Factors affecting construction costs in Thailand: A structural equation modelling approach

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ABSTRACT

Cost performance in the construction industry is important to enhance industry standard and grow a country's economy. This paper examines the key factors affecting cost performance in Thai construction projects, specifically at the pre-construction and construction phases. A questionnaire survey is used to gather data for the exploratory factor analysis (EFA) and structural equation modelling (SEM) analysis used in this study. The EFA technique extracted the key factors affecting construction cost, while the SEM revealed the interactions and causal relationships between those key factors. The EFA results confirm seven key factors: three at the pre-construction phase: lack of coordination, design management, and unclear client requirements; and four at the construction phase, including site management, resources, labour capability and contract-related. The SEM results confirm strong relationships, directly and indirectly, between the three key factors at the pre-construction phase. Good coordination between stakeholders result in less design errors and clear client requirements. The influences that the three factors at the pre-construction phase have on the four factors at the construction phase are also supported. The result highlights that unclear client requirements cause poor site management and cost overrun, which may lead to breach of contracts. Construction companies can use this study results to better plan for cost improvement by focusing on the identified pre-construction factors, as they could lead to good cost management during the construction phase.

KEYWORDS: Construction cost, Exploratory factor analysis, Structural equation modelling.

INTRODUCTION

The construction industry is one of the booming industries in the world. It is the locomotive for physical development for national economies (Enshassi *et al.*, 2009). In Thailand, the construction industry is used to indicate the country's improvement. In the past decade, the expansion of the industry averages 5.71% per year (CIT, 2016).

Construction projects comprise three main phases, including pre-construction, construction, and post-construction phases. The pre-construction phase involves preliminary planning and budgeting to define the project, identify possible issues, and analyse cost impacts. In contrast, the construction phase specifies the period from the date in an official notice to proceed with the construction project. The post-construction phase consists of contract administrative processes and maintenance of the building process through the active involvement of the commissioning agent (GSA, 2017). Erland Construction (2012) mentioned that the pre-construction phase is a critical component of any successful project. It is the time when the project team thoroughly evaluates all the elements of a project before any activities begin. Gidado (2004) added that good pre-construction planning before implementation is a critical requirement for successful delivery of any project.

Cunningham (2017) stated that cost overruns during the construction phase may seriously over-extend the client finances to the point where the project may not be finished to the expected standards or may have to be abandoned. Poor control of cost and cash flow during the construction phase would directly increase the cost of implementing a project or may lead to project delay that leads to financial penalties (Aljohani *et al.*, 2017).

Cost performance is a fundamental criterion for the success of any project (Memon *et al.*, 2012). In many developing countries, cost overruns are a major problem on construction projects. Much research has been undertaken to improve cost performance. Memon *et al.* (2010), for example, stated that a project's success could be achieved through three key factors, including time, cost, and quality. Amoa-Abban and Allotey (2014) agreed that a building project is considered successful if it is completed within the stated budget on schedule, conforming to user expectations, meeting specifications, and achieving quality of workmanship with minimized construction aggravation. Cunningham (2013) mentioned that a good design provides value in terms of total cost and cost in use.

In Thailand, construction project performance is a crucial issue that has been mentioned in many researches as it affects cost. Meeampol and Ogunlana (2006), for example, investigated the cost and time performance of highway projects from the viewpoint of the public owner using discriminant analysis, and found that success in cost performance depends on the management of construction resources, budget management, construction method, and communication. Toor and Ogunlana (2008), on the other hand, studied problems causing delays in major construction projects in Thailand, and concluded that factors relating to designers, contractors, and consultants are top problem areas. Issues such as lack of resources, poor contractor management, shortage of labour, design delays, planning and scheduling deficiencies, changed orders, and contractors' financial difficulties were highlighted in the Toor and Ogunlana's study results. Ayudhya (2011) examined disputes in public work projects that cause cost overruns, and concluded that violating the conditions of the contract, insufficient work drawing details, delays in the progress payments by the owner, poor evaluation of completed works, inaccurate bill of quantities and unrealistic contract durations are critical dispute problems during the project construction phase. Thirapatsakun (2016) identified different points to increase construction productivity through owner, consultant, contractor, subcontractor and suppliers, and suggested continuous improvement by the owner implementation aspect, employees' implementation aspect, and social and occupational safety and health implementation aspects.

To improve cost performance in Thai construction projects, however, it is necessary to understand the key factors affecting the cost performance and their interrelationships, specifically at the pre-construction and construction phases. This study identifies the factors affecting cost performance at the pre-construction and construction phases using exploratory factor analysis (EFA). The study also examines the relationships among key factors affecting cost performance, utilising structural equation modelling (SEM). This study's results can assist a construction company to better plan for cost improvement.

LITERATURE REVIEW

Construction Cost at Pre-Construction and Construction Phases

Cost overrun mainly occurs at pre-construction and construction phases. Kolltveit and Gronhaug (2004) showed the importance of the early project phases, specifically the uncertainty and influence of the project stakeholders, as this may dramatically influence project performance. Alshanbari (2010) examined the percentage of budget spending on pre-construction planning and concluded that the optimum percentage to be spent on pre-construction planning was about 12% of the total project cost. Understanding how pre-construction planning affects the project savings and duration can encourage many construction firms to adopt this and push the industry even further to achieve better results.

Cunningham (2017), on the other hand, mentioned that cost overrun in building construction, mainly occur during construction phase, is around 4.8% above the contract sum. Schedule delay is a main cause of cost overrun in construction projects. Automated look ahead scheduling during the late construction phase is a useful tool that managers use to improve the flow of work and to reduce potential rework, thus improving budget control and meeting of projected timelines (Keim, 2017). Deshmukh and Menkudle (2018) added that during the construction phase, it is the prime responsibility of the project managers to monitor cost and time and avoid both time and cost overruns. Jongo *et al.* (2019) stated that majority of project delays occur during the construction phase, where many unforeseen factors are always involved, such as poor communication between management and workers, unrealistic contract duration, poor cost control, delay of material and equipment delivery, delay of material approval by consultant, unskilled workforce, poor site management, and design errors. This study focuses on the pre-construction and construction phases, as planning during these phases have a significant effect on the total cost of construction.

