ease of constructability, flexibility, process control, and increased in the quality of new projects (Rahman et al., 2012; Aziz and Hafez, 2013; Muhammad et al., 2013). Nonetheless, the incorporation of the concept of lean thinking into the construction project development process comes with its own weaknesses and strengths. For most businesses, there is still some uncertainty concerning the suitable lean tools and its effectiveness. Without suitable lean tools, the improvement and performance of the lean project development program cannot be achieved and this may lead to poor decision making in the lean project development implementation roadmap (Schweikhart and Dembe, 2009; Li, 2011).

Also, there has been remarkably little empirical and academic research on the subject addressed in this study and much of existing lean tools application for construction project delivery are country or project specific, concentrated on lean thinking and barriers that prevent lean implementation (Sacks et al., 2010; Lajevardi et al., 2011; Muhammad et al., 2013; Marhani et al., 2013; Sarhan and Fox 2013; Nikakhtar, et al., 2015) or description of a single, two or few lean tools; thereby overlooking other suitable lean tools, whilst others are consultancy approaches, which are partly and in some instances not published. Therefore, there is a need for more empirical research that concentrates on the identification of suitable lean tools for construction projects. This is because without a clear identification of suitable lean tools reducing delays in the construction industry will be complicated. The interesting point here is about the suitability or applicability of the lean tools. To deal with the suitability, applicability, and effectiveness of the lean tools, this study identifies the applicable and/or suitable lean tools to control waste in Malaysian construction projects.

2. Lean Construction Tools

There is no doubt that lean construction is the way forward for construction industries around the world, especially Malaysia. About 57% of productive time waste are said to exist in the construction industry (Hannis-Ansah et al., 2016) and this calls for research and the use of robust and radical techniques to solve the problems the industry faces (Lajevardi et al., 2011; Zahidy et al., 2015). The conventional approaches to construction project management have inadequacies in addressing the challenges in the industry (Ballard and Howell, 1994; Johnston and Brennan, 1996; Koskela, 2000; Koskela and Howell, 2001; Hannis-Ansah et al., 2016). Conversely, lean production management and techniques provide the foundations for waste minimization or its total elimination from construction projects (Muhammad et al., 2013). One of the most effective approaches for reducing delays in Malaysian construction projects is through lean tools adoption (Nikakhtar et al., 2015). Even though Malaysian construction industry is still evolving, there is neglect of the benefits of lean tools adoption in the industry (Muhammad et al., 2013). Meanwhile, other

industries have been reaping the benefits of using lean tools (Schweikhart and Dembe, 2009; Salimi et al., 2012; Koay and Sorooshian, 2013; Anvari et al., 2014; Alireza and Sorooshian, 2014). Similarly, other construction industries elsewhere have found lean tools to be effective in delay control (Bashford et al., 2005; Abdelhamid et al., 2008; Sacks et al., 2010; Marhani et al., 2013; Sarhan and Fox 2013; Aziz and Hafez, 2013). The Malaysian construction industry is suffering from issues of high delays and low productivity and the only feasible method to cope with this situation is to adopt the lean methodology, and it will be more significant that lean tools are applied by all stakeholders involved in Malaysian construction industry (Muhammad et al., 2013).

In general, lean construction tools are intended to improve the delivery systems and processes by minimizing wastes, increasing productivity and health and safety and overall, achieving client’s requirements (Hannis-Ansah et al., 2016). In essence, it will lead to better delivery processes and value-added systems through the removal of wastes; transportation, overproduction, inappropriate processing, lead time, inventories, rework and unnecessary movements in construction processes, hence, improve project and financial performance of the industry (Hannis-Ansah et al., 2016). In order to resolve the problems associated with waste in the construction projects, several lean tools have been recommended by a few researchers. Among them include Rahman et al. (2012), Muhammad et al. (2013), Aziz and Hafez (2013), Burton and Boeder (2003), Hines and Rich (1997) and Evbuomwan and Anumba (1998), Ballard and Howell (1994), Johnston and Brennan (1996), Koskela (2000), Bashford et al. (2005), Sacks et al. (2010), Marhani et al. (2013), Sarhan and Fox (2013), among others. Emphatically, Muhammad et al. (2013) underlined 9 tools for the Malaysian construction industry. Also, Rahman et al. (2012) listed 27 tools to construction practitioners as an introductory lean implementation guide (see figure 1). Even though these works are worthwhile, however, they lack evidence in their analysis and whether or not these tools are suitable for the context of Malaysian construction projects is subjective.



