The Effectiveness of Lean Construction Tools in the Malaysian Construction Industry Towards Contractor's Environmental Performance

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Abstract. In resolving the issues of construction wastes, lean construction (LC) tools are anticipated to be used in the construction industry. LC is a sustainable approach that can accomplish the construction wastes efficiently throughout the construction processes. ThE approach also encourages organisations in sustaining their growth and profitability in the industry. This paper is a preliminary survey, therefore, aim to analyse the perceived effectiveness of LC tools in reducing construction waste for the enhancement of contractor's environmental performance in the Malaysian construction industry. A structured interview was conducted with twenty (20) key personnel from selected G7 contractors in Malaysia, which are registered with the Construction Industry Development Board Malaysia. The results revealed that total quality management and partnering were the significant LC tools in reducing construction wastes. These LC tools also have a strong relationship with the contractor's environmental performance. The findings defined in this paper could be necessary for future LC tools framework development that can strengthen the contractor's quality of work. This advancement is in-line towards enhancing the Malaysian construction industry through the fourth industrial revolution.

1 Introduction

Half of the total carbon dioxide emissions are from the construction industry [1]. The 3Ds (dirty, dangerous and difficult) industry also is a massive producer of construction wastes. Earlier on in Malaysia, 28.34 % of the construction wastes are generated to fulfil the vast demand for building and infrastructure projects [2]. It is the time for the industry to change its construction methods towards a more invention technology method of construction. Accordingly, the implementation of sustainable approaches has become a critical action reviewed and attempted by the industry players to overcome the issue of construction wastes [3].

Construction wastes are non-value adding activities from throughout of the construction processes. Construction wastes can be classified as a correction (W1), over-processing (W2), delay (W3), inventory (W4), conveyance (W5), over-production (W6) and motion activities on site (W7) [4]. Previously, Burton and Boeder [5] believed the construction wastes can be caused by human mistakes (W9). According to Abdul Rahman et al. [6], construction wastes can also be formed during the processes of designing of goods and services (W8) as well as vandalism, inclement weather and accidents exercises (W10). These construction wastes will influence the contractor's project performance, especially on the environmental aspect [7].

LC tools are anticipated in the construction industry in resolving the issues of construction wastes. This management approach has been introduced by Koskela [8], which is emphasised on eliminating construction wastes. Yahya and Mohamad [9] added LC is likely on managing and improving the construction processes. LC also capable of fulfilling the client's needs as well as contributing towards a sustainable and greener environment [10].

This paper is a preliminary survey, engaging to analyse the perceived effectiveness of LC tools in reducing construction waste for the enhancement of contractor's environmental performance. The findings then are the essential keys in developing the LC tools framework that will fill a gap in the academic literature and the industry as well. The proposed framework that suitable for the Malaysian construction industry will strengthen the contractor's quality of work towards enhancing the industry through the fourth industrial revolution.

2 Lean construction tools

LC approach is the alternative invention technology of the construction method to the industry. This approach promises in reducing the construction wastes that will be beneficial not solely to the environment but to the industrial players too. This approach also has its tools that an organisation needs to adopt in their construction

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processes. To gain the greatest benefits of this LC, an organisation requires appropriate and proper LC tools [11]. It is up to the organisation itself to adopt and implement the best LC tools that suit their project.

The literature revealed that there are lots of established LC tools that can be implemented by the industry players. Each LC tool has its own procedures on how to conduct it and all of it are following the principles of LC. The principles of LC are the key success of every construction project. The aim of each LC tool is to seek perfection in every construction process. Table 1 indicates the most implemented LC tools in reducing construction wastes in the Malaysian construction industry.

According to Caldera et al. [12], the implementation of LC can improve the environmental performance of a construction project. Previously, in placing more emphasis, Ciarniene and Vienazindiene [13] stated that the implementation of LC tools will reduce the construction wastes at the site as per Table 2. The similar research area also mentioned a project will comply with a local authority or government requirement [14] and reduce the energy consumption of a project [15]. Based on Puvanasvaran et al. [16], the implementation of LC tools will influence the construction project to produce a neat and a clean site environment.