Factors Affecting Cost Performances

A number of literatures identify key factors affecting cost performance in Thai construction industry. Roachanakanan (2003) for example, examined cost overruns in Thai condominium projects, and stated that the use of good project cost control procedures has become a concern of project investors and construction companies in Thailand since the recession of the late 1990s. Toor and Ogunlana (2007) on the other hand, stated that relationships among critical success factors, including comprehension, competence, commitment, and communication are crucial in successfully planning for cost implementation in Thai construction projects. Memom *et al.* (2010) commented that lack of ability to prevent cost overruns or to control construction costs causes many Thai construction companies to fail.

Extensive review of literature from over 30 sources relating to construction cost, especially those in Thai construction industry, has been made to extract items affecting construction cost at pre-construction and construction phases. A total of 13 pre-construction cost-related items are extracted, while 19 cost-related items in construction phase are extracted from the literature. Frequency analysis is then performed to eliminate some items that are less cited in literature. With 95% confidential level, eight and 14 items associated with cost performance in pre-construction and construction phases are used in the questionnaire survey development, respectively (see Table 1) (Poojantr & Chinda, 2016). Zaitoun (1990) for example, stated that poor communication between the designer and customer leads to design errors. Yaser (1997) mentioned that incorrect planning or an inappropriate project schedule is ranked the second factor affecting the construction cost. This is due to a lack of experience, bad communication, lack of supervision, and unclear scope of work. Poor site management causes poor follow-up of progress, incorrect distribution of work, non-commitment of site employees, and poor monitoring of the project (Enshassi *et al*., 2013). Porntepkasemsant and Charoenpornpattana (2015) concluded that insufficiently skilled labour results in low productivity. Saeed (2018) concluded that the most important factors leading to time delays and cost overruns are poor contract management, finance and payment problems, shortages of materials and changes in site conditions. In Table 1 and 2, brief descriptions of each factor or item are provided. The items are used to develop a questionnaire survey for the pilot test.

Table 1: Items affecting construction cost performance – pre-construction phase

Item		Description	Abbreviation	Reference
PRE-CONSTRUCTION PHASE				
1	Lack of communication between designer and customer	Poor communication between designer and customer can lead to design errors.	CDC	Enshassi et al. (2009), Memon et al. (2010), Durdyev et al. (2012), Polat et al. (2014), Franz et al. (2017)
2	Changes in customer requirements apart from bidding conditions	Changes in design that do not comply with bidding conditions is may cause higher construction cost.	CCR	Murray and Seif (2013), Gunduz *et al.* (2013), Robinson *et al.* (2015), Okada *et al.* (2017)
3	Lack of accuracy of cost data	An accurate project cost estimate can provide a good basis for project control during construction. Cost estimates based on updated price information should be considered to come up with a reasonable offer, and avoid any wrong estimation.	LCD	Durdyev *et al.* (2012), Polat *et al*. (2014)
4	Design errors	Design error is the deviation from plan and specification. It influences a cost performance, as more time and cost are spent to revise the design.	DSE	Polat *et al.* (2014), Robinson *et al.* (2015)
5	Changes in bidding conditions	Any changes in bidding condition cause time and cost errors	CBC	Memon *et al.* (2010), Okada *et al*. (2017)
6	Breach of local regulations	Breaches of local regulation can severely cause time and cost overrun. Coordination is needed in order to better understand local work culture and ethics.	BLR	Polat *et al.* (2014)
7	Unclear project specifications	Specifications should cover all items and work that a contractor will encounter. Having clear information during the estimating phase is very important for all parties involved	UPS	Polat *et al.* (2014), Musyoka *et al.* (2018)
8	Social impact in pre-construction phase	Methods used in the construction should be clearly explained to local community. Environmental issues, such as air pollution, noise, and water contamination should be clearly expressed to avoid protests and construction delay.	SIP	Memon *et al.* (2010), Polat ***et al.*** (2014), Hassan (2018)

