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ABSTRACT

Poor project performance in Malaysian construction industry resulting from poor cost management, time overrun, and inadequate quality has encouraged scholars to investigate the feasibility, suitability, and acceptability of lean principles in the construction sector. The purpose of this study was to assess the appropriateness and acceptability of lean principles by construction companies based in Pahang, Malaysia. This study applied quantitative methods and a simple random sampling technique to select 104 respondents from construction companies located in Pahang, Malaysia. The data were analyzed using partial least squares structural equation modelling (PLS-SEM). Results show that three variables in lean principles, namely operation in the flow of waste management, employee involvement in the flow of waste management, and continuous flow of waste management, support construction project performance. Conversely, information about flow in waste management negatively influences project performance. The findings from this study can be used as a guideline for better performance in cost management for Malaysia's construction industry.

KEYWORDS
Lean construction; waste management; flow of waste management; construction project performance; Malaysia

Introduction

The construction industry's growth is constantly challenged by various issues: low productivity level, inconsistent profit, shortages in a skilled workforce, project delay, and slow adaptation to technology (Aziz and Hafez 2013; Baiburin 2017; Francis and Thomas 2020). The most critical issue is the level of waste and non-value added activities, which are very high within construction companies. The construction industry managing waste has led to increased production costs (Banawi and Bilec 2014; Ansah et al. 2016; Bhatla et al. 2016). No doubt, it had generates a significant impact on the environment, which often results in inefficiency. According to the Lean Construction Institute (LCI), the construction industry has a higher rate of waste production than the manufacturing industry (Bajjou et al. 2017; Gursel and Ostertag 2017; Marhani et al. 2018). Concepts such as waste-to-resources and waste-to-energy have emerged as better solutions for waste management, however, they also create additional environmental problems, which lead to additional project costs (Ily and Abdul 2016; Jin et al. 2018; Mellado and Lou 2020).

In the context of Malaysia, its construction industry has executed several mega projects over the last two decades. However, most of these projects were poorly managed in terms of cost, time and quality (Jatarona et al. 2016; Meor Hasan et al. 2016; Ali et al. 2019). Tons of construction waste are generated from rapid construction activities producing adverse effects on environment and construction cost (Marhani et al. 2018). The difference between good and poor project performance lies in the capability of project team to meet the expected cost and quality. Nevertheless, there is an increasing number of construction companies undertaking initiatives to improve their project performance. These initiatives include reducing all types of waste generated throughout the construction process (Ily and Abdul 2016). The generation of waste however has led to high levels of diversity, poor performance and unsafe work environments are the main characteristics of construction industry.

Nevertheless, potential solution to this problem is found in the lean construction philosophy that emerged in the 1990s as it challenges the industry's conventional approach (Goh and Goh 2019; Francis and Thomas 2020). The term lean construction is coined in 1993 during the first *International Group for Lean Construction Conference*. The concept of lean construction as a new way to manage construction activities was first introduced by Howell and Ballard, co-founders of the Lean Construction Institute (Ansah et al. 2016). Lean production, which is rooted in manufacturing industry, has proven to be useful in construction due to both being of similar nature (Goh and Goh 2019). It is a new approach to construction that is based on practices in manufacturing sector, Toyota Production System in particular (Ingle and Waghmare 2015).

According to Howell (1999), cited in Mossman (2018), he asserted that lean construction is the result of a modern method of production management being applied to construction. A consistent set of priorities for the delivery process, aimed at optimizing customer efficiency at the project level, parallel product and process design, and the implementation of production management over the life of the product from design to delivery, are important features of lean construction. After a decade, there has been an abundance of definitions that describe the term lean construction. However, we adapt the definition by Gao and Low (2014) who illustrated lean construction as a project delivery methodology focused on production management which is especially useful in dynamic, unpredictable and fast projects.

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Lean construction has been improved in terms of its implementation and used over the last few years. Babalola et al. (2019) empirically found that the leading countries in the practice of lean construction are the US, UK and Brazil. Well-known works in this field include (Howell 1999) the conceptualization of Lean Construction (Ballard 2000) development of The Last Planner Production Management System, and (Ballard et al. 2002) the basis of lean construction and the associated tools and techniques. Whelton et al. (2002) proposed a knowledge management framework for capital project definition based on lean principle, whereas Zimina et al. (2012) introduced the concept of target value designed to reduce construction costs by adopting collaboration and lean approach (Mellado and Lou 2020). Implementation of lean construction by construction companies in Malaysia is still at the early stages and in the midst of creating a very detailed and accurate plan to drive profitability (Nikakhtar et al. 2015; Syamila Badriah et al. 2020). Thus, it is important to find innovative and creative solutions that ensure better management, minimization of waste and improvement in construction process and performance (Bajjou et al. 2017).

The lean construction approach is considered as a strategic option for implementing a new project where special tests such as suitability and acceptance must be carried out prior to execution (Ansah et al. 2016). In terms of the suitability test, if a strategic option helps a firm or an industry to overcome a weakness, such as an option would be suitable for application (Senaratne and Wijesiri 2008; Gordian 2014). In addition, the test of acceptability considers whether it will lead to opposition or criticism (Senaratne and Wijesiri 2008; Gordian 2014). Historically, the terms suitability and acceptability of lean principles were gained numerous attentions from western scholars in the last two decades ago. Three 'Strategic Option Assessments' have been put forward by Johnson and Scholes (1999), which help assess this type's strategic option before applying it to a specific setting (Botten and Sims 2005). It encompasses of suitability test, acceptability test, and feasibility test. The suitability test considers whether the choice in question is the correct one, while the acceptability test tests whether the strategic alternative will receive vital support from the individuals it needs or whether it will contribute to resistance or criticism. However, the feasibility test considers whether a business has the potential to effectively carry out the strategic choice (Botten and Sims 2005). In this study, we focus on suitability and acceptability to deliver an extensive evaluation based on the two principles. The next section discusses these two principles as a strategic option for lean construction.

