Jordan Journal of Civil Engineering, Volume **14**, No. **3, 2020**

The Strategies of Lean Planning at Selected Construction Sites in Klang Valley, Malaysia: A Structural Equation Modeling Approach

Mohammed Elhaj Alsoufi Mohammed Ahmed [1)*] and Leong Sing Wong [2)]

[1)] PhD Candidate, College of Graduate Studies, Universiti Tenaga Nasional, Malaysia.
* Corresponding Author. E-Mails: PE20705@uniten.edu.my; mohammedelsofi@yahoo.com
[2)] Senior Lecturer, College of Graduate Studies, Universiti Tenaga Nasional, Malaysia.
E-Mail: wongls@uniten.edu.my; wongls79@gmail.com

ABSTRACT

Lean thinking has already had a substantial impact on construction industry in Malaysia. At a certain level, the action to change project organization and procurement systems is to remove the traditional culture of fragmented design and construction processes in construction projects. It emphasizes the importance of strategic modeling for the implementation of lean construction. This paper aims to evaluate the strategies for lean planning at 18 selected construction sites in Klang Valley, Malaysia. The method of interview with the project team (consultants, clients, contractors and developers) was utilized to identify the barriers of the implementation of lean construction techniques at the construction sites. Using a structural equation modeling approach, the model fitness of lean construction techniques at the construction sites was developed and evaluated based on the questionnaire data collected for the study. Based on the study outcome, after checking the fitness of the model with regard to the barriers and strategies of lean construction, it was discovered that the proposed model can enhance the effectiveness of implementing lean construction techniques at the construction sites by (1) Developing efficient communication and integration among top managers and project team to adopt lean construction techniques at the construction sites, (2) Setting up concise goals among various construction firms, (3) Creating a leadership style of project managers to adopt lean construction techniques, (4) Encouraging clients and contractors to invest in lean construction techniques for implementation at the construction sites and (5) Convincing the government to provide incentives for lean construction implementation.

KEYWORDS: Lean construction techniques, Structural equation modelling, Barriers and strategies.

INTRODUCTION

Construction industry is often criticized for its poor performance. The current construction practice is very much influenced by the traditional procurement system and organizational structural arrangement. Each year, it is estimated that 72.5 million tons of construction waste are created in the UK (Egan, 1998; Wilson et al., 1998; Dajadian et al., 2014). This costs the UK's construction industry about £193 million each year in landfill tax, which excludes the disposal charges. The annual Construction and Demolition (C&D) waste was estimated to be 6.28 million tons for Scotland only. Lean thinking is dominated by an 'obsession' to eradicate waste from all business processes. By defining the value for a specific product or service from the end customer's perspective, all the non-value-adding activities (waste) can be targeted for removal step by step. Two aspects of all production systems that must be taken into consideration are conversions and flows. While all activities expend cost and consume time, only conversion activities add value to the end product. Thus, the improvement of non-value adding flow activities (inspection, waiting, moving) through which the conversion activities are bound together, should be focused on reducing or eliminating them and at the same time, the conversion activities should be made more efficient (Egan, 1998; Ballard, 2000; Johansen and Walter, 2007; Dajadian et al., 2014; Bashir et al., 2015). This concept is different from the conventional production theories which stressed that production can

Received on 15/2/2020.
Accepted for Publication on 22/5/2020.

be improved by implementing new technologies primarily in value-adding activities (non-value-adding activities are not explicitly considered). Despite that, there is overwhelming evidence of waste in construction processes. This suggests that there is still a good opportunity to develop novel research on lean construction processes. In addition, considerable resistance remains due to construction being viewed as different from manufacturing industries. Value can be maximized by focusing on value-adding activities, including information, people and shape materials and non-value adding activities (flow activities) which would then be subject to reduction (Wong and Ahmed, 2018). Lean construction provides the modern enhancement methods that must be adopted at the early stage in the project through value management technique (VM). In addition, it is done right at the first time, when customers prefer standardization and prefabrication (CE). Moreover, eliminating waste introduces waste and product flow by establishing a rate of flow, thereby synchronizing all the activities as well as focusing on the potential constraints by utilizing JIT. Also, a pull of a customer can be done by stopping the upstream movement until needed by the downstream; this is possible through the implementation of Last Planner System (LPS). Furthermore, when needed, this should be done quickly and with the correct quality by using Total Quality Management (TQM). Then, perfection is boosted by increasing the flow rate, creating transparency and striving for zero defects through Key Performance Index (KPI) (Koskela et al., 2007; Mahrani et al., 2012; Fee et al., 2016; Li et al., 2017; Ahmed and Wong, 2018; Pearce and Pons, 2019; Carvajal-Arango et al., 2019).

On the other hand, lean construction has a huge impact in construction industry at different levels which is described as follows. At the project level, it reduces risk, improves quality and reduces cost and completion time. At the business level, it reduces rework, increases profits, increases market share, enhances competitive position competitive bidding and broadens the client base. At the corporate level, it is very effective in cost reduction, increasing labor productivity, improving efficiency and increasing opportunity for innovation, continuous improvement of quality products and services as well as increasing cultural responsiveness.
Li et al. (2017) stated that there are several barriers that prevent the implementation of lean construction in China, which are lack of appropriate organization structures, lack of top management support and low level of education for workers as production experts. Sarhan and Fox (2014) identified contract issues (competitive tendering), lack of top management support, culture and human behaviour and lack of governmental support as the barriers to adopt lean construction in the UK. On the other hand, Table 1 shows the various degrees of adopting lean construction techniques in construction industry by several researchers from various countries. For the study, Likert scale was used as follows. Very High = VH, High = H, Medium = M, Low = L, Non-Used = NU.

Presently, Malaysia is still at the early stage in adopting lean construction in spite of the high growth in construction industry in recent years (Marhani et al., 2012). Ahmed and Wong (2018) added that there are several challenges that can prevent the adoption of lean construction, such as lack of staff training, lack of leadership style as well as lack of organizational structure, which are very crucial barriers to the successful implementation of lean construction. Ahmed and Wong (2018) specified that there are six lean construction techniques that were adopted partially in Malaysian projects. These are described as follows. Off-site Construction (IBS) offers significant time savings because building construction and site preparation occur at the same time. Bashir et al. (2015) revealed that building construction occurring at the same time saves as much as 60% of the total construction time for both beams and slabs, as can be achieved with lean construction. Building Information Modeling (BIM) was used to ensure the on-time delivery at the construction phase as well as to reduce material wastes. The use of total quality extends conventional quality control techniques in three areas (Marhani et al., 2012; Ahmed and Wong, 2018). Firstly, it expands the scope of quality control from the production to all upstream processes. Secondly, it expands the scope of quality control from workers to managers. Thirdly, it expands the scope of quality control to cover all processes. Key Performance Indicators (KPIs) are used to identify and clarify improvements as part of the management review process. Remarkably, the management review will take place regularly and will be coordinated by the project quality manager at the selected infrastructure sites.