Table 2: Items affecting construction cost performance – construction phase

	Item	Description	Abbreviation	Reference
CONSTRUCTION PHASE				
1	Lack of financial flow	Contractors' financial problem is a top factor causing low labour productivity. Lack of financial liquidity leads to several problems, such as delay in sub-contractors and workers payment, availability of materials at project site, and suppliers' creditability.	LFF	Murray and Seif (2013), Gunduz *et al.* (2013)
2	Inappropriate project schedule	Contractors must plan all activities and resources to ensure appropriate project time and expenditure.	IPS	Memon *et al.* (2010), Durdyev *et al.* (2012), Murray and Seif, (2013), Polat *et al.* (2014), Saeed (2018)
3	Poor site management	Poor site management causes poor follow-up of progress, incorrect distribution of work, non-commitment of site employees, and poor monitoring of project.	PSM	Memon *et al.* (2010), Durdyev *et al.* (2012)
4	Changes in scope of work	Any modification in the scope of work during the construction affects the amount and types of required materials and labour, resulting in cost overrun.	CSW	Memon *et al.* (2010), Durdyev et al. (2012), Musyoka *et al.* (2018)
5	Lack of experienced workers	Experienced workers with required skills are needed, as inexperienced workers need more time and cost to train.	LWE	Durdyev *et al.* (2012), Murray and Seif (2013), Gunduz *et al.* (2013), Ahmed et al. (2017)
6	Shortage of materials	The required resources of a project are considered as a backbone of a construction project. The unavailability of these resources may lead to project delay.	SOM	Memon *et al.* (2010), Murray and Seif (2013), Saeed (2018), Subramani and Sivakumar (2018)
7	Shortage of workers	Shortage of workers cause work pressure and project delay.	SOW	Memon *et al.* (2010)
8	Shortage of equipment	Necessary equipment must be supplied on site to avoid delay.	SOE	Memon *et al.* (2010), Subramani and Sivakumar (2018)
9	Lack of communication between the stakeholders	The efficiency and effectiveness of the construction process strongly depend on quality of communication between stakeholders, including contractors and subcontractors. Failure to communicate effectively leads to conflict.	LOC	Memon *et al.* (2010), Murray and Seif (2013), Gunduz *et al.* (2013)
10	Unforeseen site conditions	Productivity and efficiency of a construction project are affected by environmental situation e.g. weather condition and disaster.	USC	Memon *et al.* (2010), Polat *et al.* (2014)
11	Lack of teamwork	Poor teamwork may lead to poor work quality.	LWC	Gunduz *et al.* (2013), Franz *et al.* (2017)
12	Lack of skilled workers	Skilled workers are those who have professional training, have at least two-year working experience, and have knowledge about construction materials, equipment, and safety. Insufficient skilled workers result in low productivity. New construction workers should receive specific training to improve performance and knowledge of construction work.	LWS	Durdyev *et al.* (2012), Ahmed *et al.* (2017)
13	Social impact in construction phase	The social impacts during construction period, most of which are negative, are reflected in the aspects of land acquisition, resettlement, and interruptions to residents' daily transportation and travel.	SIC	NMRDIEP (2016), Hassan (2018)
14	Breach of contract	Job abandon severely affects cost of a construction project	BOC	Enshassi et al. (2009), Kristjanson and Mayovsky (2015)

RESEARCH APPROACH

A review of related literature is conducted in this study to gain basic knowledge of construction phases and construction cost, and extract items affecting construction cost at pre-construction and construction phases to be used for questionnaire survey development. A pilot test is performed to increase the confidence in the questionnaire survey. The collected data are screened using statistical analyses to increase the confidence in the data. The screened data is then analysed using EFA to group the items affecting construction cost into key factors. SEM is conducted to examine the causal relationships among those key factors that affect the construction cost in the pre-construction and construction phases.

Questionnaire Survey

A questionnaire survey method is used in this study for data collection. This data collection method creates less sampling bias and provides sufficient time for answering the survey (McBurney, 1994). In this study, the questionnaire consists of two parts. Part 1 includes demographic information of the respondents. Part 2 asks the opinions on eight and 14 items affecting cost performance at the pre-construction and construction phases, respectively. It uses a 5-point Likert scale, where 1 = strongly not agree, 2 = not agree, 3 = neutral, 4 = agree, and 5 = strongly agree. Sample statements within the questionnaire include “unclear project specifications lead to higher cost for a construction project”, “design errors lead to higher cost for a construction project”, “shortage of workers leads to higher cost for a construction project”, and “inappropriate project schedule leads to higher cost for a construction project”.

Sampling Strategy and Questionnaire Survey

The target industry for this study is medium- and large- sized residential and building construction companies in Bangkok, Thailand. According to Chinda (2014), a medium-sized company consists of 50-200 workers, while a large-sized company has more than 200 workers. Based on the Department of Industrial Works (2020) and Fresh Property (2020), lists of 50 medium- and large-sized building construction companies and 10 largest property developers are randomly selected for data collection. The targeted respondents are management and senior operating positions to gain mixed perceptions of current practices in the companies. To avoid bias in the data collected, a maximum of 10 surveys were used for each company. Mail survey is chosen in this study because it is convenient, low cost, less bias, and can cover large geographical areas. It may, however, have low response rate and misinterpretations of the questions (Pollock, 2004). No online survey is used to avoid survey fraud and possible cooperation problems (Howard, 2016).

Pilot Test

The extracted items affecting construction cost are used for questionnaire survey development. The survey is performed with a pilot test to check the validity of the questions. A total of 16 project managers and senior engineers who have experience in construction projects in Bangkok, Thailand, examined and answered the questionnaire survey. They have more than 10 years working experience, both in the construction industry and in their current organization. Engaged respondents were mainly involved in building construction projects.

The pilot test results show that the “changes in customer requirements apart from bidding conditions”, “lack of accuracy of cost data”, and “changes in bidding conditions” are the top three items in the pre-construction phase, while the “shortage of materials”, “shortage of equipment”, and “changes in scope of work” are important items in the construction phase. Respondents also suggested four additional items. Three of them are in the pre-construction phase as described on Table 3, which are: inappropriate time spent in the design phase, no technology integration, and need for specific materials. An additional item in the construction phase is poor safety management (see Table 3). This led to a final questionnaire survey with a total of 26 items, including 11 items in the pre-construction phase and 15 items in the construction phase.

Table 3: Additional items affecting construction cost performance achieved from the pilot test

No.	Item	Description	Abbreviation	Reference
PRE-CONSTRUCTION PHASE				
1	Inappropriate time spent in the design phase	Realistic time spent in design phase should be considered to avoid delays.	ITS	Pilot test
2	No technology integration	New construction technology and equipment should be used to reduce rework and maintain work standard.	NTI	Pilot test
3	Need for specific materials	Some work may require specific materials. They may result in delay and extra costs.	NSM	Pilot test
CONSTRUCTION PHASE				
1	Poor safety management	Good safety management is necessary to ensure safety on sites.	PSF	Pilot test

Data Collection

A total of 1,040 survey sets were distributed to construction companies, both through mails and in person, with 221 sets returned, representing a 21.25% response rate. With the initial 221 sets, 21 sets were removed to avoid bias in the survey responses. They were randomly removed from companies with more than 10 received responses. This led to 200 surveys used for the analyses. According to the University of Texas at Austin (2015), a minimum of 130 survey sets is needed, based on 26 items, with a minimum of five survey sets per item. The 200 usable sets are thus considered adequate for the analyses. The results show that half of the respondents are in management positions, with more than 10 years of working experience in the construction industry. Most of them have responsibilities in pre-construction and construction phases, such as determining the scope of work, setting up the project team, and controlling the budget spend. These evidence the appropriateness of the respondents to provide information for the analyses.