While construction activities generate waste in construction industry, workers are often unaware of the flow or/and causes associated to waste generation from construction activity (Ingle and Waghmare 2015). Defects and damaged material derived from poor construction management produce additional cost, time, and scope of work (Senaratne and Wijesiri 2008). Defect is identified as construction waste, which can affect construction performance in terms of cost and scope of work. It can also be interchangeably termed as a deficiency in a building's operation, efficiency, statutory or user specifications and which manifest itself within the affected building's structure, fabric, services or other facilities (Watt, 1999). This can be the cause of unclear instruction and ineffective information delivery on waste management which negatively affect construction performance (Ajayi, Oyedele, Akinade et al. 2017). If the company does not support waste management, lean construction could not be achieved. Therefore, this study will investigate the suitability and acceptability of lean principles in achieving high-performance lean construction.

Literature review

We carried out narrative literature that critiques and summarizes the body of knowledge on lean construction, flow waste of construction, suitability and acceptability of lean principles in the construction industry, performance of project using lean construction principles, and the relationship between variables involved.

Lean construction

Lean construction is a fairly recent approach, rooted in the manufacturing sector, which focuses on reducing operations that do not contribute to the project's owner producing value. Non-value - adding operations are, in this sense, known as waste (Mandujano et al. 2016; Tafazzoli et al. 2020). It has changed the traditional view of labor and workflow reliability. Lean construction practice specifically focuses on decreasing waste-generating construction processes, and minimizing irregularity and variability, so there is a steady stream of material and data without interruptions (Ansah et al. 2016; Mellado and Lou 2020).

There have been many case studies of successful implementation of lean construction. One of the studies is on Value Stream Mapping to identify waste in modular construction industries. Lean principles were applied in the form of the 5S (sort straighten, shine, standardize and sustain) to improve the identified waste-generating processes. Empirical findings have demonstrated a dramatic improvement in productivity, throughout volume and labor costs within half a year of implementation. Ultimately, lean intervention becomes a powerful method for process improvement, which is also deterministic in nature (Goh and Goh 2019; Herrera et al. 2020). The practice allows for reduction in expenses by cutting on waste generation, gaining support from individuals, and improving efficiency of a workplace (Ingle and Waghmare 2015). Lean construction is regarded as the key determinant in construction, which incorporates the flow model and value generation.

The principles of lean construction are thus proposed to reduce non-value adding activities, and increase the value of output by systematically taking customers' needs into account while reducing variability. In addition, it can reduce cycle time by simplifying construction processes through minimizing the number of steps and sections. Lean practices also allows for increased output flexibility and process transparency through focus control on a complete process. The practice promotes continuous improvement in the process and equilibrium between enhanced flow and conversion, which can eventually be used as a benchmark (Aristiz et al. 2019).

Lean principles also emphasize that every step in construction process is important to improve project performance; this can be accomplished by adopting lean and green practices. Lean construction reduces the direct cost in project delivery and helps construction managers to make informed decisions at all stages during project execution (Sarhan et al. 2017). For example, lean construction and simulations have been conducted to enhance processes in execution of house, bridge deck, and block and brick constructions. Lean construction aims to improve construction operations by minimizing waste and maximizing value added processes (Goh and Goh 2019). It is generally an application and adaptation of the concepts and principles in Toyota

Production System into construction related activities. In Toyota Production System, the focus is on reducing waste, increasing customer value, and continuous improvement (Bhargav et al. 2015).

The principles of Just-In-Time (JIT), Total Quality Management (TQM), Business Process Reengineering (BPR), Concurrent Engineering (CE) and Last Planner System (LPS) that were outlined by Alinaitwe (2009); Teamwork and Value Based Management (VBM) (Harris and McCaffer 1997); and OHSAS 18001 are all concepts which contain methodologies to achieve better constructive performance through lean construction. For example, how to integrate the key concepts of lean construction into the construction process was defined by George and Jones (2008), Small et al. (2011), Summers (2005), Excellence (2004), Seppanen et al. (2010), Bertelsen (2004) Koskela (1992), Salem et al. (2005), and Mohd Yunus (2006). Most of these concepts are interconnected, we conclude, and it is necessary to understand all of LC's core concepts, which can enhance efficiency while minimizing construction waste.

Flow of construction waste

The construction industry is known for consuming large amounts of rare natural resources and generating large amounts of construction and demolition waste (Bilal et al. 2016; Francis and Thomas 2020). Construction Waste and Demolition (CDW) is one of the world's highest and greatest waste streams. These wastes are composed of voluminous materials with high potential for recycling and reuse. The skeleton is effectively demolished after removing all construction fixtures and fittings, a process is known as soft stripping, and the CDW produced is disposed of in landfills (Henao et al. 2019; Whittaker et al. 2019).

High volume of waste are generated from excessive production, ineffective stock control, defective goods, unnecessary transportation and non-value added processes. For instance, uncontrolled urbanization encourages building renovations, whereas increase in household income combined with favorable housing loan policy facilitates emergence of new construction and renovation works, which eventually result in more waste being generated (Minh et al. 2018; Rangel et al. 2020)

The word 'waste' has a wide definition in lean construction terminology that includes many categories. Similar meaning of waste is used interchangeable throughout the body of knowledge, mainly; defects, overproduction, waiting, non-utilized skills, transportation, inventory, motion and over-processing (Tafazzoli et al. 2020). As one of the founders of Lean Thinking, for instance, Shingo (1984) suggests the following seven kinds of waste: waste due to overproduction; waste due to waiting periods; waste due to transport; waste due to the system itself; waste due to stock; waste due to operations; and waste due to defects. In construction processes, Koskela (1992) defined waste, such as the number of defects; rework; a number of design errors; omissions; the number of change orders; safety costs; and, excess consumption of materials.

In different situations, flow waste may occur from decision-making operations at the strategic level to working methods at the operational level. It is necessary to define the causes or sources of such waste in order to eradicate these non-value-adding flow operations. Alarcón (1997) identified three sources of waste: management, capital, and knowledge.