Ahmed and Wong (2018) observed that offsite work (IBS) is used in precast span-by-span bridge construction to speed up the duration of construction as well as to optimize the cost for all the elevated site locations of the Malaysian MRT projects. Safety management is an increasingly important component of the overall quality management system for a project. Whatever the location of the construction project, it will need to comply with the relevant legislation that is related to health and safety. The provision of the HS & E systems should be in full compliance with the applicable local authorities. Occupational Health and Safety Assessment Series (OHSAS) 18001 is a registered management system on various construction projects in Klang Valley to deliver health and safety objectives (Marhani et al., 2012; Hwee and Poon, 2013; Marhani et al., 2013). H & S regulations are essentially necessary, because construction is characterized by having a wide range of different activities involved in the execution of a relatively complex task. In addition, the nature of the work and the execution process make construction a high-risk activity. Kline (2010) added that SEM is a confirmatory method for "a comprehensive means of providing the best model fits". Several researchers have discovered that Structural Equation Modeling (SEM) can be used as an adequate tool for testing their hypotheses. SEM software AMOS 6.0 (Analysis of Moment Structures) is used to explore the statistical relationships among the items of each factor and between the factors of independent (lean construction techniques at infrastructure projects, lean construction techniques at building projects and barriers of lean construction implementation) and dependent variables (construction waste at infrastructure projects, construction waste at building projects and strategies of lean construction implementation). Moreover, researchers can determine, assess, calculate and show the model in a causal path diagram to illustrate hypothesized relationships among the variables. This paper aims to evaluate the strategies of lean planning at selected construction sites in Klang Valley, Malaysia using Structural Equation Modeling (SEM). Firstly, it provides an overview on the implementation of lean construction in several countries to achieve the project objectives and several lean construction techniques that have been partially adopted in Malaysia. This is followed by an explanation of the research methodology and data collection. Then, strategies of lean planning using SEM are elucidated. Conclusions are presented in the last section of the study, which also includes the limitations of the present study and future research required.

Table 1. The various degrees of implementing lean techniques by several research works

(Li et al., 2017) in China	H	H	L	L	L	H	H
(Fernandez-Solis et al., 2006) in the USA, Europe, Asia and South America	H	H	L	H	H	H	H
(Ogunbiyi et al., 2014) in the UK	H	H	L	H	H	H	VH
(Ahmed and Wong, 2018) in Malaysia	NU	H	VL	L	H	H	VH

RESEARCH METHODOLOGY

Qualitative and quantitative approaches were utilized for data collection in the study (Li et al., 2017; Ahmed and Wong, 2018). The first phase of the qualitative research was adopted to identify the barriers of lean construction implementation at the selected construction sites in Klang Valley on the basis of the lean construction techniques illustrated in the literature review and qualitative research (interview). After that, quantitative research was used to rank the barriers and the strategies of lean construction implementation in Klang Valley, as presented in Figure 1. The contracting companies in Malaysia were categorized in accordance to the financial capabilities starting from the lowest (first class) to the highest financial capabilities (seventh class). The seventh-class category of contracting companies was selected on the basis of their high possibility of adopting lean construction.

Purposive sampling was chosen to select the project team inclusive of clients, contractors, consultants and developers according to their knowledge and experience to evaluate the implementation of lean construction and the barriers of lean construction implementation, as well as the strategies at the selected construction projects in Klang Valley. Notably, the sampling size is recommended to be greater than 200 in order to perform structural equation modeling (SEM) for analyzing the collected data by using the AMOS program (Kline, 2005; Field, 2013). Accordingly, the researchers distributed 100 questionnaires to each of the relevant personnel from the 18 selected construction sites. Overall, 1800 questionnaires were distributed and only 255 were answered. A pilot test was conducted through distribution of the research questionnaires to make sure that the various variables (lean construction techniques in either infrastructure projects or building projects, construction wastes in either infrastructure or building projects, barriers as well as strategies of lean construction implementation) were understood by the respondents and as such no modification was required. The questionnaire was conducted with the project teams as a result of a survey (direct observation and interview). Field (2013) clarified that the interview is the most effective means to design a questionnaire according to the completeness of the information. The purpose of conducting the pilot test was to ascertain the authenticity of the questionnaire. Therefore, the validity of the questionnaire can be verified by performing such test. Discriminant validity and convergent validity including construct, content and criterion validity have been examined in this research work (Kline, 2010). These types of validity are related to the internal validity of respective items of the scales. External validity has also been investigated for the aim of generalizability of the findings of the research work. CFA was used to assess the discriminant and convergent validity. Holmes-Smith et al. (2006) demonstrated that for convergent validity, the magnitude of the direct structural relationship between the factor (latent construct) and the item must be statistically loaded at a factor loading ≥ 0.5. In addition, Likert scale (1 to 5) was used in the questionnaire to measure the effectiveness of lean construction techniques and to provide strategies in applying lean construction in Klang Valley. The research work used Statistical Package for Social Sciences (SPSS) version 20 to analyze the preliminary data and Structural Equation Modeling (SEM) using confirmatory factor analysis to test the hypothesized model. This section describes and justifies the application of these statistical techniques in the study (Tabachnick et al., 2001; Mallinckrodt et al., 2004; Arbuckle, 2005).

Kline (2005) defined Structural Equation Modeling (SEM) as "a collection of statistical tools that allow a set of relationships between one or more independent and dependent variables, either continuous or discrete, to be tested. Kline (2005) showed that structural equation modeling software AMOS 6.0 (Analysis of Moment Structures) can be used to explore statistical relationships among the items of each factor and between the factors of independent (lean construction techniques at either infrastructure or building projects, barriers of lean construction implementation) and dependent variables (various kinds of wastes at either infrastructure or building projects, strategies of lean construction implementation). The sample was chosen to cover the people at the selected construction sites (contractors, developers, consultants and clients) to rank the barriers and strategies of lean construction implementation at the selected construction sites. Field (2013) claimed that a sample of 400 and more is also considered undesirable, because the method then becomes too sensitive in terms of goodness-of-fit measures with an indication of a poor fit. With no agreement about the appropriate sample size among scholars, Field (2013) confirmed that 200 questionnaires would be ideal. The sample size of this study is 255, which is considered appropriate for the analysis in Structural Equation Modeling. CFA was used to determine whether the number of factors and the loadings of measured indicator items (lean construction techniques at selected infrastructure projects, lean construction techniques at selected building projects, barriers of lean construction implementation, various kinds of wastes at selected infrastructure projects, various kinds of wastes at selected building projects and strategies of lean construction implementation).

