International Journal of Engineering & Technology, 7 (4.35) (2018) 125-130

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper



Assessment of Lean Construction Practice at Selected Construction Sites in Klang Valley

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Abstract

Lean construction is known to reduce costs, improve profit or increase competitiveness, increase business opportunity and customer base, improve health and safety, improve quality, yield higher employee salaries, shorten production timescales and increase customer satisfaction. With little attention on research of lean construction in Malaysia, it remains a problem of non-standardization in waste elimination strategies thereby sub optimizing waste management in Malaysian construction projects. The objective of this paper is to evaluate lean construction techniques and measure the feasibility in term of their applicability for construction at selected sites in Klang Valley, Malaysia. The study is novel and significant in a sense that it can help to develop reliable management strategies for implementing lean construction technologies at the construction sites. Case studies were carried out as a strategic method and comprehensive survey that covers both questionnaire and interview were adopted as a method of data collection. Likert scale 1 to 5 was used in the written questionnaire with workers in order to assess the level of awareness and acceptance on the need of lean construction techniques for eight construction sites in various places and with various categories (infrastructure and building construction projects) in Klang Valley, Malaysia. Later, semi structural interview was conducted with expert judgment to justify the factors which affect the implementation of lean construction at the construction sites. From the study outcome, it was discovered that both Total Quality Management (TQM) and Industrialized Building System (IBS) were rated by the respondents to be highly effective in both infrastructure and building construction projects.

Keywords: *Lean construction; Strategic method; Questionnaire; Interview; Expert judgment*

1. Introduction

Egan [1] stated that lean thinking is dominated by an 'obsession' to eradicate waste from all business processes. Waste is viewed as any part of any process that does not add value to the output that will be provided to customers. Howell and Ballard [2] and Koskela et al. [3] illustrated that its origins are reasonably clearly rooted in the Japanese automotive production sector. It is generally accepted that Toyota is regarded as the author of Lean thinking. However, Lean thinking was influenced by Total Quality Management (TQM) which has US origins (although this too was first effectively implemented in a Japanese setting). Aziz et al. [4], Marhani et al. [5] and Wahi et al. [6] pointed out that there are seven kinds of pure waste in construction industry which are described as follows. Firstly, overproduction waste and it means making too much, too early or just in case. Secondly, Waiting waste and it implies that time is not used effectively and it creates delay to value adding activities like plant breakdowns, material shortages (late deliveries), material not being used, labor shortages, tool setups (power failures) and poor planning or coordination. Thirdly, transportation waste which comes from movement of components and materials on around a site by different ways such as distances travelled to site and on site, material handling, delivery to stock or storage as well as empty returns from delivery lorries. The waste is also inclusive of inappropriate processing construction works that do not meet the customer requirements inclusive of snagging, defects rectification and re-work, purchase orders, quotations, inspection and invoicing. In addition, unnecessary inventory like early deliveries, storage space, safety shocks or over ordering and shortages due to damage of goods stored for too long [6] can be categorized as a pure waste under lean construction concept. Another pure waste comes from unnecessary movement such as machine watching, stretching to reach goods or materials, searching for materials, drawings, walking to fetch materials, drawings, bending, lifting and congestion due to poor work coordination. Next category of pure waste from construction industry is the defect waste transportation like damage, paperwork errors, lost goods, stock loss or damage as well as rework which can cost money, time and reputation [5]. Other than that, defects, inappropriate processes and over production waste are considered as construction material waste.

Lean construction philosophy is a matter of adopting manufacturing industry in order to develop the requirements to meet the global challenges by minimizing waste, fastening the iteration operation and innovating through various production processes to insure continuous improvement. There are advantages in adopting lean thinking in construction industry namely cost reduction, improvement in profit or increased competitiveness, increased business opportunity and customer base, improved health and safety, improved quality, higher salaries (for employee's), shorter production timescales as well as increased customer satisfaction [7]. Lean production thinking argues that production consists of conversions and flows. Furthermore, none value adding activities (flow activities) would then be subjected to reduction or elimination while value adding activities (conversion activities) must be made more efficient by using both standardization as well as technology. In

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addition, conversion processes transform raw materials or components into products and modules [3].