Table 1. Most implemented LC tools in the Malaysian construction industry. Source: Adopted and modified from Marhani et al. [17]

LC tools & procedures	Authors	Coding	Capable of reducing construction waste
Total quality management (TQM): - It is a cross-functional product planning processes that concentrate on the quality & cost of gaining the client's need through management practices.	[18]	LC1	W1, W2, W3
5S (Housekeeping system): - This tool helps to create a better working environment through a logical order that needs to maintain daily.	[19]	LC2	W4
Partnering: - The tool helps all the parties involved in a project to focus on what each party does best through the establishment of long or short-term	[20]	LC3	W5

win-win relationship based on mutual trust & sharing of both risks & rewards.			
Teamwork: - It is a tool that creates an environment of an organisation that understands & believes that thinking, planning, decision making, & actions are better when done cooperatively.	[21]	LC4	W6, W9
Increased visualisation: - This tool is a technique used to communicate clearly with the workers using signs & labels around the site.	[19]	LC5	W7
Concurrent engineering: - The tool focuses on the optimisation of resources of an organisation in designing & developing a product by considering all elements of the product's lifecycle.	[18]	LC6	W8
Error proofing (Poka-yoke): - It is a tool that uses to eliminate or minimise the requirement for inspection by eliminating or minimising errors before they occur.	[18]	LC7	W10

Table 2. Environmental attributes characteristics

Environmental attributes characteristics	Coding	Authors
Reducing construction wastes	P1	[13]
Compliance with local authority's or government requirement	P2	[14]
Reducing energy consumption of the project	P3	[15]
Producing a neat & clean site environment	P4	[16]

3 Methodology

The aim of this paper is to analyse the most significant LC tool in reducing construction waste for the enhancement of environmental performance. A structured interview was conducted between April to August 2017 with the LC practitioners to collect quantitative data. This preliminary survey was designed to get in-depth information regarding the LC approach in the Malaysian construction industry. All the interviewees are registered G7 contractor with the Construction Industry Development Board Malaysia (CIDB), which have been identified and shortlisted from the CIDB directory. They also were highly involved in the whole LC implementation processes of their organisation.

To get consistency and fairness, the interviewees were fully informed regarding the aim and objectives of this survey. This method was effective since the processes of collecting data were quick to conduct. A statistical technique was engaged to be more objective in this quantitative analysis. The study used a 5-point Likert as a point of scales, which range from 1 = strongly disagree to 5 = strongly agree. The technique adopted is a descriptive statistic that will be used to measure the strength of the relationship between the variables. The data collected from this survey were analysed by using the Statistical Package for the Social Sciences (SPSS) version 24.

A Kolmogorov-Smirnov test on the data has been conducted to check the normality of the data [22]. This test assessed the normality of the distribution of the data. A non-significant result (Sig. value of more than 0.05) indicated normality. In this survey, the Sig. value was 0.000, suggesting a violation of the assumption of normality, which was quite common in larger samples. Thus, the non-parametric technique was considered more suitable for the analysis of this survey.

The non-parametric technique used in this survey was a Spearman's rho. This Spearman's rho or Spearman's rank correlation coefficient was assessing the strength of the relationship between two ranked data variables [23]. The value of the correlation coefficient determined the strength of a relationship, which is ranging from –1.00 to 1.00. According to Cohen [24], as cited by Pallant [22], there are guidelines on how to interpret the values. The guidelines are: -

- Small   r=.10 to .29
- Medium   r=.30 to .49
- Large   r=.50 to 1.0

The negative sign of the values refers only to the direction of the relationship, not the strength of it. Hence, in this research, the Spearman's rho was conducted to analyse the relationship between construction wastes and LC tools; and LC tools and environmental performance.

4 Result and discussion

This section presents an analysis of the findings obtained through the quantitative research. A structured interview was conducted to collect the data amongst the LC practitioners. The analyses of the most significant of LC tools in reducing construction waste for the enhancement of environmental performance had been determined. The findings of this research will then be applied to establish further and refine the LC tools framework.

4.1 The relationship between construction wastes and LC tools

A Spearman's rank correlation coefficient was computed to assess the relationship between delay (W3) and TQM (LC1) as per Table 3. There was a strong and positive correlation between the two variables, r = 0.651, n = 20, p = 0.002. A Spearman's rank correlation coefficient was also gauged to assess the relationship between delay (W3) and partnering (LC3). There was a strong and positive correlation between the two variables, r = 0.571, n = 20, p = 0.002. The relationship between over-production (W6) and concurrent engineering (LC6) has been figured out through a Spearman's rank correlation coefficient. There was a strong and positive correlation between the two variables, r = 0.608, n = 20, p = 0.002.