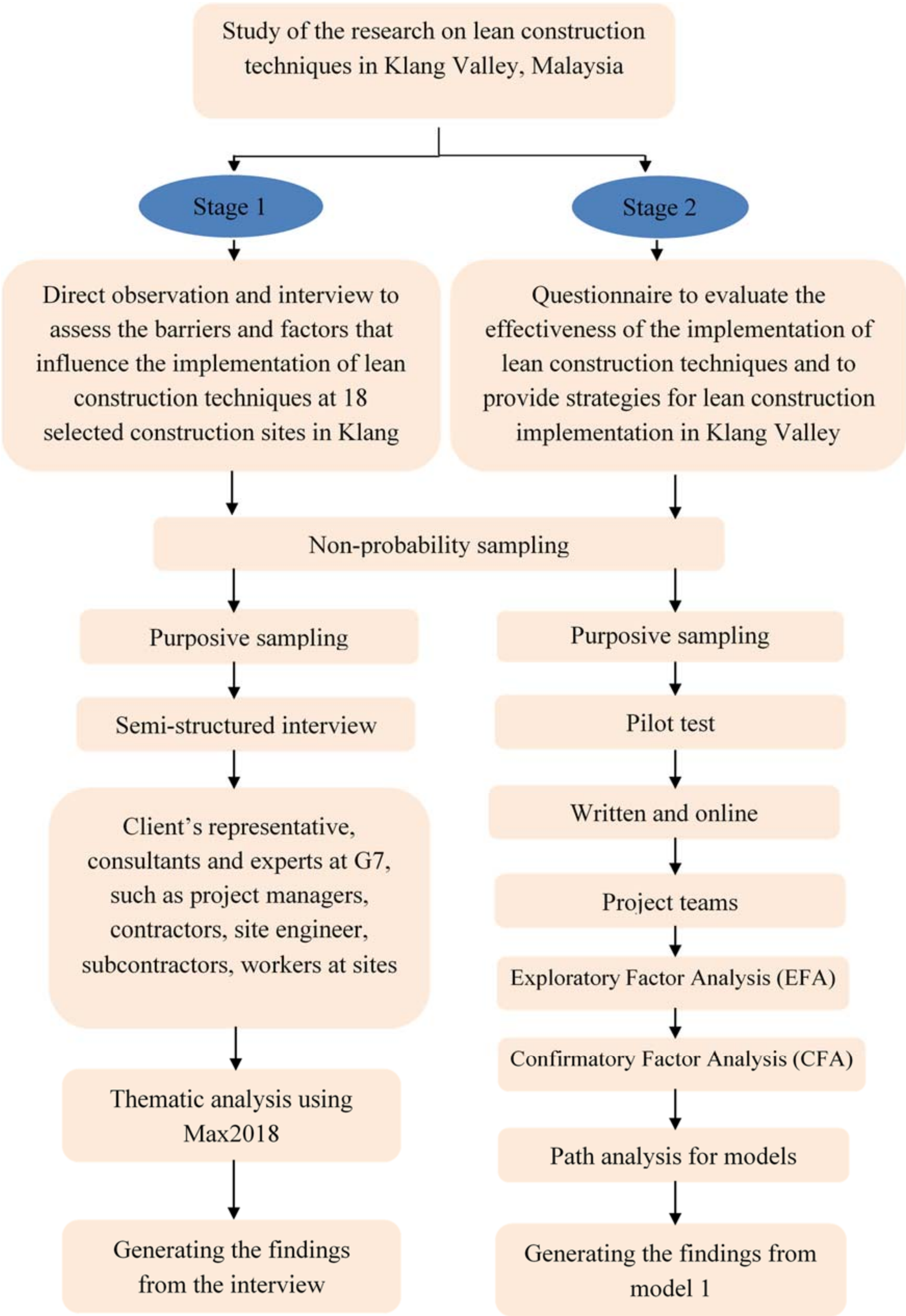

Figure (1): Flowchart of research methodology

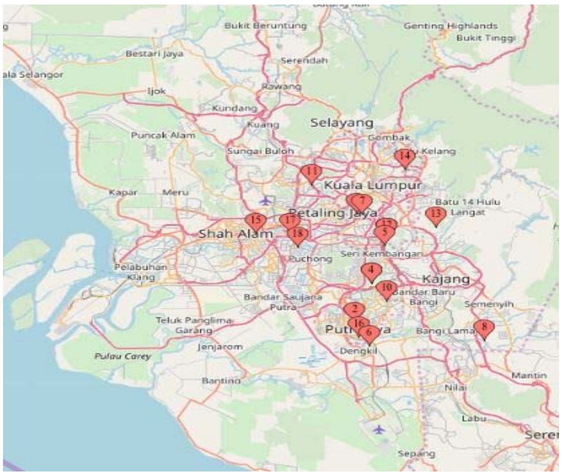

Figure (2): Selected construction sites in Klang Valley, Malaysia

RESULTS AND DISCUSSION

One feedback from the outcomes of the interviews is that the selected construction projects in Klang Valley in Malaysia have been very much focused on competitive strategies for decades and fundamentally and that radically changes in the nature of competition are required. In addition, competitive tendering was used at all construction projects and there are four types of contract for these projects. The first contract type is between the design team and the client for design and project supervision. The second contract type is between the client and the main contractor to the construction work. The third one is between the client and suppliers for materials delivery at the construction phase (in the case of infrastructure projects) being with the suppliers were appointed by the contractors at the selected building projects. The fourth contract type is between the main contractor and any nominated subcontractor. It was revealed from the interview feedback of project and site managers of infrastructure projects that all infrastructure case studies were delivered on-time (JIT), which was illustrated 2 times in the text based on the thematic analysis for coded segment, as shown in Table 1 and Figure 3 with the exception for the projects involving the construction of Mass Rail Transit (MRT) stations, of which the delay in materials happened due to the influence of the traffic regulations. The interview results with the client representatives and consultants at MRT sites revealed that BIM, which was mentioned 5 times in the text due to the thematic analysis for segment codes, as declared in Table 2 and Figure 3, was adopted as a software program in order to contribute to on-time materials with the nomination of the suppliers by the clients. BIM was also used to reduce the materials' wastes at the construction phase according to customer satisfaction (defects and inappropriate processes). The over-production waste implies that the materials provision into the sites was high as a result of the conventional planning method using pull production. The interview findings from some of the project engineers revealed that there was a cost of disposal of the materials back to the suppliers (this is based on the agreement between the clients and the suppliers at all the MRT site locations to take back the extra materials). In contrast, it was realized based on the interviews with the project managers at the selected buildings projects, that the suppliers were nominated by the main contractors with the adoption of conventional design software program (AutoCAD) as a common soft work program at most of the building projects. Therefore, delay in material delivery was very high at all the selected buildings projects. Efficient management of transportation and inventory waste is important to prevent site disruption on flow of work. It was also discovered that AutoCAD was highly used in the major projects as compared to Building Information Modeling (BIM) software due to the lack of staff with adequate exposure to lean construction knowledge, training and client support for adopting BIM. On the other hand, it was observed that offsite work (IBS) was used in precast span-by-span bridge construction to speed up the duration of construction as well as to optimize the cost for all elevated site locations of the MRT. It was noticed that based on the technical perspective of a site engineer in a building apartment project, IBS components were used at the lowest floor level only due to lack of skilful staff and workers to execute the technology for the