Exploratory Factor Analysis EFA

EFA is a variable reduction technique that identifies a number of latent constructs, and underlines factor structure of a set of variables (Suhr, 1999). Seo *et al.* (2004) mentioned that EFA is a precursor to SEM. It is widely used in research studies in various areas, such as supply chain (Lockamy and McCormack, 2004), education (Yu and Richardson, 2015), hospital (Amerioun *et al.*, 2018), and construction industry (Chan, 2012; Soewin and Chinda, 2018); Jadidoleslami *et al.*, 2018).

As there are many items affecting construction cost, the EFA method is used in this study to identify the common factors that explain the order and structure among items affecting construction cost in pre-construction and construction phases, making it easy to understand key cost factors, and plan for cost improvement in Thai construction industry. There are three main steps in performing EFA: 1) assessment of the suitability of the data; 2) factor extraction; and 3) factor rotation (Pallant, 2005). The sample size is commonly used to determine whether a particular dataset is suitable for factor analysis. Pallant (2005) recommended that five cases for each item are adequate in most cases. Coakes and Steed (2003), in contrast, mentioned that a sample size of 100 cases is acceptable. In this study, there are a total of 26 items affecting construction cost performance, leading to a minimum of 130 sets to be analysed (Pallant, 2005). With the 200 returned data set, EFA was considered appropriate. Factor extraction involves determining the smallest number of factors that can be used to best represent the interrelations among a set of variables (Tabachnick & Fidell, 2007). This study utilises the principal component analysis method, which is one of the most commonly used techniques in factor extraction, as it reduces the number of variables while retaining as much of the original variance as possible (Coakes & Steed, 2003). It will be performed with 11 items in pre-construction phase and 16 items in construction phase to group the items into a number of key factors influencing construction cost performance. Factor rotation is normally used to present a pattern of loadings in a manner that is easy to interpret. The most commonly used is the Varimax rotation method, as it maximizes the variance of factor loadings by making high loadings higher, and low loadings lower for each factor (Coakes & Steed, 2003; Tabachnick & Fidell, 2007). Apart from these considerations, a cut-off factor loading of 0.4 is used to screen out the items that were weak indicators of the constructs (Hair et al., 1998)

Structural Equation Modelling (SEM)

A number of research methods can be applied to examine factors and interrelationships among them. SEM technique is a combination of factor analysis, multivariate regression analysis, and path analysis, that can simultaneously estimate causal interrelationships among independent and dependent variables and is confirmed to be more helpful than multivariate regression methods (Nghia, 2017). In this study, SEM is performed to provide further evidence of validity and investigate the causal relationships among key factors affecting construction cost. It comprises two tests: the measurement and the structural models. The measurement model specifies the posited relations of the observed variables to the underlying factors, while the structural model examines the direction of the assumed relationships among those factors. It is important to confirm the measurement model before the structural model can be conducted. The results of SEM helped clarify the causal relationships, as well as the degrees of influence of the key factors (Chinda & Mohamed, 2008).

SEM analysis is widely used in construction-related literature to examine interrelationships among, for example, key profit factors of residential projects (Nghia and Chinda, 2018), factors affecting low back pain due to whole body vibration exposure in heavy equipment operators (Vitharana and Chinda, 2019), and project cost and its influential factor (Zhao *et al.*, 2019. SEM is utilised in this study to examine causal relationships among key factors affecting construction cost in pre-construction and construction phases. It comprises of two types of models: measurement and structural models. Measurement is concerned with how well the observed variables measure the latent factors, addressing their reliability and validity. Structural model is, on the other hand, concerned with modelling the relationships between the latent factors, by describing the amount of explained and unexplained variance, which is akin to the system of simultaneous regression models (Wong & Cheung, 2005).

Three fit indices are used to assure the model fit, both measurement and structural models: Chi-square test (CMIN/DF), Root mean square error of approximation (RMSEA), and Comparative fit index (CFI) in line with Kohn *et al.* (2011). Based on Kline (2005), a CMIN/DF of ≤ 2 is considered acceptable. An RMSEA of ≤ 0.08 is considered acceptable, with a value of ≤ 0.05 considered as the best fit (Tabachnick & Fidell, 2007). Based on Tabachnick and Fidell (2007), a CFI value of ≥ 0.8 is considered acceptable. To adjust the model to improve the model fit, a modification index (MI) is used. Path coefficients with high MI values should be added to improve the model fit. Paths with low coefficients of less than 0.1, on the other hand, should be removed from the model, as it is considered insignificant (Hox & Bechger, 1998).

In this study, measurement model is performed with the key construction cost factors extracted from the EFA to confirm the correlation among them. It is first hypothesized that all factors are correlated with each other. The model is analysed, and correlations with low correlation coefficients are removed. The confirmed correlations are further performed with the structural model to examine directions of relationships among key factors affecting construction cost performance. Hypothesised directions of relationships are achieved from literature review and are confirmed through the structural model analysis. The model fit indices are calculated and are used to accept the final model of construction cost performance.

RESULTS AND DISCUSSIONS

EFA Results

The 200 screened surveys are performed with the EFA method to extract key factors affecting cost performance at pre-construction and construction phases. The principal component analysis method with varimax rotation are used as the extraction methods. The analysis is separated into two parts: EFA of the 11 items in the pre-construction phase and EFA of 15 items in the construction phase. The details are explained in the next section.