2. Research Background for Lean Construction

Egan [1] and Koskela et al. [3] clarified that lean thinking deals mainly on waste reduction and the principles are as follows. Firstly, it eliminates variations in the production process. Secondly, it setup the infrastructure to accommodate variations should it happens (people and equipment) (cellular production). Thirdly, production system should drive design whenever possible (concurrent engineering). Then, supply chain management and long term partnering should be implemented. After that, it emphasizes on getting the right work to be done for the first time (eliminate rework) as well as continuous improvement on the work (emphasize on measurement). Table 1 illustrates the barriers in adopting lean construction by several researchers from various countries. Li et al. [7] opined that when evaluating lean construction in firms, several technological techniques can be used to build an evaluation index system. Considering high maturity of lean construction in Malaysia, the following techniques are adopted for evaluation. The framework suggested in this study contains several of lean construction techniques to achieve customer objectives. After conducting pilot test with workers in the questionnaires, some of the techniques are either removed or combined. Lean construction is adopted to reduce unnecessary costs (waste) at the design phase by using value management as a strategic approach and concurrent engineering for technical approach. Then, at construction phase, supply chain management is adopted to insure high integration between upstream (suppliers) and downstream (customers) groups of construction projects. High integration is participated to accomplish Just In Time delivery (JIT) with the adaptation of Last Planner Method (LPS) as a planning strategy to specify the exact amount of activities that must be done and the required amount of materials according to pull production. In addition, Total Quality Management (TQM) at both upstream and downstream levels in construction projects are used to insure high rate of quality. Eventually, Key Performance Indicator (KPI) is applied to assure continuous improvement and achievement of zero defects.

Table 1: Barriers in adopting lean construction techniques by several researchers from several countries

Researches work	Barrier in adopting lean construction techniques
Li et al. [7] China	Lack of appropriate organizational structures. Lack of top management support. Low level of education.
Fernandez-Solis et al. [8] USA	Lack of required staff training, experience and knowledge. Lack of leadership style Contracts issues (competitive tendering).
Alinaitwe [9] Uganda	Buildable designs. Uncertainty in the supply chain. Steady prices of commodities. Lack of team work. Contributively management style for the workforce.
	Organizational culture.

2.1 Value Management (VM) for Cost Reduction through the whole life Cycle Cost of the Project

Value Management (VM) is a management approach used in many industries to deliver the customer outcomes [10-14]. However, it is fairly applied to construction projects [15]. It is more likely to be found as rigid application of set of tools and techniques to engineer out excess cost without due consideration of value or processes. Both value management and value engineering are conducted through workshop at early stage in projects. VM can be achieved as follows. The first step is to gather information with respect to the process, product or service. The second step is to use functional analysis method to identify the cost of each component relevant to the process, product or service. Then, a brainstorming session is conducted to list down the advantages and disadvantages of each component. Lastly, evaluation and implementation on the best idea for each component are done to make sure every improved aspect of the component meets the expectation [16].

2.2 Concurrent Engineering (Industrialized Building System) (IBS)

Off-site construction is a modern method of construction, based on off-site manufacturing of building elements. Offsite construction is highly recognized in Malaysia by Industrialized Building System (IBS) [17]. Such approach is widely used in construction sector that can offer economic, environmental and social advantages as follows. Firstly, structures can be built at different location other than the location of use. The structural components are produced in manufacturing plants which are specifically designed for this type of process. Individual modules of the building are produced in factories before they are transported to the site on specially designed trailers for construction purpose [7].

2.2.1 Building Information Model (BIM) for Designing Construction Projects in the Case of the Onsite and Offsite Work

Building Information Modelling (BIM) is a process of generating and managing building data during its life cycle [18]. Typically, it uses three dimensional, real-time and dynamic building modelling software to increase productivity in building design and construction. BIM is the most current advanced software program that is widely used for both offsite and on site work. It helps design and construction teams to collaborate on coordinated model, thereby providing everyone in the team with better insight into how their work fits into the whole project ultimately helping the project to run efficiently. Mutual exchange of data between all stakeholders throughout the whole life cycle cost of the project is a crucial element for the successful implementation of BIM [7], [13].