whole building project. IBS barriers were declared 4 times in the text according to Table 2 and Figure 3 for coded segments. Total quality management (TQM) at MRT projects extends conventional quality control techniques in the following three areas (Ahmed and Wong, 2018). Firstly, it expands the scope of quality control from production to all upstream processes. Secondly, it enhances the scope of quality control from workers to managers. Thirdly, it develops the scope of quality control to cover all processes. This helps reduce the waste because of quality control shifts from inspection to continuous improvement in Key Performance Index (KPI). Internal audits were carried out in terms of quality assurance (QA) and quality control (QC) at the selected building projects. Notably, Tun Razak Exchange (TRX) project used both internal and external auditors, because it is owned by the government to provide services to the public. Based on the interview with the H & S manager, it can be stated that audit was selected to conform to the H & S standards and technical aspects and intended to conform to specific projects related to H & S plans (PMBOK 6th, 2017; Johnson et al., 2019; Yiua et al., 2019). The interview findings with the supervisors in some of the building projects revealed that the auditors from the Department of Occupational Health and Safety, Malaysia used to pay a regular visit at the construction sites to check the implementation of H & S regulations at the building sites. H & S implementation rate in infrastructure projects was much higher when compared to the building projects, because infrastructure projects meet the public service as well. Notably, TQM and H & S barriers were declared 2 times in the text based on the thematic analysis for the coded segments, as described in Table 2 and Figure 3. Table 3 shows the barriers and their possible strategies for the implemenation of lean construction. Table 2 illustrates the barriers as well as the strategies of the implementation of lean construction techniques at the selected construction sites. Based on interviews with the site engineers, CM has a low rate of implementation in building projects due to competitive tendering and lack of non-adversarial partnership to ensure that only the best outcomes can be achieved for the projects.

Table 2. Percentages of repetition of both parent code and code for all documents using Maxqda 2018

Color	Parent Code	Code	Coded Segments of All Coded Documents
		Building information model BIM	5
		JIT	6
	Building information model BIM	Transportation	1
		Conference Management CM	3
		Total Quality Management TQM	6
		Key Performance Indicator KPI	3
		IBS	4
		H&S	6
	Building information model BIM	Barriers	5
	H&S	Barriers	2
	Total Quality Management TQM	Barriers	2
	JIT	Barriers JIT	2
	Conference Management CM	Barriers CM	2
		Lean construction techniques	4
	IBS	Barriers	6

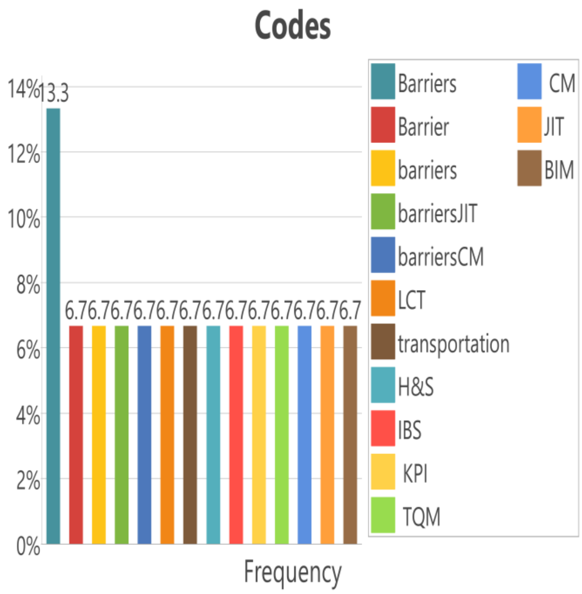

Figure (3): Thematic analysis for codes of all documents suing Maxqda 2018

Table 3. Barriers and their strategies at the construction sites

Barriers	The possible strategies
Lack of incentives by the government	Providing incentives by the government
Lack of common goals among various firms	Developing common goals among various firms
Legal and contract issues	Legal and contract issues
Expensive cost to adopt BIM, IBS, KPI, TQM and HS	Encouraging clients and contractors to adopt lean construction
Lack of staff competent to adopt BIM, IBS, KPI,TQM and HS	Developing staff competent to adopt lean construction
Lack of knowledge to adopt BIM, IBS, KPI,TQM and HS	Introduction to university curriculum
Lack of organization structure	Developing organizational structure
Lack of organization culture	Encouraging and forcing lean construction adoption by the goverment