EFA results of 11 items at pre-construction phase

The 11 items in the pre-construction phase are analysed with the principal component analysis method, together with varimax rotation and factor loading of 0.4 (Park *et al.*, 2002; Wood & McCarthy, 1984). The results extract the 11 items into three key factors (see Table 4). Factor 1 consists of four items related to the coordination between the parties and is called the Lack of Coordination factor. Factor 2 consists of three items related to customer requirements and is called the Unclear Client Requirements factor. Factor 3 consists of four items related to the design and is called the Design Management factor. These are consistent with Rezaei and Jalal (2018), for example, that lack of coordination between design team and customer leads to delay and cost overrun in the construction industry. They also mentioned that design errors and discrepancies in contract documents may cause delay and cost overrun. According to

Charles *et al.* (2015), client requirements that are not clearly captured and stated in the specifications may cause additional cost.

Table 4: EFA results in pre-construction phase

No	Item	Abbreviation	Factors Extracted		
			Lack of coordination	Unclear client requirements	Design management
1	Breach of local regulations	BLR	0.80		
2	Lack of communication between designer and customer	CDC	0.55		
3	Changes in bidding conditions	CBC	0.54		
4	Social impact in pre-construction phase	SIP	0.47		
5	Changes in customer requirements apart from bidding conditions	CCR		0.73	
6	Unclear project specifications	UPS		0.68	
7	Need for specific materials	NSM		0.45	
8	Design errors	DSE			0.68
9	No technology integration	NTI			0.62
10	Lack of accuracy of cost data	LCD			0.54
11	Inappropriate time spent in the design phase	ITS			0.52

EFA results of 15 items at construction phase

The 15 items in the construction phase are also analysed with the principal component analysis method, varimax rotation, and factor loading of 0.4. The first run results in eliminating the "unforeseen site conditions", "shortage of equipment", and "lack of financial flow" items, as they have low factor loadings of 0.25, 0.32 and 0.30 respectively.

The results of the second run extract the 12 remaining items into four factors (see Table 5). Factor 1 consists of four items related to the site management and is called the Site Management factor. Factor 2 is called the Resources factor, as it consists of three resource items. Factor 3 consists of three items related to the workers and is called the Labour Capability factor. The last factor, Factor 4, consists of three items related to the contract details, and is called the Contract Related factor.

The extracted factors are confirmed by, for example, Long *et al.* (2008) that poor of site management contributes to problems of cost overrun in construction projects. Ali and Kamaruzzaman (2010) mentioned that resources, in terms of materials, equipment, and labours must be considered in cost performance of building construction projects. They also stated that poor contract management leads to higher cost in building construction projects. Nicolaou (1989) mentioned capability as one of key criteria in construction performance. The construction company should have capable and competent labour to effectively manage the projects.

Table 5: EFA results at construction phase

No	Item	Abbreviation	Factors Extracted			
			Site management	Resources	Labour capability	Contract related
1	Social impact in construction phase	SIC	0.46			
2	Poor site management	PSM	0.71			
3	Lack of communication between the parties	LOC	0.67			
4	Poor safety management	PSF	0.65			
5	Shortage of materials	SOM		0.80		
6	Shortage of workers	SOW		0.77		
7	Lack of worker skills	LWS			0.78	
8	Lack of worker cooperation	LWC			0.73	
9	Lack of worker experience	LWE			0.66	
10	Changes in scope of work	CSW				0.77
11	Breach of contract	BOC				0.64
12	Inappropriate project schedule	IPS				0.59

In summary, a total of seven factors, three in the pre-construction phase and five in the construction phase, are extracted from the EFA. These seven factors are next analysed with SEM to examine their interrelationships.

SEM Results

The seven key factors affecting cost performance in a construction project are further performed with SEM to examine interrelationships among those key factors, both in pre-construction and construction phases. The measurement model is first performed to confirm the correlations between the key factors. The structural model is then used to confirm directions of the relationships among the key factors affecting construction cost performance.

Measurement model results

A total of seven key factors form the baseline model (see Figure 1). The model is run, and the results suggest an adjustment, as fit indices are not in the acceptable ranges (see Table 6). The MI values, shown in the model output, suggest the addition of two correlations, between the "social impact in the pre-construction" item and the "social impact in construction" item, and between the "poor site management" item and the "changes in scope of work" item. This is confirmed by, for example, Enshassi *et al.* (2013) that poor site management has an influence on the scope of work, leading to higher cost.

After the modifications, the model is run, and the best-fit measurement model is achieved, with all fit indices in the acceptable ranges (see Tables 6).

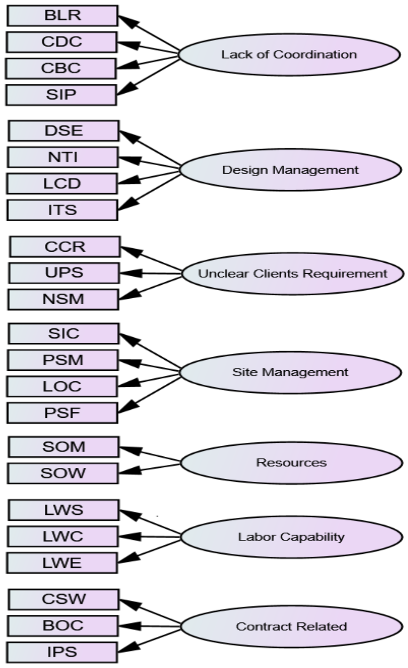

Figure 1: Baseline model of factors affecting construction cost performance

Table 6: Fit indices values of the measurement model

Fit Index	Acceptable Level	Base Run Result	Best-Fit Measurement Model
CMIN/DF	< 2.00	1.70	1.55
CFI	≥ 0.80	0.84	0.85
RMSEA	< 0.08	0.05	0.05

The best-fit measurement model shows correlations among the seven key factors (see Table 7). According to Explorable (2019), the strength of relationship is indicated by the value of correlation coefficient. To explain, correlation coefficient of more than 0.5 explains strong correlation, a correlation coefficient between 0.3 and 0.5 shows a moderate correlation, and a correlation coefficient of less than 0.3 shows a weak correlation. In this study, only medium and strong relationships are considered in the best fit measurement model, resulting in 18 strong and medium relationships among the seven key factors affecting construction cost performance.