2.3 Supply Chain Management (SCM) for Cost Reduction Construction Phase

Egan [1], Koskela et al. [3] and Demirkesen & Ozorhon [18] claimed that SCM is a management of downstream and upstream relationships with customers and suppliers to achieve customers' satisfaction at the least cost to the supply chain as a whole. To fully realize the benefits of SCM, firms stop competing with firms that they used to compete with and begin to share and pool resources towards the accomplishment of specified and agreed goals that can benefit them all [3]. It is notable that all parties in a given supply chain must trust each another in term of contractual trust, competency trust as well as goodwill trust.

2.4 Lean Construction Technology (Just in Time) (JIT) for Delivering Resources at Construction Phase

Just in Time is widely used in industrial supply chains in terms of manufacturing of construction products or components. In order to apply the lean manufacturing concept the suppliers' network must be improved [7, 13, 19]. Nowotarski et al. [13] stated that the main reason for adopting JIT technology is to fasten the flow of activity and make it moves smoothly through construction process by adopting pull production for resources in order to prevent inventory waste (Buffers). JIT relies on long term relationship with the contractors at construction phase which requires full commitment at top management level. It also eliminates rework as well as the

transportation waste of construction activities because it emphasizes early finish of each activity while timely securing resources in term of materials and equipment. Just in Time is effective to reduce inventory waste (Buffers) in the case of delivering off-site components into the construction site such as linking between fabrication and assembly of steel structures or pipelines, or material supplies and construction of large highways or major activities which take a long time to carry out.

2.5 Last Planner System (LPS)

Howell & Ballard [2], Gao & Law [20] and Fewings [21] found that Last Planner System (LPS) has two key ingredients used in producing work assignment such as The Look Ahead (LK) Plans and The Weekly Work Plans (WW). LK may be executed on the basis of a 4 to 6 week rolling program as follows. Firstly, the work flow is shaped, sequenced and rated. Secondly, the master schedule activities are distributed in work packages and operations. Thirdly, detailed work completion methods are developed with a workers contribution. Then, use pull production for resources. In addition, Weekly Work Plan can then be produced from The Look Ahead Plan. Also, the Weekly Work Plan identifies and sequences exactly what work should be done on each day to complete the identified assignments. Moreover, tasks are carried out when they are ready to be progressed. This removes waste and increases efficiency, but the work flow for the master project program may be more fluid. This does not mean that there should be a frequent change in activities' completion dates, but rather that the program serves as a dynamic tool which is more readily reflected by the complexity found in projects that are completed in a dynamic environment. Furthermore, construction times can be accelerated due to the efficiency gains that can be realized by better work flows that are resulting from more realistic (at site) planning assessments.

2.6 Total Quality Management (TQM) for Improving Construction Performance

Project Management Institute [22] stated that quality thinking is now almost universally accepted in mainstream construction activities. Various field documentations are used in construction to insure that quality is guaranteed for the project in accordance to the standard (ISO 9001) such as nonconformance reports, list form as well as progress report which are done by quality manager throughout the construction processes. Quality coordinator plays a role to assure all tests of items are fulfilled according to the relevant standards of quality control. The idea of establishing such roles is to ensure that a high level monitoring work is carried out so as to ascertain the project's quality performance standards are being met. All Quality Assurance (QA) and Quality Control (QC) activities are subjected to external audit and both are essential if any QA or QC system is to operate effectively and insure continuous quality improvement [21-23].

2.7 Measurement for Construction Performance (Key Performance Index) (KPI)

Egan [1] stated that the Key Performance Index (KPI) promoted by UK Government Sector was quickly adopted by the private sector clients and construction industry in the United Kingdom. KPI comprise of elements such as client satisfaction on product, client satisfaction on service, defects, cost predictability, time predictability, profitability, productivity, safety, construction cost, and construction time. With KPI, the level of achievement of each activity of the project can be gaged, thereby ensuring its progress towards realizing the project strategic goals.