Figure 1: Waste Management Framework

In confirmation of the literature gap and how to fill this gap, this paper through comprehensive literature identifies some suitable lean tools for further empirical inquiry in the context of construction project development.

Table 1: Lean Construction Tools

No.	Reference	Tools	Description
1	Alireza and Sorooshian (2014), Rahman et al. (2012), Muhammad et al. (2013)	5S	Stands for Seiri, Seiso, seiton, Seiketsu and Shitsuke, (meaning Sort, Straighten, Shine, Standardize, and Sustain). This is a process for waste removal from the workplace through the use of visual controls.

2	Aziz and Hafez (2013), Rahman et al. (2012)	Concurrent Engineering	This methodology involves the various tasks parallelly executed multi-disciplinary teams with the aim of optimizing engineering cycles of products for efficiency, quality, and functionality.
2	ASQ (2015), Rahman et al. (2012)	Check Sheet	Also known as Defect Concentration Diagram. This is a structured form prepared for collecting and analyzing data. It is a generic tool adapted for a variety of purposes including observation and a collection of data on the frequency of patterns of problems, events, defects, causes, etc.
4	Lee et al. (1999), Rahman et al. (2012)	Construction Process Analysis	This actualizes process charts and top-view flow charts common among process analysis methods. These diagrams and charts depend on standardized symbols and effectively describe process flow and enable a quick determination of areas where problems exist in the process. The charts comprise of six symbols; Operation, Storage, Transportation, Volume Inspection, Delay, and Quality Inspection. The process diagram records every progression or step of a construction operation. Furthermore, it records flow within units, sections, and departments
5	Alireza and Sorooshian (2014), Rahman et al. (2012)	Six Sigma	Sets of tools and techniques for improving quality through identification and removal of defects and reduction of variability in processes. Six Sigma is able to achieve process quality of 99.99966% that is free from defects.
6	ASQ (2015), Rahman et al. (2012)	Pareto Analysis	This is a bar graph that is used for analyzing data about the frequency of the causes or problems in processes. It visually depicts which situation are more important.
7	Alireza and Sorooshian (2014), Rahman et al. (2012)	Check Points and Control Points	These are mechanisms used to regulate and determine the levels of improvement in the activities of managers occupying different levels of positions
8	ASQ (2015), Rahman et al. (2012)	Failure Mode and Effects Analysis (FMEA)	This is a step by step approach for identifying potential failures in product or service, design, and manufacturing, etc. The failures are further ranked to determine the seriousness of their consequences in order to take actions to eliminate them, starting with the highest ranked ones.
9	Aziz and Hafez (2013), Alireza and Sorooshian (2014)	Continuous Flow	This means to constantly provide or process and produce through a progressive system of uninterrupted steps in the process.
10	Alireza and Sorooshian (2014)	FIFO line (First In, First Out)	This is an approach for handling work request in order of flow from first to the last.
11	Alireza and Sorooshian (2014)	Jidoka/Automation	The purpose of Jidoka is to design machines to partially automate the manufacturing process and operations in order to separate people from machines so that operators carry out other task(s) while the machines are running.
12	Rahman et al. (2012), Alireza and Sorooshian (2014)	Kanban (Pull System)	This is a Japanese word which literally means “billboard or signboard”. It is an information control process which regulates the movements or flow of resources so that parts and supplies are ordered and released as they are needed.
13	Alireza and Sorooshian (2014)	Kaizen	This is Japanese business philosophy for continuous improvement. This is an approach that seeks to improve quality and efficiency through the elimination of waste from the value stream.
14	Rahman et al. (2012), Muhammad	The Last Planner	The last planner is a person or group of people with the task to control production unit. They are responsible necessitating