Suitability and acceptability of lean principles in the construction industry

Lean principles is a strategic option that must be evaluated before implementation in a new context. The reason is that the practice needs to be evaluated in terms of suitability and practicality before applying to a particular environment such as that of construction activity (Dixit et al. 2017; Syamila Badriah et al. 2020). Acceptability of lean principle is also important which requires assessment in level of acceptance among the stakeholders involved. General management theorists argue that people will accept a new philosophy if they accept its principles and believe it to be true (Carnall 2007).

If players in construction industry can identify the right approach that can be used to overcome problems or weaknesses in construction activities, it would be appropriate for them to adopt that approach. Waste generation is considered the biggest shortcoming in construction industry. It used to be a common belief before the introduction of lean construction as construction practitioners keep attempting at identifying residual flows. Many studies on the use of lean approaches have identified categories of waste generated at various stages of project delivery (Adamu 2015; Rangel et al. 2020). The catalysts for lean construction are identified as defective, damaged and unnecessary materials, and unnecessary labor movements that include reworking, design errors, delay in activity, wasted resources due to waiting period, pilfering and the need for ongoing clarification (Senaratne and Wijesiri 2008).

Many construction professionals are aware of construction waste generation as they have witnessed the impact and experienced the temporal aspects of the waste disposal. To choose the right approach in addressing the issue of flow of wastes requires identification of the causes and sources of waste. Studies of lean construction show that waste is produced due to many reasons (Adamu 2015). Among the causes are late information, environmental factors, poor management control, planning and quality of resources, shortages in resources, and defective and unclear information (Senaratne and Wijesiri 2008; Dal Forno et al. 2016; Erol et al. 2017; Minh et al. 2018; Aghayer et al. 2020).

If construction workers implement lean construction in every activity, they must believe in all core principles associated to such practice. Lean construction critics are still arguing that the importance of lean thinking in terms of removing waste and increasing efficiency is far outweighed by the burdens imposed on the workers (Senaratne and Wijesiri 2008). If workers (general workers) consider that lean construction can cause hardship for them, they may not accept this philosophy. Therefore, assessing the level of acceptance of lean construction among all stakeholders involved is necessary (Senaratne and Wijesiri 2008). Thus, it sparks the question as to how the principles in lean construction are being accepted by construction workers.

The final assessment or qualification test reflects on whether a company has the ability to successfully implement methods for lean construction. However, it is hard to test the practicality of this method for common practice in the industry as a whole. In addition, the test must involve various construction companies of various levels to produce reliable data on conformity and acceptance level among stakeholders. Therefore, this test was not executed in this study.

Performance of project using lean construction principles

Most past studies focused on how to implement lean tools such as the Lean Production System, Value Stream Mapping, and the

Kanban System to improve performance (Zhang and Chen 2016; Sarhan et al. 2017). However, this study assessed the performance of lean construction based on suitability and acceptability of lean principles in construction ecosystem. Performance of a project using lean construction can be evaluated based on several aspects including responsiveness, flexibility, cost reduction and quality. The creation of efficient lean knowledge can enhance innovation capability of a construction company and encourage them to investigate ways to effectively solve problems and eliminate waste while remaining competitive. It also provides future projects with enhanced knowledge which can be useful prior to starting construction, and for quick decision-making and improved responsiveness. In addition, it helps to reduce costs and improve construction quality (Zhang and Chen 2016; Salhieh et al. 2018; Shashi et al. 2019)

Lean construction helps to produce efficient construction procedures that facilitate value-added distribution by keeping everything in place, and moving materials and labor effectively. Adopting lean construction methods contributes to high-quality construction. The approach primarily encourages delivery of clear information on how to reduce the variability in construction process and improvement in the quality of final product (Bajjou et al. 2017). In addition, the main advantage of lean construction is that it can reduce construction costs due to efficient use of materials and less waste generation.

To assess project performance, this study incorporated a Resource-Based View Theory as proposed by Wernerfelt (1984), Rumelt (1984) and Barney (1986). The theory is not only used to analyze the competitive advantages of a firm but also other aspects of business ventures that relate to obtaining multi resources such as attracting investors, management skills, and managing operations and markets in order to survive and grow in the industry (Barney 1991). Several studies have also adopted this theory to assess the performance of lean construction (Nawanir et al. 2013; Henao et al. 2019; Shashi et al. 2019). This theory allows the project managers to spread resources according to alignment with strategy, to identify the value of such resources and required capabilities for the competitive advantage of the organizations. In addition, providing the managers a snapshot of strength for intervention, or for mergers and acquisition purposes.

Relationship between operation, information, employee involvement, and continuous flow of waste management of lean principles on construction performance

The relationship between operation, information, employee involvement, and continuous flow of waste management of lean principles on construction performance is explained in the following sections.

Relationship between operation flow in waste management and project performance

This study was conducted to understand the suitability of lean principles through the operation flow in waste management. For this assessment, the researchers only selected flows of waste generated as a result of defected and damaged materials, and unnecessary material and labor movements. Material defects are one of the main sources of problems at construction sites which requires significant attention. Material defects occur when materials or building elements do not meet the standard of performance or functionally weakened. Material defects can cause damage to human life and assets (Wibowo 2017; Kasi et al. 2018; Shashi et al. 2019). The costs due to defective materials and the associated reconstruction result in expenses that is higher than the estimated construction cost (Baiburin 2017). Waste management in lean construction is part of the responsibility, especially when the contractor and construction company guarantee the entire process and is responsible for the quality of the building sand any damage that the building might sustain (Brioso and Humero 2016).