3. Methodology

Case studies were used as strategic approach for the study to survey selected complex infrastructure and building projects in Klang Valley, Malaysia. Li et al. [7] stipulated that case studies are very effective mean to study a new subject (phenomena) for the purpose of establishing their causal relationships and justifications. CIDB Manual Guidelines [17] stated that a total of 752 construction companies have high budgets in Klang Valley which can be categorized as G7 as shown in Table 2. These companies run many complex construction projects at sites throughout Malaysia. For convenience, non-probability sampling was adopted for sample size determination. 8 construction projects (4 infrastructure and 4 building construction projects) from various locations within Klang Valley were chosen for the study purpose. List of the 8 construction projects is shown in Table 3. Figures 1 and 2 show typical material wastes found at the construction sites. The number of construction projects under study is sufficient considering the application of non-probability sampling for the study. It must be noted that by comparison, Li et al. [7] selected 10 projects from two big firms for their study on lean construction in China. On the other hand, Fernandez-Solis [8] chose 5 projects from United Kingdom and 1 project from Finland to study the challenges of applying LPS in the projects. A comprehensive survey that covers both quantitative (written questionnaires) and qualitative (semi-structured interviews) approaches were conducted for the purpose of collecting data to assess the level of awareness and acceptance on the need of lean construction technologies at the selected sites in Klang Valley.

3.1 Questionnaire Method

Altogether, 100 questionnaires were distributed and 80 workers responded to the questionnaires accordingly. Written questionnaires were aimed at construction workers in order to survey their level of awareness regarding the various technologies involved in lean construction. The questionnaires contain questions related to the evaluation of lean construction techniques according to Likert scale (1 to 5) (1: Very Low, 2: Low, 3: Medium, 4: High, 5: Very High). Quota sampling was adopted as a method of non-probability sampling for quantitative research in the form of questionnaires under the study. Kothari [24] added that quota sampling method helps to divide the population into strata or groups of individuals that are similar (homogenous) for the importance of responses. SPSS software program was used to do the reliability and validity check of the questionnaire results. Then, independent sampling T test was used to analyze and compare the mean of the results for lean construction techniques for both infrastructure and building construction projects on the basis of Likert scale (1 to 5).

3.2 Interview Method

Interview method was chosen to gather qualitative views of project managers, contractors, subcontractors, site foremen and construction workers at 8 construction sites in Klang Valley so as to assess their perceptions about lean construction on the basis of their knowledge and experience. Purposive sampling was chosen as the type of non-probability sampling for the interview method because it is an effective sampling type for qualitative studies and people selection for the interview can be done in accordance to the specific characteristics such as experience and knowledge. Semi-structured interview was selected as the interview method for the study because its results were able to reflect respondents' ability and flexibility to give their opinions on the subject matter.

Table 2: The various categorization of contracting companies in Malaysia in accordance to their financial capabilities

Grade of contracting company	Budget of contracting company (BOC)
Grade 1	BOC<200,000
Grade 2	200,000 < BOC <500.000
Grade 3	500,000 < BOC <1000.000
Grade 4	1000,000 < BOC <3000.000
Grade 5	3000,000 < BOC <5000.000
Grade 6	5000,000 < BOC <10.000.000
Grade 7	BOC >10.000.000

Table 3: The selected construction sites in Klang Valley under study

Construction site
16 Sierra MRT station site (SSP Line)
Bandar Malaysia North/ South MRT station sites (SSP Line)
Putrajaya Sentral MRT station site (SSP Line)
Kuchai Lama MRT station site (Elevated station) (SSP Line)
Citizen 2 Apartment at Old Klang road
Harmoni Apartment in Eco Majestic Township, Semenyih
Vogue Suites at KL Eco City near Mid Valley
23 acres Damansara Apartment at Empire City, Damansara Perdana