A Spearman's rank correlation coefficient was computed to assess the relationship between delay (W3) and TQM (LC1). There was a moderate and positive correlation between the two variables, r = 0.493, n = 20, p = 0.027. A Spearman's rank correlation coefficient was also gauged to assess the relationship between the design of goods and services (W8) and partnering (LC3). There was a moderate and positive correlation between the two variables, r = 0.490, n = 20, p = 0.028. The relationship between human potential (W9) and partnering (LC3) has been figured out through a Spearman's rank correlation coefficient. There was a moderate and positive correlation between the two variables, r = 0.541, n = 20, p = 0.014.it can be seen that when an organisation manages to cross-functional product planning processes by focusing on the quality and cost, they can reduce delay. By having the establishment of long or short-term win-win relationship among each party involved in a project also, an organisation gets reaps the benefit of the LC approach.

Table 3. Construction wastes correlations between LC tools

	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	LC1	LC1	LC1	LC2	LC3	LC4	LC5	LC6	LC4	LC7
W1	1.000	0.405	.583**	0.272	0.235	0.234	.633**	.607**	.712**	.525*	0.395	0.111	-0.109	-0.065	0.282	-0.011	0.151	0.084	0.112	0.051
W2		1.000	0.370	0.278	0.187	.520*	0.349	0.394	0.366	0.076	0.136	0.251	0.009	-0.069	0.368	-0.046	0.165	0.285	-0.003	-0.103
W3			1.000	.523*	.473*	0.265	0.324	.510*	0.419	0.440	.651**	.493*	0.167	0.218	.571**	0.290	0.362	0.142	0.249	0.290
W4				1.000	0.370	0.159	0.331	0.423	0.246	0.367	0.338	0.429	0.259	0.238	0.216	0.290	0.131	0.130	0.208	0.397
W5					1.000	0.157	.460*	.502*	0.420	.684**	0.215	0.245	0.070	0.287	0.337	0.150	0.351	0.154	-0.149	0.031
W6						1.000	0.198	0.275	0.348	0.138	0.394	0.444	0.060	0.370	0.396	0.395	0.339	.608**	0.202	0.261
W7							1.000	.555*	.712**	.751**	0.061	0.023	-0.253	-0.124	0.143	-0.034	-0.054	0.022	-0.242	-0.091
W8								1.000	.809**	.511*	0.289	0.366	-0.142	0.090	.490*	0.001	0.193	0.305	0.003	0.204
W9									1.000	.544*	0.388	0.347	-0.163	0.071	.541*	0.063	0.210	0.156	0.110	0.222
W10										1.000	0.099	-0.079	-0.121	0.022	0.076	0.018	0.002	0.038	-0.242	-0.071
LC1											1.000	.762**	0.409	.706**	.684**	.675**	0.402	0.294	.683**	.696**
LC1												1.000	.604**	.652**	.792**	.620**	.463*	0.395	.643**	.644**
LC1													1.000	.554*	0.313	.465*	0.274	0.046	.554*	0.378
LC2														1.000	.495*	.590**	.537*	0.284	0.394	.693**
LC3															1.000	0.322	.593**	0.407	.458*	.452*
LC4																1.000	0.062	.559*	.700**	.677**
LC5																	1.000	0.163	-0.038	0.339
LC6																		1.000	0.320	0.305
LC4																			1.000	.578**
LC7																				1.000

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

Notes:
W1 = Correction	W2 = Over-processing	W3 = Delay	W4 = Inventory	W5 = Conveyance
W6 = Over-production	W7 = Motion	W8 = Design of goods & services	W9 = Human potential	W10 = Others
LC1 = Total quality management		LC2 = 5S	LC3 = Partnering	LC4 = Teamwork
LC5 = Partnering		LC6 = Concurrent engineering	LC7 = Error proofing	

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Table 4. LC tools correlations between environmental performance