Albuquerque et al. (2020) found that operation flow in waste management is important to enhance performance of lean construction. The paper reported positive effects of flow operation in waste management on various classes of businesses including small family businesses, multinational public companies and local private companies located in the city of Sao Paulo. Nawanir et al. (2013), Battista et al. (2014), Banawi and Bilec (2014), Mostafa et al. (2015), Appelqvist et al. (2016), Sajan et al. (2016), Gursel and Ostertag (2017), Shah and Khanzode (2017), Dlouhy et al. (2018), Jin et al. (2018) as well as Shashi et al. (2019) reported findings similar to Albuquerque's. In addition, past studies from Sweis et al. (2016) and Zhang et al. (2017) have reported a negative relationship between operation flow in waste management and project performance. Thus, a hypothesis was derived as follows:

H1. Operation flow in waste management has a positive relationship with project performance.

Relationship between information about flow of waste management and project performance

Information about flow of waste management was obtained to determine the suitability of waste management procedures according to lean principles in construction industry. Clear information is essential for ensuring the design is within a targeted budget and error-free. Incorrect information and slow delivery can lead to excessive wastage due to poor operation management. Adequate and clear information will prevent errors that may lead to re-work, which subsequently ensure that construction activities are carried out with design freeze in place. Design documentation typically lacks important and clear information for successful construction work, resulting in contractors having to deal with unnecessary waste generation (Ajayi, Oyedele, Bilal et al. 2017). There have been previous studies to investigate the capability of building information modelling (BIM) to simulate generation of construction waste, which demonstrate successful waste reduction (Li et al. 2017; 2019). Such practices can prevent incorrect and slow information delivery. Some studies reported the role of an architect in reducing wastage in construction projects by creating form of requirements for customers, consistent design quality and a clear flow information (Bhagwat 2019).

Many past works have found positive relationship between information about flow of waste management and performance of construction project. For instance, a study by Chun and Cho (2018) reported that information about flow of waste management among superiors strongly supports project performance. Similar findings have been reported in the works of Banawi and Bilec (2014), Dal Forno et al. (2016), Ward et al. (2018), Saieg et al. (2018) and Li et al. (2017; 2019). Abushaikha et al. (2018) conducted a research on 90 firms located in Jordan, Saudi Arabia, United Arab Emirates, Oman and Kuwait, which resulted in discovery of significantly positive association between information about flow of waste management and project performance. A recent cross-sectional study conducted in Colombo, Chile and Spain by Herrera et al. (2020) also proved similar relationship. However, a few studies confirmed that information about flow of waste management did not influence the project performance (e.g., Erol et al. 2017; Senouci et al. 2016; Aghayer et al. 2020). Thus, the following hypothesis was derived:

H2. Information about flow of waste management has a positive relationship with project performance.

Relationship between employee involvement in the flow of waste management and project performance

To understand the acceptability of lean principles in construction industry, this study examined acceptance of waste management by individual, subordinate, peers and company. Someone who accepts the removal of waste will agree with the practice of lean principles in construction activities. Environmental performance is influenced by individual acceptance of waste management. A previous study used Life Waste Management (LWM) to support breakdown detection and characteristics of material in different waste management scenarios (Astrup et al. 2018). Early descriptions of waste reduction process are important knowledge, especially to subordinates and peers in construction industry. A study by Wibowo (2017) observed poor performance of subordinates due to slow and unclear information delivery. Conversely, companies supporting waste management would provide deconstruction services to ensure that valuable and reusable materials from renovation or demolition activities are carefully restored (Huang et al. 2018).

A study by Alhuraish et al. (2017) reported on significant positive association between employee involvement in flow of waste management and construction project performance. Lohne et al. (2017) also supported that performance of construction project is determined by employee involvement in waste management flow. In addition, a similar result was obtained in the study by Nadeem et al. (2017) who proved that equipping employees with knowledge about waste management produce positive impact on project performance. Empirical studies by Aziz and Hafez (2013), Banawi and Bilec (2014), Sajan et al. (2016), Dal Forno et al. (2016), Sweis et al. (2016), Zhang et al. (2017), Shashi et al. (2019) and Herrera et al. (2020) have demonstrated a positive link between employee involvement in the flow of waste management and performance construction project. It is worth to note that a recent study by Aghayer et al. (2020) reported that knowledge on waste management among construction employees in Azerbaijan did not result in high performance of lean construction. Benn et al. (2015) revealed that the employee involvement in the flow of waste management is not related to the project performance. Based on collective evidence a hypothesis was derived as follows:

H3. Employee involvement in the flow of waste management has a positive relationship with project performance.

Relationship between continuous flow of waste management and project performance

Acceptance of lean principles in construction industry can be observed through a continuous flow of waste management due to improvement in quality of workplace, on-site activities and reduction in non-value added activities. Companies practicing effective and environmentally friendly processes have great potential to improve the flow of waste management, as the processes require manpower from various organizations, which is difficult to manage. Improvement in activities at workplace and construction site are characterized by enhanced consultation activities related to waste management at various levels from work stations to operating stations and distribution centers, as well as to vendors and end-users. Reduction in non-value added activities enhances knowledge of how lean principles and environmental management can be integrated, which focuses on operation in waste management (Minh et al. 2018). Previous studies have shown that improvement in on-site activities can significantly reduce waste generation through a strict adherence to project drawings, and by ensuring minimal or no design changes during construction process. This can reduce the non-value added activities during project execution (Ajayi, Oyedele, Akinade et al. 2017).

The past studies have reported a significant positive relationship between waste reduction through continuous flow of waste management and project performance. Similarly, Aziz and Hafez (2013) proved the positive effects of continuous flow of waste management on project performance. Other studies by Banawi and Bilec (2014), Sharma and Shah (2016), Senouci et al. (2016), Mandujano et al. (2016), Erol et al. (2017), Salhieh et al. (2018), Henao et al. (2019) and Herrera et al. (2020) have demonstrated that a good practice of continuous flow in waste management facilitates the performance of manufacturing companies. The influence of continuous flow of waste management on the performance of lean construction have also been reported in studies by Heravi and Qaemi (2014) and Heravi and Firoozi (2017). In contrast, studies by Sweis et al. (2016) and Aghayer et al. (2020) shown that project performance is not influenced by continuous flow of waste management. A hypothesis was formed as follows

H4. Continuous flow of waste management has a positive relationship with project performance.