	et al. (2013), Aziz and Hafez (2013)		control of workflow, verify supply stream, design, and installation in all the production units.
15	Alireza and Sorooshian (2014)	Heijunka (Level Scheduling)	This is an evenly spreading of production for customer orders by looking at the average demand and combining them into a production schedule that takes into consideration the volume and mix.
16	Muhammad et al. (2013), Alireza and Sorooshian (2014)	Poka-Yoke (Error Proofing)	This is a mechanism design to detect and prevent errors in processes with the aim of achieving zero defects.
17	Salem et al. (2005), Rahman et al. (2012), Muhammad et al. (2013)	First Run Studies	Trial execution of a process with a specific end goal to decide the best means, strategies, sequencing, among others to perform it. First run studies are done a couple of weeks ahead of the scheduled execution of the process, in order to secure some time to acquire diverse or extra essentials and resources. In construction, this is used for redesigning critical assignments. This is part of continuous improvement effort, and incorporate efficiency studies and review work techniques by redesigning and streamlining the distinctive functions involved. The techniques involve the use of photographs, video files or graphics to demonstrate the process.
18	Alireza and Sorooshian (2014)	Time and Motion Study	A procedure for evaluating industrial or other operational efficiency on the basis of the taken or needed time for an operation or production.
19	Rahman et al. (2012), LeanProduction.Com (2015)	Bottleneck Analysis	This is the identification of the part of the process that put a limitation on the overall productivity in order to improve the performance of that part.
20	Alireza and Sorooshian (2014)	Total Productive Maintenance (TPM)	This is a holistic maintenance approach for equipment in order to maximize the operational time of the equipment.
21	Rahman et al. (2012), Muhammad et al. (2013), Alireza and Sorooshian (2014)	Visual Management	This is information communication technique employ to increase efficiency and clarity in processes through the use of visual signals.
22	Alireza and Sorooshian (2014)	Synchronize/Line Balancing	This involves leveling of workload across all processes in a value stream to remove excess capacity and bottlenecks.
23	Tsao et al. (2004), Rahman et al. (2012)	Work Structuring	This is used for the development of process design and operation in alignment with the supply chain structure, allocation of resources, product design, and assembly design efforts with the objective of making work process more reliable and quick while delivering quality to the client.
24	Alireza and Sorooshian (2014)	Multi-Process Handling	This involves assigning operators tasks in multiple processes in an oriented layout of a product flow.
25	Tsao et al. (2004), Muhammad et al. (2013)	5 Whys	This is a quality management tool for problem-solving and it tries to find the root cause of an issue. It stipulates that workers should be asking why five times repeatedly until they identify the underlying root or the nature of the issue and its solution becomes clear. The procedure tries to fix a system by eliminating the root cause to avoid its recurrence
26	Salem et al. (2005)	Fail Safe for Quality	This relies on the generation of ideas which alert for potential defects. This is almost the same as Poka-Yoke techniques but it can be extended to safety. However, the concentration in safety is on potential hazards rather than potential defects, and

			it is identified with the risk assessment technique. It requires action plan that avoids bad outcomes
27	Salem et al. (2005), Muhammad et al. (2013)	Daily Huddle Meetings	This a technique used for communicating and for everyday meeting process of the project team in order to accomplish workers involvement. With project awareness and problem-solving contribution alongside some training that is given by different tools, the satisfaction of job (sense of growth, self-esteem,) will increase.
28	Alireza and Sorooshian (2014)	Preventive Maintenance	This is regular maintenance performed on equipment to reduce the probability of its failure. It is usually performed while the equipment is working to avoid unexpected breakdown.
29	Alireza and Sorooshian (2014)	Quality Function Development (QFD)	This refers the use of customer's voice and different organization functions and units for final engineering specification of a product.
30	Leanproduction.Co m (2015)	SMART Goals	Goals that are Specific, Measurable, Attainable, Relevant, and Time-Specific.
31	Leanproduction.Co m (2015)	PDCA (Plan, Do, Check, Act)	This is an iterative approach for improvements implementation. It involves; Plan (set up a plan and expect results); Do (execute the plan); Check (verify anticipated result achieved); and Act (evaluate; do it again).
32	Alireza and Sorooshian (2014)	Setup Reduction	This is a changeover technique use to speedily change tools and fixtures in order for multiple products to be run on the same machine.
33	Muhammad et al. (2013), Alireza and Sorooshian (2014)	Work Standardization	Manufacturing documented procedures that capture best practices. This "living" documentation that is easy to change.
34	Alireza and Sorooshian (2014)	Statistical Process Control	This is a quality control tool that monitors and control process in order to ensure that system output variables operate to its full potential through periodic measurement.
35	Alireza and Sorooshian (2014)	Suggestion schemes	This is a formal mechanism which allows and encourages employees to actively contribute productive ideas for product and process improvements.
36	Rahman et al. (2012), Muhammad et al. (2013), Aziz and Hafez (2013), Alireza and Sorooshian (2014)	Just-in-Time (JIT)	This is a technique aimed primarily at minimizing flow times within a production as well as response times from suppliers and to end users. In any case, JIT is a way of thinking, working and managing to eliminate wastes in processes.
37	Alireza and Sorooshian (2014)	Team Preparation	This is a process of conducting training on waste, continuous flow and standardizes work for the lean team or employees.
38	Rahman et al. (2012), ASQ (2015)	Muda Walk	Muda is a Japanese word meaning waste. Muda walk is a technique used to identify waste through observation of operations, how work processes are conducted, and noting areas where improvements are needed.
39	Rahman et al. (2012), Leanproduction.Co m (2015)	Value Stream Mapping	A technique for visually analyzing, documenting and improving the flow of a process in a way that highlights improvement opportunities.
40	Leanproduction.Co m (2015)	Root Cause Analysis	This is a problem-solving technique that focuses on discovering and resolving the real problem instead of quick fix application that only solve problem symptoms.