In the pre-construction phase, strong correlations are found among the three key cost performance factors, with the correlation coefficients of 0.69, 0.64 and 0.62 respectively. The strong relationship between the Lack of Coordination and Design Management factors is confirmed by, for example, Love *et al*. (2013) that lack of communication between the designer and the client (an item in the Lack of Coordination factor) leads to design errors (an item in the Design Management factor). Lack of coordination between stakeholders may cause several changes in bidding conditions and customer requirements (items in the Lack of Coordination factor), resulting in no accuracy in cost data and pressure for design team (items in the Design factor) (Okada *et al*., 2017; Polat *et al*., 2014; Robinson *et al*., 2015). No coordination between designer team and client (an item in the Lack of Coordination factor) may also lead to unclear specification (an item in the Unclear Client Requirement factor), resulting in design changes and inappropriate time spent in the design phase (items in the Design Management factor) (Polat *et al.*, 2014; Robinson *et al.*, 2015).

In construction phase, the Site Management factor is found having strong correlations with the Contract Related, Resources, and Labour Capability factors, with the correlation coefficients of 0.63, 0.59 and 0.51, respectively. Inappropriate project schedule (an item in the Contract Related factor) causes work pressure, stress, and less focus on safety (items in the Labour Capability and Site Management factors, respectively); these may lead to high accident rates. Changes in scope of work during the construction (an item in the Contract Related factor) affect the amount and types of required materials and labour, and may lead to materials unavailability, shortage of skilled workers, and eventually poor site management (items in the Resources, Labour Capability, and Site Management factors, respectively) (Durdyev *et al.*, 2012; Memon *et al.*, 2010; Musyoka *et al.*, 2018).

Table 7: Correlation coefficients of the best-fit measurement model

Factor	Correlation Coefficient	Level of Relationship
PRE-CONSTRUCTION PHASE		
Lack of Coordination ⟷ Design Management	0.69	Strong
Lack of Coordination ⟷ Unclear Client Requirements	0.64	Strong
Design Management ⟷ Unclear Client Requirements	0.62	Strong
CONSTRUCTION PHASE		
Site Management ⟷ Contract Related	0.63	Strong
Site Management ⟷ Resources	0.59	Strong
Site Management ⟷ Labour Capability	0.51	Strong
Resources ⟷ Labour Capability	0.48	Moderate
Labour Capability ⟷ Contract Related	0.33	Moderate
Resources ⟷ Contract Related	0.25	Weak
PRE-CONSTRUCTION AND CONSTRUCTION PHASES		
Lack of Coordination ⟷ Site Management	0.48	Moderate
Unclear Client Requirements ⟷ Site Management	0.47	Moderate
Design Management ⟷ Labour Capability	0.46	Moderate
Lack of Coordination ⟷ Contract Related	0.42	Moderate
Design Management ⟷ Contract Related	0.41	Moderate
Unclear Client Requirements ⟷ Resources	0.38	Moderate
Lack of Coordination ⟷ Labour Capability	0.38	Moderate
Design Management ⟷ Site Management	0.36	Moderate
Design Management ⟷ Resources	0.30	Moderate
Unclear Client Requirements ⟷ Contract Related	0.30	Moderate
Lack of Coordination ⟷ Resources	0.27	Weak
Unclear Client Requirements ⟷ Labour Capability	0.21	Weak

Moderate correlations are also found among factors at the pre-construction and construction phases. Kreitler (2011) for example, mentioned that lack of communication in the pre-construction phase (an item in the Lack of Coordination factor) leads to poor site management in the construction phase (an item in the Site Management factor). Breach of local regulations (an item in the Lack of Coordination factor) may lead to protests from local community due to, for example, interruption to residents' daily transportation and travel and air and noise pollution (items in the Site Management factor), thus causing work delay (Hassan, 2018). Polat *et al*. (2014) mentioned that accurate project cost estimate in the pre-construction phase can provide a good basis for project control during construction. No accuracy of cost data (an item in the Design Management factor) may severely lead to work abandon (an item in the Contract Related factor).

To further explore the directions of relationships among the key factors affecting cost performance in the pre-construction and construction phases, the structural model is used.

Structural model results

The 18 strong and medium relationships among the seven key factors affecting construction cost performance are further explored with the structural model, to examine the directions of relationships. The hypothesised directions are supported by a number of construction-related papers, as the followings (see Figure 2).