Fig. 1: Typical construction material wastes at the construction site



Fig. 2: Typical concrete wastes at the construction site

4. Results and Discussion from the Questionnaire Survey

The results of both infrastructure and building construction case studies from the questionnaires are consistent and reliable since the average Cronbach's Alpha coefficient was discovered to be greater than 0.70. The average Cronbach's Alpha coefficient for the infrastructure construction projects is 0.897. Other than that, the average Cronbach's Alpha coefficient for building construction projects is 0.91. This provides an indication that the results' reliability is excellent. Figures 3 and 4 show the results in Likert scale (1 to 5) regarding the effectiveness of lean construction techniques in Klang Valley projects for both infrastructure and building construction projects. Noticeably, at the fifth rating level (Rating number 5) which is the highest in Likert scale, TQM is viewed as the very highly implemented technique in lean construction as 15 respondents selected it when compared to other techniques in infrastructure construction projects. At the same level of rating, 5 respondents chose IBS as a very high implemented lean construction technique in building construction projects. At level four rating for both infrastructure and building construction projects, TQM and IBS were selected as highly implemented techniques with the number of respondents of 15 and 5 respectively. At level 3 of the Likert scale, KPI, VM and JIT were chosen as the averagely implemented lean construction techniques for infrastructure construction projects with the respective number of respondents of 22, 18 and 15. In contrary, TQM and KPI were viewed have average level of implementation in building construction projects with the respondents' number of 14 and 13 respectively. At level 2 of the Likert scale, VM is seen to have a low level of implementation in infrastructure projects with 14 respondents chosen it. At the same level of Likert scale, VM and JIT can be categorized to have low level of implementation in lean construction of building construction projects when 14 and 17 respondents selected them respectively. At the lowest level of rating (Level 1 in Likert scale), LPS was found to be the lowest implementation technique in infrastructure construction projects with 20 respondents selected it. On the other hand, JIT and IBS were found to be the least implemented tecchniques in lean construction for building construction projects with each technique has 29 respondents selected it.

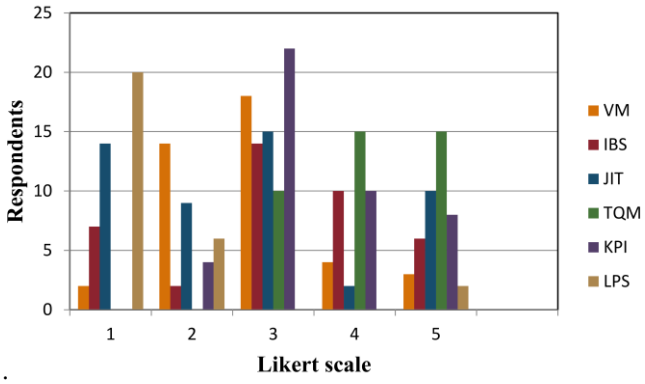


Fig. 3: The rate of implementation of lean techniques in infrastructure construction project according to Likert scale 1 to 5

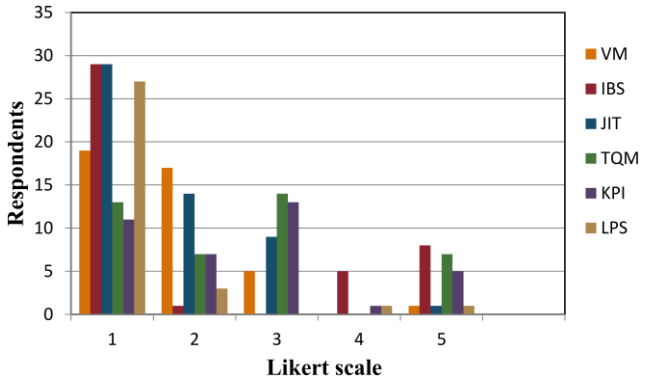


Fig. 4: The rate of implementation of lean techniques in building construction projects according to Likert scale 1 to 5

It can be observed in Table 4 that for T test, the general mean, m is equal to 6.5 for infrastructure construction projects.The number is higher when compared to that of building construction projects (m = 2) and such a difference is relatively big. TQM and JIT are seen to be highly implemented in infrastructure construction projects as shown by the mean values, m= 15 and m = 10 respectively. IBS on the other hand, has the highest rate of implementation in buildings construction projects with m = 5. VM and LPS are lowly implemented in infrastructure construction projects with m = 3 for both techniques. The rating for the implemetation of LPS and JIT is the lowest in building construction projects m = 2 and m = 1 respectively. The T test results confirm the reliability of the questionnaire results in a sense that TQM and IBS are regarded as the mostly implemented

techniques of lean construction at sites for the respective infrastructure and building construction projects.