Research methodology

The data for this study is collected using a questionnaire survey via a simple random sampling approach to the targeted populations such as project managers, engineers and contractors who work at construction companies located in Pahang, Malaysia. In Kuantan, Pahang, there are 244 registered construction companies as reported by the Malaysian Business Directory (Business List 2018). From the list, there are more than 600 staffs who works as project managers, engineers and contractors. To determine the sample size, this study used G*Power 3.1.9.7 for Windows (a statistical power analysis programme). The results indicate that the sample size required for the study is 102. The procedure of simple random sampling approach was executed by means of IBM SPSS Statistics for Windows, Version 23.0. A total of 140 questionnaires were distributed to targeted respondents, and 104 were returned (response rate of 74.3%). 36 questionnaires were discarded due to incomplete and inaccurate information. The study utilized enumerators who personally distributed, face-to-face the questionnaires to the respondents within one month in 2019.

The questionnaires used in this study consists of two sections. Section One was designed to gain information about the roles of operation, information, employee involvement and continuous flow of waste management on the project performance. Section Two was prepared to capture the profiles of respondents. There were 18 items in Section One, which were adapted from previous studies developed by (Senaratne and Wijesiri 2008) and Sarhan and Fox (2012). The questionnaires used a five-point Likert scale

Table 1. Constructs and sources.

Measurement	Sources	Scale
Information about flow in waste management	(Senaratne and Wijesiri 2008)	1 = Strongly disagree – 5 = Strongly agree
Employee involvement in the flow of waste management		
Continuous flow of waste management		
Project performance		
Operation flow of waste management	(Sarhan and Fox 2012)	

ranging from (1) strongly disagree to (5) strongly agree. Subsequently, the questionnaires were refined after receiving comments and suggestions based on experts' opinions and pre-test procedures. Only a few words of the indicators (e.g., Item 1 and 3 in the continuous flow of waste management and item 3 in the employee involvement in the flow of waste management) from the survey questionnaire was modified and rearranged the sequence as suggested by the experts and pre-testing respondents. The experts were identified through Google search-based and were selected based on their experience and position. Table 1 summarizes the constructs and sources adapted in this study.

The data was tested using partial least squares structural equation modeling (PLS-SEM). Two major analyses of PLS-SEM namely the measurement model and structural model were applied to the data. The PLS-SEM was used in this study to verify the predicted model and explain the variance in the key construct (project performance) using explanatory variables such as operation, information, employee and continuous flow of waste management as shown in Figure 1. The PLS-SEM is suitable for analysis using relatively small sample size (Hair et al. 2010). On another note, PLS-SEM offers greater statistical power than other models in detecting statistically significant relationships and requires no distributional assumptions (Ringle et al. 2012; Shackman 2013). Moreover, the reflective measured construct (project performance) is particularly useful for explanatory constructs.

Results

Respondents' characteristics

The respondents in this study were represented by various types of jobs, work experiences and levels of education. Figure 2 summarizes the characteristics of respondents in the study. For instance, 26.9% of respondents work as project managers, 23.1% as engineers and 15.4% as contractors. Few of the respondents have work experience of more than 15 years (5.8%) while the majority (67.3%) have less than 5 years of work experience. In regard to educational levels, slight majority of the respondents (44.2%) are diploma graduates while the rest (40.4%) are graduates with bachelor degree.

Common method bias

In this study, the measurement of constructs was only based on the judgment of single individual (project managers, engineers and contractors) which could result in common method bias. Therefore, this study used two statistical analyses to test the common method bias. Firstly, this study applied a Harman's single-factor test to identify common method bias (as recommended by Podsakoff et al. 2012). In this approach, all items measuring latent variables were loaded into one common factor, whereby a total variance for a single factor less than 50 percent indicates that the common method bias does not affect the data or results (Podsakoff et al. 2012). For this study, the percentage variance of a single factor was 44.8 percent, which was less than the threshold value. Thus, the data and results generated from this study are not affected by common method bias. Secondly, by analyzing the correlation matrix as suggested by Bagozzi et al. (1991), it was found that no significant correlations were observed between the constructs. Majority of correlation coefficients obtained shows moderate correlation (Hair et al. 2007). The lowest value recorded was 0.224 (significant at 0.05 level) and the highest was 0.762 (significant at 0.01 level). None of the correlation coefficient values achieved more than 0.91 to signify high correlation (Hair et al. 2007). Thus, no initial evidence of possible common method bias found in this study (Bagozzi et al. 1991). Table 2 summarizes the results from correlation analysis. This study tested the common method bias using IBM SPSS Statistics for Windows, Version 23.0.

Exploratory factor analysis

To test unidimensionality of the construct variables of the study, exploratory analysis was performed on all the 18 items by using Principal Component Analysis (PCA) with direct oblimin rotation. Three criteria suggested by Hair et al. (2007) were used to finalize the variables: (1) Eigen values greater than or equal to 1 were used to identify the number of factors; (2) Items with a loading smaller than 0.5 (low factor loadings) were deleted; and (3) Items that demonstrated cross loadings greater than 0.5 on more than one factor were dropped.

The results shown in Table 3 indicated that five components of Eigen values are greater than 1 and identified as continuous flow of waste management, employee involvement in the flow of waste management, information about flow of waste management, operation flow of waste management, and project performance. No items were reported with low factor loadings (below than 0.5). Furthermore, no items were demonstrated cross loadings greater than 0.5 on more than one factor. The result of Bartlett's Test of Sphericity and the Kaiser-Meyer-Olkin Test of Sampling Adequacy (KMO) is shown in Table 3. In the current study, the value for KMO matrix is 0.857, which falls under the range of marvelous (Beavers et al. 2013) and test the value of chi-square is 1994.619, which is significant at five percent level ($p < 0.05$). Hence, data indicate the suitability and appropriateness because the items are generally loaded on their intended scales.