MODEL FITNESS

The model diagram in this study consists of measured variables (composite variables), the constructs as unobserved variables, with arrows representing relationships between the variables and measurement errors. The single-headed arrows in the diagram represent linear dependencies, indicating the extent to which one variable (construct) is dependent on another (relationships or causal paths). The first arrow connects lean construction techniques at infrastructure projects with the relationship to the construction wastes in infrastructure projects (Figure 4). The second arrow links lean construction techniques at building projects with construction wastes in building projects (Figure 5). Figure 6 establishes the barriers of implementing lean construction with the strategies. They represent a direct relationship that is hypothesized between these two variables. The absence of arrows linking variables implies that no direct relationship has been hypothesized. Also included in the model are residual errors associated with the latent variables and measurement errors associated with the composite variables. Residual errors are represented as (z) in small circles. Measurement errors are represented as (*e*) and enclosed in small circles. The overall fit indices indicate that the final model is the best fit to the data with the hypotheses of CM, IBS, LPS, JIT, KPI and TQM which were derived from testing the CFA model. The decision will be supported if the p-value = ***p<0.005, **p<0.01, *P<0.05. However, if p-value > 0.05, the decision will be not accepted (Xiong et al., 2015; Ajaya and Oyedele, 2018). The factor loadings for these hypotheses for construction wastes at infrastructure projects were found to be 0.14, 0.17, 0.21, -0.56, 0.27 and 1.07, while the factor loadings for these hypotheses for construction waste at building projects were discovered to be 0.43, 0.55, 0.25, -0.16, 0.06 and 0.18, which are acceptable. On the other hand, the results of testing the hypothesized model indicate that the hypotheses of strategy 1, strategy 2, strategy 3, strategy 4, strategy 6 and strategy 8 were statistically significant and in the hypothesized direction. The standardized estimates for these hypotheses were all significant and found to be 0.38, 0.80, 0.79, 0.53, -0.06 and 0.55, respectively. Thus, these hypotheses are deemed to be acceptable. The hypotheses of strategy 5, strategy 7 and strategy 9 were rejected, because they were statistically insignificant at the values of 0.68, 0.68 and 0.70, respectively. The indices for goodness-of-fit demonstrate that this model adequately fits the data. According to the (barriers-strategies) path analysis, the effective strategies at adopting lean construction can be described as follows. The government encouragement to adopt lean construction at various selected construction sites is considered as one of the most effective strategies that can increase the implementation of lean construction at the selected construction sites in Klang Valley. Based on the views of the respondents, the government can opt to actively participate in and encourage various contracting companies to create and innovate for a change in the current culture of construction projects by providing incentives to people in construction industry. Therefore, the government should provide a standard guideline of using lean construction, such as a new form of contract (partnership contract). Noticeably, having government support is a crucial element to adopt lean construction at the selected projects in Klang Valley. Other countries, such as the USA and the UK, have partially implemented lean construction by either encouragement or enforcement from their governments (Li et al., 2017). In view of the lack of skilful staff to implement lean construction at the selected building projects, it is necessary to develop common goals among the various firms at the selected construction projects, as there is a dire need to ensure a high rate of communication and integration between the top management and the construction team, so as to encourage the adoption of lean construction at the selected building projects (third, fourth and eighth strategies). From the respondents' points of view, the lack of skilful staff with sufficient knowledge to implement lean construction is attributable to the lack of their exposure to relevant training. With the focus of construction industry on realizing performance goals in terms of construction processes and enviornmental challenges, it is arguable that there is a need for innovative, challenging and vigorous approaches at implementing Supply Chain Management (SCM) and developing strategic alliances in construction (Egan, 1998). Therefore, construction firms must exchange resources, information, knowledge and technology in order to adopt SCM at the construction projects in Klang Valley. It should be noted that conventional procurement structure brings its own organizational design and imposes it on the project, which implies that the PM may end up with little actual direct influence on the organizational structure (Arif et al., 2011; Meng and Boyd, 2017; Müller et al., 2018). The problem faced by many PMs in almost all construction project organizations is that they are afforded with relatively little formal (contractual or legitimate) authority. The PM must be a skilful leader, so that he/she can develop the scope of the informal authority to motivate and build a team that can overcome deficiencies in the organizational design caused by procurement or industry culture to adopt lean construction at the selected construction projects. Therefore, the PMs at the selected building projects in Klang Valley played very important roles to ensure a high rate of integration between the top management and technical people at the selected construction projects. The last planner method (pull production) could be viably used to replace the conventional planning method (push production) at the selected construction projects to ascertain on-time delivery with required cost and zero defects. Lastly, the respondents opined that clients and contractors should be encouraged to make more investment in adopting the lean construction approach, particularly IBS and BIM at the selected construction sites in Klang Valley with active support from both the government and PMs of the projects.

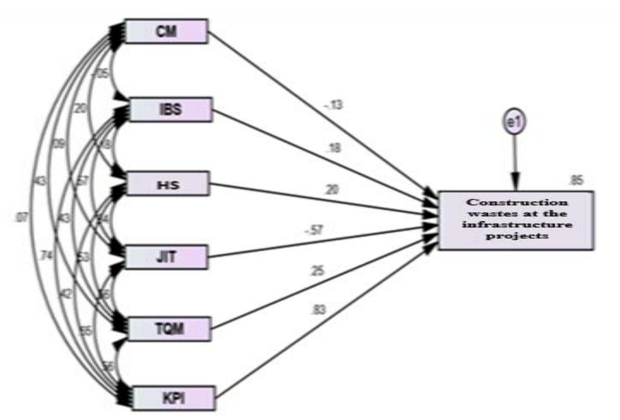

Figure (4): Path analysis of lean construction techniques and construction wastes for the infrastructure projects

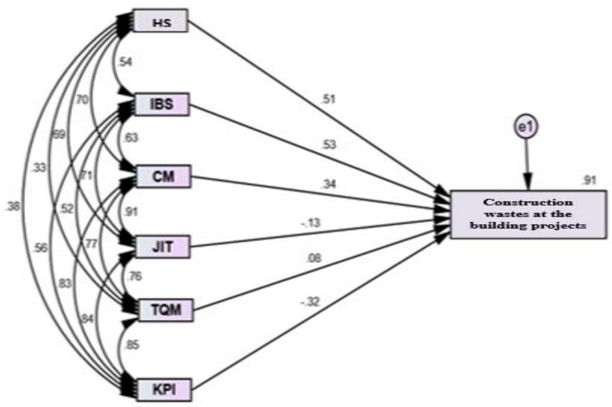

Figure (5): Path analysis of lean construction techniques and construction wastes for the building projects

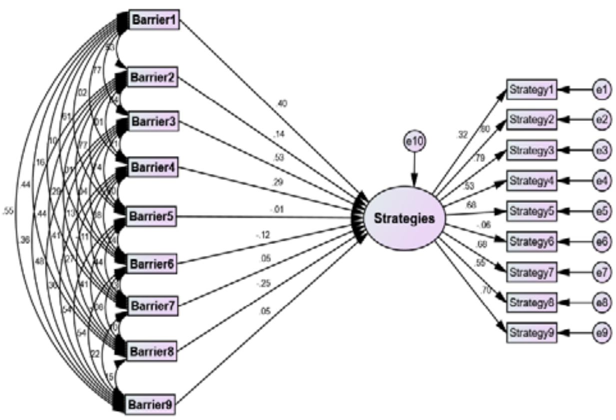

Figure (6): Path analysis among the barriers and strategies of lean construction of the projects

EXPLORATORY FACTOR ANALYSIS (EFA)

Preliminary data analysis pointed put that the average Cronbach's Alpha coefficient values for lean construction techniques and various kinds of wastes of the infrastructure projects are 0.781 and 0.811, respectively. The values of the respective parameters were discovered to be 0.906 and 0.941, respectively, for the building projects. EFA indicates that the correlation between the observed variables and constructs is significant due to AVE > 0.5, which is described as follows. The Average Variance Extracted (AVE) and CR values for lean construction techniques and various kinds of wastes of the building projects were found to be 0.83, 0.93 and 0.82, 0.93, respectively. The values of their respective parameters were noticed to be 0.81, 0.82 and 0.61, 0.83 for the infrastructure projects. These results confirmed that the parameters used to quantify the factors; namely, the average Cronbach Alpha and the Average Variance Extracted (AVE) values are reliable, since the average Cronbach's Alpha coefficient was noted to be greater than 0.70 and AVE > 0.5, as depicted in Figures 7, 8, 9, 10 and 11.