Table 4 The mean for lean techniques according to independent T test for infrastructure and building construction projects for the respondents of the 8 construction sites in Klang Valley, Malaysia

Test purpose	The mean value	
VM	Infrastructure	3.0
	Building	2.0
IBS	Infrastructure	6.0
	Building	5.0
JIT	Infrastructure	10.0
	Building	1.0
TQM	Infrastructure	15.0
	Building	4.0
KPI	Infrastructure	7.0
	Building	1.0
LPS	Infrastructure	3.0
	Building	2.0

5. Results and Discussion from the Interview Survey

Based on an interview with a CIDB manager, it was found that CIDB (Construction Industry Development Board) which is a governmental part in charge of construction industry in Malaysia, does not have a role in lean construction system for waste reduction in Malaysian construction projects. Competitive tendering is used in many construction projects in Klang Valley. Conventional planning method is the most common planning approach adopted by both infrastructure and building construction projects.

Based on the interviews with the project managers at the building construction sites, it was discovered that there is no clear response regarding the implementation of lean construction in their projects for waste reduction in term of unnecessary cost. Instead, conventional method of construction management is applied in spite of their awareness regarding the importance of applying lean construction techniques for providing profits to their projects. The motivation to change organizational culture is a very important element for the project managers to adopt lean construction at sites while developing their effective leadership styles. Li et al. [7] justified that firms are constantly required to change their management system and provide training to their staffs in order to implement lean construction for returning profitability.

On the other hand, the project managers in infrastructure construction projects opined that BIM is highly applied at sites and it helps to partially reduce construction wastes. The average waste per week in infrastructure construction sites is about 1.5 tons and the amount is much less as compared to that of the building construction projects (4 tons). Furthermore, the project managers reasoned that TQM is mostly implemented in infrastructure construction projects due to high quality provision in accordance to client (government) instructions at both upstream and downstream levels, which is resulting from a high quality demand for public service. In contrary, quality in building construction projects is based on the need to meet the requirements of Standard and Industrial Research Institute of Malaysia (SIRIM).

From the perspective of client representatives in infrastructure construction projects, JIT is seen as a highly effective technique to be implemented at all MRT projects because the suppliers were hired by the clients to manage as well as to adopt BIM to ensure on time delivery (JIT) at construction phase. Thus, it can be stated that only with strong financial support from the government, they can be financially motivated to adopt these techniques for the assurance of both high level of quality (TQM) and on time delivery using BIM. Furthermore, IBS was found to be popularly used in building construction projects. A project manager for a building construction project added that it is mainly used at lower levels of buildings particularly car park floors with the choice of implemetation highly influenced by the cost of lifting up the prefabricated components for construction purpose. According to site foremen and subcontractors, LPS and VM are rarely used in building construction projects due to competitive tendering and lack of non-adversarial partnership to ensure that only the best win-win solutions can be applied in managing construction projects.

6. Conclusion

In conclusion, TQM and JIT are regarded as highly used techniques in the organizations of the infrastructure construction projects. On the other hand, IBS is highly utilized in the building construction projects. Other techniques under study are less applicable in the construction organizations for various reasons such as inappropriate organizational culture, lack of strategic leadership, lack of commitment to innovate and lack of understanding on modern model of network competition (win to win thinking or partnering) rather than competitive tendering.

As such, it is recommendable to encourage construction organizations to adopt lean construction approach and provide free training programs on lean construction techniques for their staffs. In addition, there is a need to devise the organizational structure to adopt partnership relationship among their stakeholders rather than competition and this requires a change in organizational culture of managing construction projects. With regard to that, the managing role of project manager is crucial to change the current organizational culture of construction projects in Klang Valley, Malaysia.

Acknowledgement

The authors would like to recognize the financial support from UNITEN Internal Grant, UNIIG 2017 (Project number: 10289176/B/9/2017/17).

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