Analysis of reflective measurement model

To measure the reflective measurement model, several tests were conducted namely the indicator, reliability, convergence and discriminant validity tests. In this study, the reflective indicators with loadings equal to or greater than 0.50 were accepted while loadings below the acceptable value (0.50) were removed as suggested by Duarte and Raposo (2010) and Hair et al. (2014). Table 4 shows the loading of the indicator. It was discovered that the loading values of all 18 indicators were above the acceptable benchmark of 0.50. The loadings were between 0.771 (Item

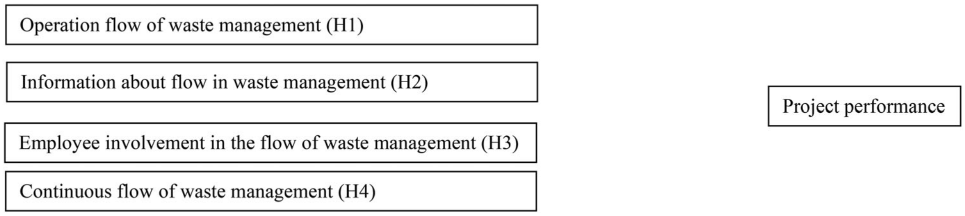

Figure 1. Conceptual model.

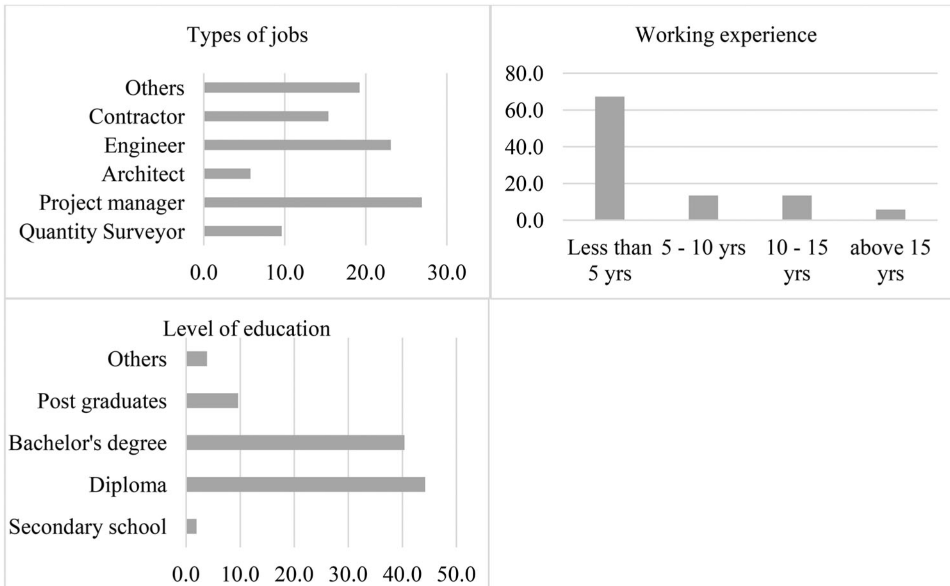

Figure 2. Graphs of respondents' profiles based on types of jobs, working experience and level of education.

Table 2. Summary of correlation analysis (N = 104).

Variables	OFWM	IFWM	EFWM	CFWM	Project performance
OFWM	–				
IFWM	.454**	–			
EFWM	.412**	.224*	–		
CFWM	.708**	.361**	.495**	–	
Project performance	.648**	.294**	.506**	.762**	–

Notes: CFWM = Continuous flow of waste management; EFWM = Employee involvement in the flow of waste management; IFWM = Information about flow of waste management; OFWM = Operation flow of waste management; SD = Standard deviation;
**Correlation is significant at the 0.01 level (2-tailed);
*Correlation is significant at the 0.05 level (2-tailed).

Table 3. Results of explanatory factor analysis for all items.

Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy.					.857
Bartlett's Test of Sphericity	Approx. Chi-Square				1994.619
	Degree of Freedom				153
	Significant				.000
Item	OFWM	CFWM	EFWM	IFWM	Project performance
OFWM4	.872				
OFWM3	.860				
OFWM2	.847				
OFWM1	.812				
CFWM1		.712			
CFWM3		.607			
CFWM2		.575			
EFWM3			.852		
EFWM1			.838		
EFWM2			.785		
EFWM4			.742		
IFWM3				.869	
IFWM2				.855	
IFWM1				.846	
PP4					.868
PP1					.840
PP2					.785
PP3					.722
% of variance explained	39.085	12.200	10.977	8.391	5.644
Total variance explained					80.297

Notes: CFWM = Continuous flow of waste management; EFWM = Employee involvement in the flow of waste management; IFWM = Information about flow of waste management; OFWM = Operation flow of waste management.

1: continuous flow of waste management) and 0.973 (Item 2: employee involvement in the flow of waste management). In this study, the internal consistency of the constructs was determined by using the composite reliability (CR). As demonstrated in Table 4, the values of CR which ranged from 0.858 (Item 1: continuous flow of waste management) to 0.969 (Item 3: operation flow of waste management), where a CR of 0.70 or greater is considered acceptable and reliable according to Fornell and Larcker (1981).

Table 4 also shows the results from convergent validity analysis which was tested using average variance extracted (AVE). The results show that the AVE obtained range from 0.668 (Item 1: continuous flow of waste management) to 0.888 (Item 3: operation flow of waste management), which are above the accepted value (Fornell and Larcker 1981). Thus, the results indicate that

Table 4. Summarized results of loading, CR, AVE and VIF analysis.