Notably, the factor loadings (AVE) of construction wastes in the infrastructure projects are much lower than for wastes in the building projects. Based on that, waiting time and transportation were discovered to be 0.15 and 0.32, respectively, in construction wastes in the infrastructure projects due to high factor loading of JIT (0.73). On the other hand, the values of AVE for CM and HS were realized to be 0.07 and 0.47, respectively, in lean construction at the infrastructure projects, while the factor loading of the defects is 0.48 according to high factor loading values of TQM and KPI (0.8 and 0.73, respectively).

The results also indicated that this model adequately fits the data. The values for lean construction techniques of infrastructure projects and their construction wastes of composed reliability were realized to be 0.80 and 0.82, respectively. It was discovered that the average Composite Reliability (CR) of lean construction and the construction wastes at the selected infrastructure projects have the values of the Cronbach Alpha of 0.781 and 0.811, respectively. Lean construction and construction wastes in building projects have the same value of average Composite Reliability (CR) which was noticed to be 0.93. The average Composite Reliability (CR) of lean construction and the construction wastes at the selected infrastructure projects has the same values of Cronbach Alpha of 0.906 and 0.941, respectively (Garza-Reyes et al., 2018). Furthermore, the average factor loading of AVE for the correlation between the barriers and strategies is insignificant, since the respective AVE values were found to be 0.37 and 0.398, which are less than 0.5. In a similar manner, the respective AVE values were improved to 0.52 and 0.48 after the removal of irrelevant factors from the models as shown in Figures 13 and 15. Based on the observation of Figure 12, the values of AVE for the barriers 4, 6 and 7 with items 12, 15 and 16 were realized to be 0.075, 0.077, and 0.216, respectively, which are less than 0.5.

The values of AVE for strategies 1, 6 and 8 with items 1, 6 and 8 were found to be 0.207, -0.004 and 0.427, respectively, which are below 0.5 as well (Figure 14). Based on the findings, it can be justified that the least factor loadings (AVE < 0.5) of barriers are for lack of knowelge about lean construction, expensive cost to adopt lean construction at the selected building projects and lack of staff training to be aware of and adopt lean construction. Meanwhile, the least factor loadings for the strategies are detailed as follows. One of the least effective AVE strategies is a matter of provision of incentives by the government (Figure 15). It must be stressed that the government through the Construction Industry Development Board (CIDB) continue to organize training courses and seminars regarding lean construction techniques, particularly IBS and BIM techniques, in order to attract the clients, contractors and consultants in construction industry as well as university students to adopt lean construction (Zakaria et al., 2013; CREAM, 2014). The other least factor loading is for the encouragement of clients and contractors to fully utilize lean construction techniques at the selected building construction sites. It was discovered that the average Composite Reliability (CR) values for barriers and strategies were noticed to be 0.80 and 0.81 with approximately equal values of Cronbach Alpha which were discovered to be 0.757 and 0.798, respectively (Field, 2013; Ajaya and Oyedele, 2018).

CONFIRMATORY FACTOR ANALYSIS (CFA)

It was found that the average composite convergent validity was also supported by ensuring that the value of AVE is 0.50 or above. In the case of validity, convergent validity was supported by all items being dramatically significant ($P<0.001$) and loadings on their specified factors. The CFA results also showed the chi-square values for lean techniques for the building projects. The CFA results also revealed the chi-square values for lean techniques for the infrastructure projects (x^2 = 28.863, df = 6, P = 0.000). The values of CFI = 0.964, TLI = 0.911, RSMEA = 0.122 and x^2 /df = 4.8 6(Figure 8). It is also evident that the values of chi-square for lean techniques for the building projects were discovered to be x^2 = 28.04, df = 6 and P = 0.000, CFI = 0.986, TLI = 0.966, RSMEA = 0.12 and x^2 /df = 4.673, as shown in Figure 7. Figure 11 illustrates the chi-square values for the various kinds of construction wastes in building projects, which are x^2 = 31.54, df = 5, P = 0.000, CFI = 0.988, TLI = 0.949, RSMEA = 0.145 and x^2 /df = 6.308. On the basis of that, the values of these indices were found to be within the recommended values which are deemed to be adequate. Also, these values for lean construction techniques in infrastructure projects, construction wastes in infrastructure projects, lean construction techniques in building projects as well and construction wastes in building projects suggested an adequate fit to the model and the correlations between the underlying factors are less than 0.85. Therefore, no further adjustments were required in such case. The measurement model can be observed to provide an acceptable fit with the chi-square values being statistically significant, particularly with a large sample (Kline, 2010; Xiang et al., 2015; Ajaya and Oyedele, 2018). On the other hand, the chi-square values for the various kinds of construction wastes for the infrastructure projects are x^2 = 106.024, df = 11 and P = 0.000. The other chi-square values are CFI = 0.903, TLI = 0.814, RSMEA = 0.184 and x^2 /df = 9.639 (Figure 9). TLI was found to be slightly below the threshold value of 0.9 and other indices are within the recommended threshold levels; therefore, further adjustments to the model were required. The removal of waiting time and transportation factors improved the fit of the model, even though the chi-square values are not statistically significant (x^2 = 7.793, df = 1 and P = 0.005). The other values for the chi-square were noticed to be CFI = 0.991, TLI = 0.908, RSMEA = 0.164 and x^2 /df = 7.793 as depicted in Figure 10. Accordingly, these indices were found to be sufficient and within the recommended levels.