- H1: Lack of Coordination → Design Management: Changes in bidding conditions may result in pressure for design team, and may lead to design errors (Okada *et al*., 2017; Polat *et al*., 2014; Robinson *et al*., 2015).
- H2: Design Management → Unclear Client Requirements: The use of business information technology, such as virtual reality, intelligent agents, multi-media, and video conferencing within the construction industry will improve co-ordination, visualization and construction supply chain management. This in turn should result in clear specification, increased client involvement, and improved client satisfaction (Khalfan & Raja, 2016).
- H3: Lack of Coordination → Unclear Client Requirements: Al-Qershi and Kishore (2018) stated that many contract claims and disputes arise from lack of coordination and good communication between the owner and the contractor or between the contractor and the consultant, subcontractors, and suppliers during the time of bidding and during the execution of the project.
- H4: Lack of Coordination → Site Management: No coordination and cooperation from stakeholders and local community may cause impacts during construction period (Hassan, 2018).
- H5: Lack of Coordination → Labor Capability: Changes in bidding conditions may affect skilled and experienced workers required in the construction (Ahmed *et al*., 2017; Okada *et al*., 2017).
- H6: Lack of Coordination → Contract Related: Changes in bidding conditions interrupt project schedule and may seriously lead to project abandon (Memon *et al*., 2010; Okada *et al*., 2017).
- H7: Design Management → Site Management: Mryyian and Tzortzopoulos (2013) stated that design errors cause poor site management, especially in terms of waste management.
- H8: Design Management → Resources: Design errors may cause poor material selection (Mryyian & Tzortzopoulos, 2013).
- H9: Design Management → Labor Capability: Lack of accurate cost data may lead to shortages of skilled workers (Durdyev *et al*., 2012; Polat *et al*., 2014).

- H10: Design Management → Contract Related: Design errors interrupt project schedule and may lead to job abandon (Abdul-Rahman *et al.*, 2015; Kristjanson & Mayovsky, 2015).
- H11: Unclear Client Requirements → Site Management: Doloi (2013) mentioned that unclear client requirements may lead to poor site management.
- H12: Unclear Client Requirements → Resources: Need for specific materials from clients may cause late delivery of materials and equipment (Doloi, 2013).
- H13: Unclear Client Requirements → Contract Related: Unclear project specification causes changes in scope of work, and may delay the construction (Musyoka *et al*., 2018).
- H14: Resources → Site Management: Lack of safety equipment may cause site accidents (Ali *et al*., 2010).
- H15: Resources → Labor Capability: According to Memon *et al*. (2010), work pressure increases when workers are inadequate.
- H16: Labor Capability → Contract Related: Poor teamwork and lack of skilled workers could severely delay the project time (Nejati *et al*., 2010).
- H17: Labor Capability → Site Management: Poor teamwork causes poor site management (Memon *et al*., 2010; Durdyev *et al*., 2012).
- H18: Site Management → Contract Related: Conflicts with local community can interrupt project schedule (Hassan, 2018).

The model is run, and the fit indices are as shown in Table 8.

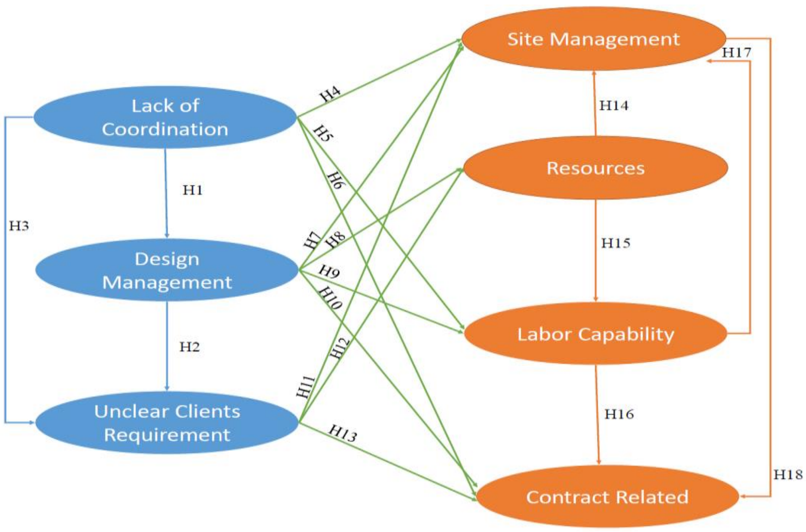

Figure 2 Hypothesised directions of relationships among the seven key factors affecting construction cost

The analysis results suggest the elimination of eight hypotheses due to low path coefficients (i.e., less than 0.1) (Wong, 2013), as follows.

H3: Lack of Coordination → Unclear Client Requirements
H4: Lack of Coordination → Site Management
H5: Lack of Coordination → Labor Capability
H7: Design Management → Site Management
H8: Design Management → Resources

H10: Design Management → Contract Related
H13: Unclear Client Requirements → Contract Related
H16: Labour Capability → Contract Related

After the adjustment, the model is re-analysed, and the best fit structural model, or final model of factors affecting construction cost, is achieved, as shown in Table 8 and Figure 3.

Table 8: Fit indices values of the structural model

Fit Index	Acceptable Level	Base Run Result	Best-Fit Structural Model
CMIN/DF	< 2.00	1.55	1.41
CFI	≥ 0.80	0.85	0.88
RMSEA	< 0.08	0.05	0.04

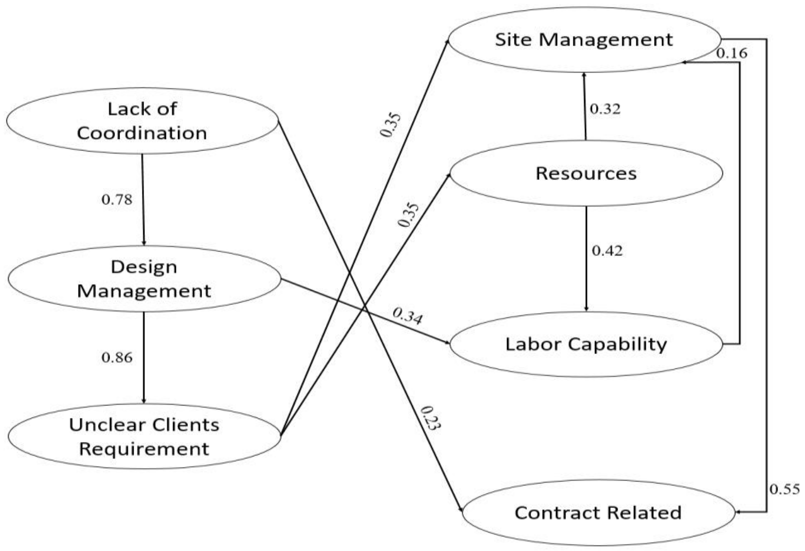

Figure 3 Final model of factors affecting construction cost

The final model of factors affecting construction cost confirms 10 hypothesised directions, as shown in Table 9.