Construct/Item	Loading	CR	AVE	VIF
Continuous flow of waste management (CFWM)		0.858	0.668	2.082
CFWM1	0.771			
CFWM2	0.828			
CFWM3	0.852			
Employee involvement in the flow of waste management (EFWM)		0.956	0.844	1.348
EFWM1	0.936			
EFWM2	0.943			
EFWM3	0.973			
EFWM4	0.816			
Information about flow in waste management (IFWM)		0.924	0.802	1.270
IFWM1	0.927			
IFWM2	0.823			
IFWM3	0.933			
Operation flow of waste management (OFWM)		0.969	0.888	2.090
OFWM2	0.954			
OFWM3	0.952			
OFWM4	0.911			
OFWM1	0.951			
Project performance (PP)		0.957	0.848	
PP1	0.925			
PP2	0.957			
PP3	0.874			
PP4	0.925			

Notes: CR = Composite reliability; AVE = Average variance extracted; VIF = Variance inflation factors.

these indicators satisfied the requirement for convergent validation of the respective constructs. On the other hand, to identify the multicollinearity, the variance inflation factors (VIF) were tested. As presented in Table 4, the VIF values for all constructs are below 3.0, which signify no collinearity issues between the constructs in the proposed conceptual model (Diamantopoulos and Siguaw 2006). In addition, the calculated R^2 was 0.560, indicating that the exogenous factors can only influence endogenous factors at 56.0 percent. The R^2 value obtained in this study is considered moderate (Chin 1998).

This study used the heterotrait-monotrait (HTMT) ratio of correlations to assess discriminant validity. HTMT incorporates two techniques to measure discriminant validity. The first technique is called the criterion or statistical test. To achieve discriminant validity of statistical test, the HTMT value should not be greater than the HTMT.85 value of .85 (Kline 2011) or HTMT.90 value of .90 (Gold et al., 2001). As shown in Table 5, all values have passed HTMT.85 measures (Kline 2011; Ramayah et al. 2017). The second technique is known as $\text{HTMT}_{\text{Inference}}$. This technique was employed to test the null hypothesis (H0: HTMT $\geq$ 1) as compared to alternative hypothesis (H1: HTMT $<$ 1). Confidence interval with a value of 1 signifies discriminant validity. $\text{HTMT}_{\text{Inference}}$ (second method) shown in Table 5 reveals that the confidence interval value for each construct is below 1, which confirm that the discriminant validity exists among the constructs in this study.

The results indicate that the construct is distinct from related constructs and have no influence on the variation of more than just the observed variables to which they are theoretically related. In addition, the constructs show not perfectly correlated (HTMT.85 and $\text{HTMT}_{\text{Inference}}$ below 1) even though the scales used to assess the constructs were the same. Hence, the results can be used to confirming the hypothesized structural paths.

Table 5. Criterion of HTMT.

Constructs	CFWM	EFWM	IFWM	PP	OFWM
CFWM					
EFWM	0.573[a]				
	0.371;0.765[b]				
IFWM	0.460	0.250			
	0.286;0.645	0.090;0.464			
PP	0.828	0.535	0.344		
	0.708;0.967	0.335;0.709	0.198;0.492		
OFWM	0.816	0.449	0.477	0.651	
	0.679;0.956	0.234;0.650	0.267;0.656	0.529;0.759	

Notes: CFWM = Continuous flow of waste management; EFWM = Employee involvement in the flow of waste management; IFWM = Information about flow of waste management; PP = Project performance; OFWM = Operation flow of waste management;
[a]The criterion for HTMT ratio is below .85;
[b]The criterion for HTMT upper confidence intervals (CI) is below 1.

Analysis of structural model

After validating the measurement model (inner model), the next step in a PLS-SEM analysis is to establish a structural model. To validate the proposed hypotheses and structural model, the path coefficient between two latent variables was determined. Validation test of structural model used the bootstrap procedure with 5000 times of resampling. Table 6 presents the calculated path coefficient, which demonstrates that only three hypotheses are supported. Results also demonstrate that the supported hypotheses are significant at the level of 0.01 and 0.05, with expected sign directions (i.e., positive association) and path coefficient (β) ranging from 0.183 to 0.466.

Results from analysis indicates that the project performance is influenced by suitability of lean construction in operation flow of waste management ($\beta = 0.222$, $t = 2.231$, $p < 0.05$) thus supporting Hypothesis 1. In addition, it was found that information about flow in waste management negatively influences project performance ($\beta = 0.015$, $t = 0.171$, $p > 0.05$). Therefore, Hypothesis 2 is not supported in this study. Moreover, results presented in Table 6 demonstrate that project performance is positively influenced by employee involvement in the flow of waste management ($\beta = 0.183$, $t = 2.063$, $p < 0.05$) and thus, Hypothesis 3 is supported. In this study, the employees' participation was indirectly measured through their contribution such that of project managers. Respondents agreed that improvement in project performance using lean construction is related to employees' participation in the flow of waste management.

Table 6. Summary of hypothesis testing.

Hypothesis	Path	Std Beta	Std Error	t-value	Decision	f^2
H1	OFWM = >PP	0.222*	0.101	2.231	Supported	0.055
H2	IFWM = >PP	0.015	0.062	0.171	Not Supported	0.000
H3	EFWM = >PP	0.183*	0.089	2.063	Supported	0.057
H4	CFWM = >PP	0.466**	0.090	5.060	Supported	0.229

Notes: CFWM = Continuous flow of waste management; EFWM = Employee involvement in flow of waste management; IFWM = Information about flow of waste management; PP = Project performance; OFWM = Operation flow of waste management;
*$p < 0.05$; **$p < 0.01$.

Furthermore, acceptance of continuous flow of waste management in lean construction significantly influences project performance ($\beta = 0.466$, $t = 5.060$, $p < 0.01$) and thus, support Hypothesis 4.

This study also measured the size of effects as shown in Table 6, which presents f^2 as size of the effect that exogenous antecedent constructs produce on endogenous construct (project performance). The size of the effect is a measure of magnitude of an effect that is independent of the sample size (Kock 2014). According to Cohen (1988), f^2 of 0.02 is considered as small effect, 0.15 as medium effect and 0.35 as large effect. The results reveal that the antecedent constructs affects the performance of a project adopting lean construction principles to a varying degree. The magnitude of the effect that information about the flow of waste management has on project performance is represented with computed f^2 of 0.000, which is considered very weak (Cohen 1988). Other constructs such as operation flow in waste management and employee involvement in the flow of waste management are represented by computed f^2 value of 0.055 and 0.057, respectively. These values signify the small effect size. However, the computed f^2 for continuous flow of waste management construct signify medium effect size with a value of 0.229.