3. Results and Discussions

An extensive synthesis of literature was conducted and 40 lean tools were identified in the construction project environment. After literature screening, an interview which attempts to extend the quantitative data was undertaken with experts, who are managers at the Construction Research Institute of Malaysian (CREAM) to confirm the suitability and/or applicability of the lean tools in relation to the Malaysian construction industry. Following the interview, only 30 lean tools were endorsed as being effective and suitable for the industry. An interview approach was used to ensure that the experts provide a reliable and comparable assessment. The list of the endorsed tools has been presented in Table 2.

Table 2: Suitable Lean Construction Tools

No.	Lean Tool
1	Last Planner System (LPS)
2	Concurrent Engineering
3	Daily Huddle Meetings
4	5S
5	First Run Studies
6	Visual Management
7	Fail Safe for Quality
8	Construction Process Analysis
9	Kanban (Pull System)
10	Just-In-Time
11	Work Standardization
12	Value Stream Mapping
13	Statistical Process Control (SPC)
14	Work Structuring
15	Pareto Analysis
16	Poka-Yoke (Error Proofing)
17	Continuous Flow
18	Six Sigma
19	Failure Mode and Effects Analysis (FMEA)
20	Bottleneck Analysis
21	Kaizen
22	PDCA (Plan, Do, Check, Act)
23	5 Whys
24	Muda Walk
25	Root Cause Analysis
26	Check Sheet
27	Synchronize/Line Balancing
28	Jidoka/Autonomation
29	FIFO line (First In, First Out)
30	Team Preparation

4. Future Research Direction

Firstly, the variables in the study relied on some pre-identified conceptual tools and so may not be as all-embracing as it may perhaps have been. Thus, could only describe a portion of the lean management tools and in the outcome. There may possibly be other lean construction tools which, were not included in this study, yet, could have a considerable effect on waste in construction project development. Besides, the study was conducted in a specific research context where the results are limited to the opinions and experiences from the experts, thus, may limit the reliability of the results. Although lean tools adoption is specific to the context, the results may differ when different experts are used. There may be differing preferences based on individualistic preferences or expertise. In lieu of this, replications of this study with different experts or in different contexts would strengthen the results.

Future studies could concentrate on comparative analysis using different or distinctive groups of experts. Such an analysis would discover some interesting results. Thus, any intervention that arranges to improve waste would be in

great acceptance. This will help build an understanding of the results found from different settings and different groups.

5. Conclusion

In this paper, a new set of lean construction tools for addressing construction projects has been presented. In order to ensure that every aspect of LC tools is captured in relation to the lean tools suitability, the study extended the existing LC tools. The identified lean tools were evaluated through the interview and the findings confirmed 30 lean tools including Last Planner System (LPS), Concurrent Engineering and Daily Huddle Meetings as being the most effective lean-delay control tools for the delay sources mitigation. The result from this study would serve as an implementation guideline for lean construction projects, thus, offer an understanding of the specific lean tools to adopt in projects. It is expected that this provides construction managements with suitable lean construction tools to build a realistic and rational lean application guide.

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Biography

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