In another development, the chi-square values for the barriers were found to be x^2 = 271.36, df = 24, P = 0.000, CFI = 0.800, TLI = 0.699, RSMEA = 0.201 and x^2 /df = 11.307 (Figure 12). For the strategies of lean construction implementation at the selected construction projects, the chi-square values were found to be x^2 = 242.23, df = 24, P = 0.000, CFI = 0.800, TLI = 0.692, RSMEA = 0.189 and x^2 /df = 10.093, as indicated in Figure 14. The CFA results also indicate that the inter-correlations among the barriers and strategies are relatively high, demonstrating a lack of discriminant validity, given the fact that the relational bond factors are highly inter-correlated and several indices (i.e., x^2, GFI, AGFI) are insignificant and therefore, not accepted. As such, the discriminant validity needed to be improved by performing a further detailed assessment (Kline, 2005). After iteratively removing these redundant items, the barriers 4, 6 and 7 with items 13, 15 and 16 as well as the strategies 1 and 6 with items 1 and 6 were found to lack discriminant validity and were further removed. The aim of repeating the filtering process was to delete as few items as possible, taking into consideration the requirement for deriving more parsimonious model redundant items. As such, a total of three items of barriers and two items of strategies were removed. In spite of that number of items that were removed is relatively high, the item removal did not significantly change the content of the construct. This is because the initial factor loadings for the remaining items of barriers and strategies are relatively high and thus the meaning of the factors was preserved by these items. With the enhancement of the goodness of fit indices, the modified model illustrated a better fit to the data for the barriers, as indicated by the chi-square parameter values of $x^2 = 39.684$, df = 6, $P = 0.000$, N = 271, CFI = 0.961, TLI = 0.902, RMSEA = 0.149 and x^2 /df = 66.614, as shown in Figure 13. The modified data of strategies yielded chi-square values of $x^2 = 101.3$, df = 12, $P = 0.000$, N = 271), CFI = 0.899, TLI = 0.824, RMSEA = 0.171 and x^2 /df = 8.44 (Figure 15). These values suggest that the model adequately fits the data. It is important to stress that chi-square estimates may not be acceptable for a model with a large sample size (Garza-Reyes et al., 2013).

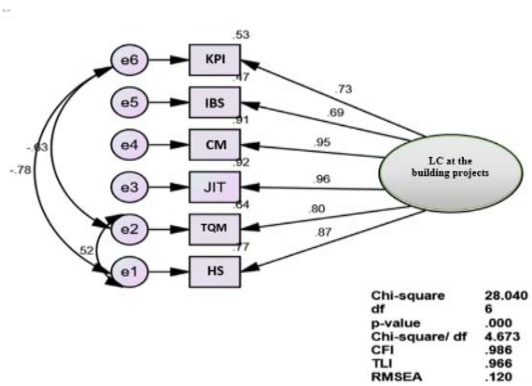

Figure (7): CFA model for lean construction implementation at the building construction sites

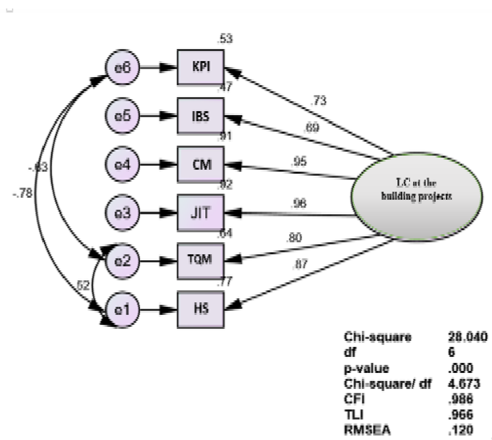

Figure (8): CFA model for lean construction implementation at the infrastructure construction sites

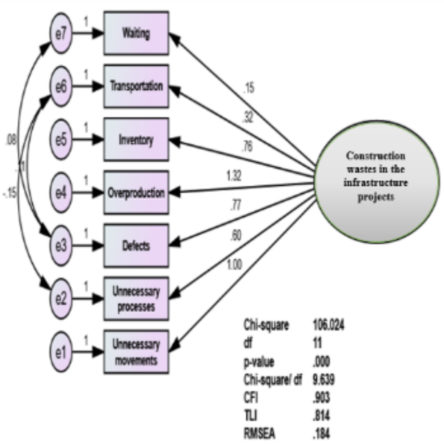

Figure (9): CFA model for construction wastes at the selected infrastructure construction sites

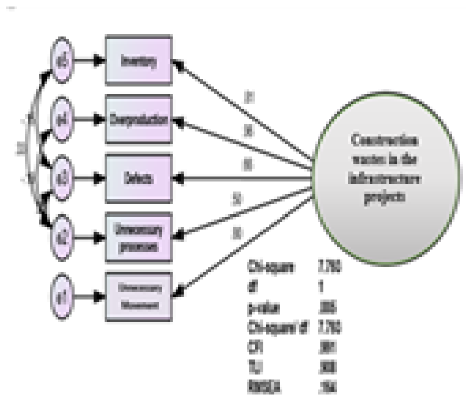

Figure (10): CFA model for construction wastes for the infrastructure projects after deletion of waiting and transportation

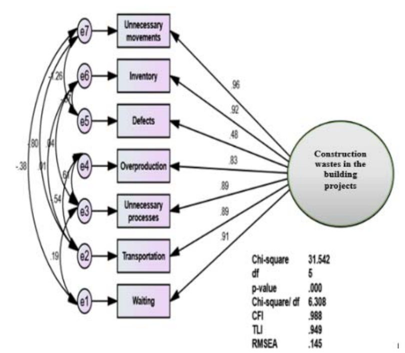

Figure (11): CFA model for construction wastes at the selected building construction sites

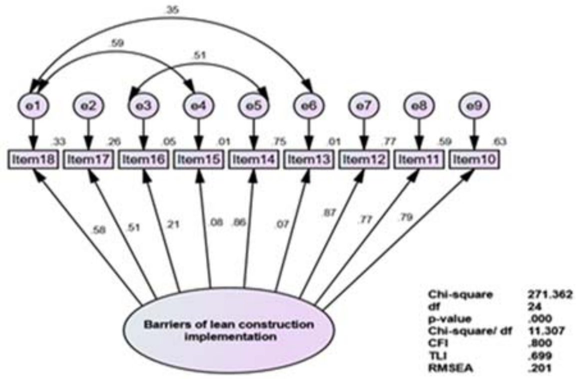

Figure (12): CFA model for barriers of adopting lean construction at the selected construction sites