Discussion

The results of this study show that the operation flow of waste management (H1), employee involvement in the flow of waste management (H3), and continuous flow of waste management (H4) had positive effects on project performance. Despite the strong belief that information about the flow of waste management (H2) is a significant predictor of project performance, the result is insignificant. These results explain how constructs are related or unrelated to project management and have important implications for both theory and practice.

Theoretical implications

From a theoretical standpoint, this study contributes to project management literature, particularly in developing countries. The results show that operation flow of waste management has a positive effect on project performance, which confirms prior studies showing that this construct affect project management (e.g., Mostafa et al. 2015; Appelqvist et al. 2016; Gursel and Ostertag 2017; Dlouhy et al. 2018; Shashi et al. 2019). The finding suggests that reducing defective and damaged materials could improve the construction project's final products' quality. In addition, a smooth and quick response toward any problems that interfere with construction processes, and reduction in unproductive employee movements during construction processes could also lead to good project performance (Ansah et al. 2016). This study proves that the operation flow of waste management is critical to project performance in developed countries and in developing countries like Malaysia.

Moreover, this study did not find support for the relationship between information about flow in waste management and project management which supports previous work Aghayer et al. (2020). Their study revealed that disseminating information on waste management to Azerbaijan construction employees does not support project performance. In this study, the construction companies faced the challenges to improve several mistakes in information about flow in waste management such as late information, defective information, and unclear information. However, the results are in contrast with the works of Saieg et al. (2018), Li et al. (2017; 2019), Abushaikha et al. (2018) and Herrera et al. (2020), which reported a positive relationship between information about the flow of waste management and project performance. For instance, Li et al. (2019) have suggested that the construction companies must developed an established online and offline communication system to ensure the success of information about flow of waste management in construction companies.

In addition, the results of this research show that project performance is positively influenced by employee involvement in the flow of waste management. Previous literature has reported consistent findings on the relationship between employee involvement in the flow of waste management and project management (e.g., Dal Forno et al. 2016; Zhang et al. 2017; Herrera et al. 2020; Shashi et al. 2019). The evidence proves that employees at construction companies in Kuantan have practiced and are truly responsive to waste management at construction sites. (Wibowo 2017) highlighted that acceptance of waste management among subordinates and peers as a part of daily responsibility improves flexibility and organization of construction processes. Eventually, the cost of construction can be reduced and the quality of the final product delivered can be assured (Huang et al. 2018).

Finally, the results indicate that continuous flow of waste management leads to project performance, which is in line with past studies (e.g., Erol et al. 2017; Mandujano et al. 2016; Salhieh et al. 2018; Henao et al. 2019; Herrera et al. 2020). The results demonstrate that continuous improvement in workplace and construction activities encourages employees to be proactive, leading to increased awareness about construction processes regularly (Minh et al. 2018). Therefore, the construction cost can be maintained within the allocated budget and non-value added processes can be removed to improve project performance according to principles in lean construction (Ajayi, Oyedele, Bilal et al. 2017).

Practical implications

This study proposes that business managers or owners of construction companies must consider the following implications of the lean principles in project performance. First, the findings may assist the business managers and owners of construction companies in Kuantan, Pahang, to reduce defects and damaged material to minimize construction costs without compromising the quality. In addition, the findings also demonstrate the need to diminish unnecessary movement of material and labor, which can negatively affect project performance in terms of responsiveness, timing, and flexibility.

Secondly, managers or owners at construction companies should re-evaluate the flow and communication methods to deliver clear information on waste management to employees.

This is important to enable smooth and high-quality construction that meets the customers' expectations. Finally, managers at construction companies also need to believe the importance of suitability and acceptability of continuous flow of waste management for construction project performance; responsiveness toward waste management and flexibility in construction processes such as time and cost reduction, and quality are highly important to the majority of construction companies.

Conclusions and limitation

This study aimed to analyze the suitability and acceptability of lean principles by construction companies located in Pahang, Malaysia. This paper helps researchers and practitioners to better understand the effect of suitability and acceptability of lean principles on the performance of construction project. Findings from this study prove that only three variables have been identified as the key determinants in the performance of construction project adopting lean principles in Pahang. These variables are employee involvement in the flow of waste management, operation flow of waste management and continuous flow of waste management. The similar results are believed to have impact on project management in developed countries (Erol et al. 2017; Jin et al. 2018; Herrera et al. 2020). Notably, the findings also demonstrate that the negative effect of information about flow of waste management on project performance. Thus, the management of a construction company must find a way to improve on current practices related to information about the flow of waste management (Aghayer et al. 2020).

Response by respondents also demonstrates that employees at construction companies contribute in elimination of waste from construction sites and fully support the adoption of lean principles to improve performance of construction project. The employee needs to report and record in the system for the process of elimination of waste. By doing this, the construction companies have a specific data on waste elimination. In terms of continuous flow of waste management, everyone in the construction company can contribute to improve activities at workplace. Respondents believe that activities at the construction site can be improved. Such improvements include reducing and eliminating non-value added activities.

This study has some limitations. Firstly, the study focused on construction companies in Pahang, Malaysia. Secondly, sole focus was on construction industry and did not represent other sectors in the economy. For future studies, it is suggested that the scope of the study widened to construction industry in Malaysia and other practices related to implementation of lean principles in construction industry; assessment on suitability and acceptability of lean concept in construction industry in Malaysia can be carried out. In addition, future studies should compare the performance of construction companies practicing principles of construction and demolition to those practicing lean construction principles. A study should also be conducted to specifically determine how construction companies can implement lean construction, managing waste, sustain the practice of lean principles, and continuously improve activities at workplace in construction industry in Malaysia.

Disclosure statement

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