	LC1	LC1	LC1	LC2	LC3	LC4	LC5	LC6	LC4	LC7	P1	P2	P3	P4
LC1	1.000	.762**	0.409	.706**	.684**	.675**	0.402	0.294	.683**	.696**	.671**	.618**	.607**	.512*
LC1		1.000	.604**	.652**	.792**	.620**	.463*	0.395	.643**	.644**	.809**	.720**	.772**	.665**
LC1			1.000	.554*	0.313	.465*	0.274	0.046	.554*	0.378	.631**	.610**	.659**	.635**
LC2				1.000	.495*	.590**	.537*	0.284	0.394	.693**	.867**	.775**	.795**	.698**
LC3					1.000	0.322	.593**	0.407	.458*	.452*	.603**	.545*	.559*	.506*
LC4						1.000	0.062	.559*	.700**	.677**	.468*	0.411	.510*	.516*
LC5							1.000	0.163	-0.038	0.339	.567**	.535*	.515*	.480*
LC6								1.000	0.320	0.305	0.227	0.178	0.160	0.206
LC4									1.000	.578**	0.393	0.381	0.432	0.387
LC7										1.000	.661**	0.422	.550*	.451*
P1											1.000	.861**	.928**	.794**
P2												1.000	.892**	.858**
P3													1.000	.920**
P4														1.000

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

Notes:
LC1 = Total quality management   LC2 = 5S   LC3 = Partnering   LC4 = Teamwork
LC5 = Partnering   LC6 = Concurrent engineering   LC7 = Error proofing
P1 = Reducing construction wastes   P2 = Compliance with local authority's or government requirement
P3 = Reducing energy consumption of the project   P4 = Producing neat and clean site environment

4.2 The relationship between LC tools and environmental performance

A Spearman's rank correlation coefficient was computed to assess the relationship between TQM (LC1) and reducing construction wastes (P1). Table 4 illustrates that there was a strong and positive correlation between the two variables, r = 0.671, n = 20, p = 0.001. A Spearman's rank correlation coefficient was also gauged to assess the relationship between TQM (LC1) and compliance with local authority's or government requirement (P2). There was a strong and positive correlation between the two variables, r = 0.618, n = 20, p = 0.004. The relationship between TQM (LC1) and the reducing energy consumption of the project (P3) has been figured out through a Spearman's rank correlation coefficient. There was a strong and positive correlation between the two variables, r = 0.607, n = 20, p = 0.021. A Spearman's rank correlation coefficient was computed to assess the relationship between TQM (LC1) and producing neat and the clean site environment (P4) too. There was a moderate and positive correlation between the two variables, r = 0.512, n = 20, p = 0.021.

A Spearman's rank correlation coefficient was computed to assess the relationship between partnering (LC3) and reducing construction wastes (P1). Finding also revealed there was a strong and positive correlation between the two variables, r = 0.603, n = 20, p = 0.005. A Spearman's rank correlation coefficient was also gauged to assess the relationship between partnering (LC3) and compliance with local authority's or government requirement (P2). There was a moderate and positive correlation between the two variables, r = 0.545, n = 20, p = 0.013. The relationship between partnering (LC3) and reducing the energy consumption of the project (P3) has been figured out through a Spearman's rank correlation coefficient. There was a moderate g and positive correlation between the two variables, r = 0.559, n = 20, p = 0.010. A Spearman's rank correlation coefficient was computed to assess the relationship between partnering (LC3) and producing neat and the clean site environment (P4) too. There was a moderate and positive correlation between the two variables, r = 0.506, n = 20, p = 0.023.

Thus, it shows that a construction project will gain advantages of the environmental performances if an organisation is keeping discipline in practicing the LC tools.

5 Conclusion

There are seven (7) LC tools implemented by the industry players throughout the construction processes [17]. Each tool is designated to overcome each type of construction wastes. This paper, thus, aimed to analyse the most significant LC tools in reducing the construction wastes for the enhancement of environmental performance.

Based on the findings, it is discovered that TQM and partnering were the significant LC tools in reducing construction wastes in the Malaysian construction industry. The relationships are in-line with Koskela [8] that LC tools are capable of eliminating the construction wastes. There was a strong and positive correlation between delay and TQM, and there was a strong and positive correlation between delay and partnering with.

The findings also revealed that TQM and partnering have a strong and positive correlation between all the environmental attributes performance. The performances are reducing construction wastes, compliance with local authority's or government requirement, reducing the energy consumption of the project and producing a neat and clean site environment [13–16]. The findings proved a research by Caldera et al. [12] that the implementation of LC can improve the contractor's environmental performance

The findings reported in this paper could assist the industry players in determining the appropriate and proper LC tools that suitable for their organisation as per recommended by Suresh et al. [11]. The findings are imperative in enhancing contractor's environmental performance by establishing an LC tools framework. The LC tools framework is potentially to be a stepping stone to the organisation in achieving a better construction product. This improvement is in-line towards enhancing the Malaysian construction industry through the fourth industrial revolution.

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