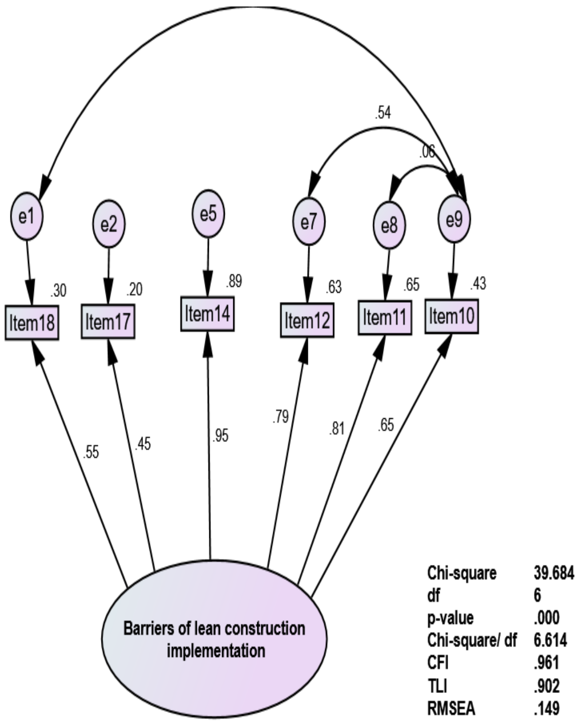

Figure (13): CFA model for barriers of adopting lean construction at the selected construction sites after item deletion

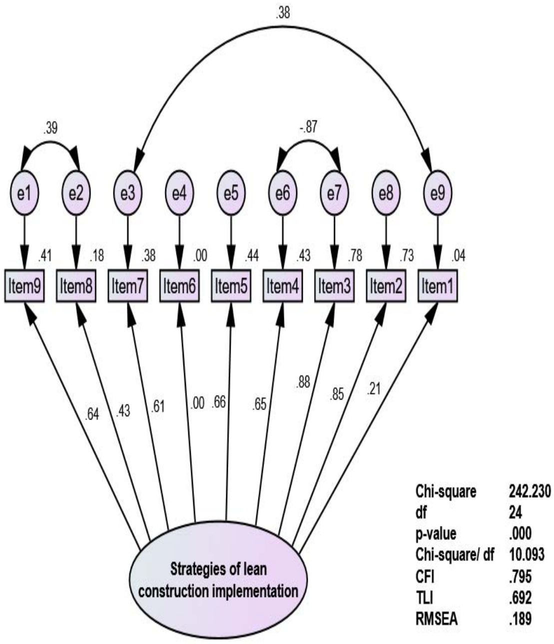

Figure (14): CFA model for strategies of adopting lean construction at the selected construction projects

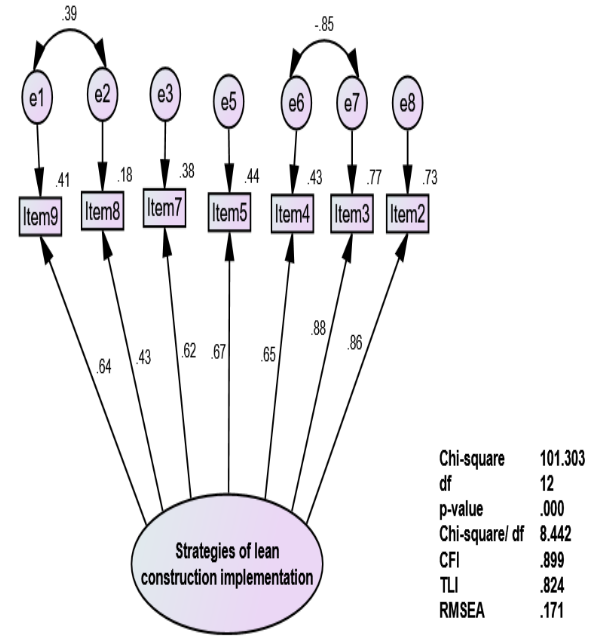

Figure (15): CFA model for strategies of adopting lean construction at the selected construction sites after item deletion

Table 4. The Comparative fit indexes in the modified model

Model fit	**Lean construction at building projects**	**Lean construction at infrastructure projects**	**Construction wastes at building projects**	**Construction waste at infrastructure projects**	**Barriers of the implementation of lean construction**	**Strategies of the implementation of lean construction**
Chai Square	28.04	28.863	31.54	106.024	39.68	101.303
P value for the model	0.00	0.00	0.00	0.00	0.00	0.00
CFI	0.986	0.964	0.988	0.903	0.961	0.899
RMSEA	0.122	0.122	0.145	0.184	0.149	0.171
TLI	0.966	0.911	0.949	0.814	0.902	0.824
Df	6	6	5	11	6	12

CONCLUSIONS

- A number of barriers that prevent the implementation of lean construction are identified. They are organizational culture to change and innovate at various selected projects, lack of common goals between the various firms at different selected projects, lack of organizational structure to adopt lean construction at the selected construction projects, lack of competent staff to operate lean construction at the selected building projects, lack of knowledge about lean construction at the building projects and expensive cost to apply lean construction at the selected building projects.

- Furthermore, the proposed strategies that will improve the effectiveness of the implementation of lean construction at the selected construction sites in Klang Valley can be concluded. The concluded points are: encouragement and stimulation by the government to adopt lean construction, development of common goals among various firms, development of a high rate of communication and integration between top managers and construction teams to adopt lean construction at the selected construction sites, competent staff to operate lean construction at the building projects, introduction to university curriculua, staff training on lean construction in the building construction sites, encouragement of clients and contractors to pay extra to adopt lean construction at the selected building construction sites, provision of incentives e by the government, as well as contracts and legal issues relevant to lean construction.
- On the other hand, the association between the elements of the proposed relationship of lean construction techniques and the various kinds of construction wastes models at the selected construction sites was empirically examined. The model fitness of the effectiveness of the implementation of lean construction techniques (HS, JIT, IBS, KPI and TQM) for construction wastes (waiting, transportation, inventory, unnecessary processes, unnecessary movements and defects) in both infrastructure and building projects was accepted.
- It was also discovered that the proposed model for the strategies for lean construction implementation at the selected construction sites can be described as follows. Firstly, staff training on lean construction should be promoted at the building projects. Secondly, the government should encourage and incentivize companies to adopt lean construction. Thirdly, there is a need to set up concise goals among the various construction firms with standards. Fourthly, there is a need for competent staff to operate lean construction in the building projects. Fifthly, it is vital to encourage clients and contractors to invest in lean construction techniques for implementation in the building projects; and lastly, it is necessary to develop efficient communication and integration among the top managers and project teams to adopt lean construction techniques at the construction projects. Based on that, their factors loadings were found to be 0.38, 0.80, 0.79, 0.53, -0.06 and 0.55, respectively.

Acknowledgement

The authors would like to acknowledge the financial support from the Fundamental Research Grant Scheme (FRGS) (Project reference code: FRGS/1/2018/TK10/UNITEN/02/3).

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