The results show that, in the pre-construction phase, the Lack of Coordination factor strongly influences the Design Management factor, with a path coefficient of 0.74. There is no direct, but an indirect effect on the Unclear Client Requirements factor through the implementation of the Design Management factor. Love *et al.* (2013) said that a lack of communication leads to design errors. This results in unclear work specifications.

Three factors in the pre-construction phase also have influences on the four factors in the construction phase, with path coefficients ranging from 0.23 - 0.35. For example, unclear project specifications (an item in the Unclear Client Requirements factor) result in poor site and safety management (Durdyev *et al.*, 2012).

Table 9: Path coefficients of the best-fit structural model

Hypothesis	Path Coefficient	Hypothesis Testing Result	Degree of Relationship
H1	0.74	Support	Strong
H2	0.86	Support	Strong
H3	0.09	Not support	-
H4	0.09	Not support	-
H5	0.08	Not support	-
H6	0.23	Support	Weak
H7	0.08	Not support	-
H8	0.09	Not support	-
H9	0.34	Support	Moderate
H10	0.09	Not support	-
H11	0.35	Support	Moderate
H12	0.35	Support	Moderate
H13	0.06	Not support	-
H14	0.32	Support	Moderate
H15	0.42	Support	Moderate
H16	0.09	Not support	-
H17	0.16	Support	Weak
H18	0.55	Support	Strong

In the construction phase, strong paths are found between the Site Management and Contract Related factors, and the Resources and Labour Capability factors, with path coefficients of 0.55 and 0.42, respectively. The Resources factor indirectly affects the Contract Related factor through the Site Management factor. For example, a shortage of necessary equipment may interrupt construction, leading to poor site management and project schedule delay (Memon *et al*., 2010). Direct and indirect influences among the seven key factors are summarized in Table 10.

Table 10: Direct and indirect influences among the seven key factors affecting construction cost

FACTOR	DIRECT AND INDIRECT INFLUENCE
Design Management	0.78 x Lack of Coordination
Unclear Client Requirements	(0.86 x Design Management) + (0.67 x Design Management x Lack of Coordination)
Site Management	(0.35 x Unclear Client Requirements) + (0.32 x Resources) + (0.16 x Labor Capability) + (0.30 x Unclear Client Requirements x Design Management) + (0.23 x Unclear Client Requirements x Design Management x Lack of Coordination) + (0.11 x Resources x Unclear Client Requirements)
Resources	(0.35 x Unclear Client Requirements) + (0.30 x Unclear Client Requirements x Design Management) + (0.23 x Unclear Client Requirements x Design Management x Lack of Coordination)
Labour Capability	(0.42 x Resources) + (0.34 x Design Management) + (0.15 x Resources x Unclear Client Requirements) + (0.12 x Resources x Unclear Client Requirements x Design Management) + (0.27 x Design Management x Lack of Coordination)
Contract Related	(0.55 x Site Management) + (0.23 x Lack of Coordination) + (0.18 x Site Management x Resources) + (0.19 x Site Management x Unclear Client Requirements) + (0.17 x Site Management x Unclear Client Requirements x Design Management) + + (0.13 x Site Management x Unclear Client Requirements x Design Management x Lack of Coordination)

CONCLUSION

The construction industry is a key industry for developing countries, including Thailand. To improve the effectiveness of the industry, cost performance must be considered. This study aimed at examining key factors affecting construction cost at the pre-construction and construction phases utilising the EFA and SEM analyses. The EFA result grouped 11 items at the pre-construction phase into three factors, which are: lack of coordination, design management and unclear client requirements. A total of 14 items in the construction phase are extracted into four factors, namely: site management, resources, labour capability and contract-related. Seven factors are then analysed with SEM to explore their interrelationships. The results show direct and indirect relationships among key factors at pre-construction and construction phases. The analysed result support theories that the lack of coordination factor has direct influence on the design management factor, and an indirect effect on the unclear client requirements factor through the implementation of the design management factor. Throughout the design process, changes are frequently introduced, and are needed to be properly managed among stakeholders to ensure the correctness. Effective communication among stakeholders should be encouraged to enhance construction performance and reduce cost. This is consistent with Meeampol and Ogunlana (2006) that effective communication is a key success factor for Thai construction cost performance. Renault and Agumba (2016) agreed that poor communication among stakeholders results in design errors and changes in customer’s requirement. These, in turn, lead to construction delay and cost overrun. Yap *et al*. (2017) highlighted the importance of effective communication and project learning towards improving the level of competency and cohesiveness of project team in mitigating design changes and managing future projects. These, in turn, reduce changes in customer’s requirement. Stylidis *et al*. (2016) agreed that it is important to set up customer’s requirements and translate these into the technical specifications with the highest level of precision at the early stages, since the changes in the late design phases have extremely high cost. Aljohani *et al*. (2016) stated that contractors often face financing issue during the construction phase, as they normally receive payment after completing part of projects or the whole projects. Contractors, thus, should make sure that they have sufficient funds available to enable them to undertake projects.

The lack of coordination factor also affects the contract related factor at the construction phase. Peansupap and Cheang (2015) identified top priority change issues related to cost conflicts in Thai construction industry, including changes in scheduling made by the owner, project scope change made by the owner, change due to poor and incomplete design, change in design functions required by owner/client, and change in material specifications. Changes in bidding conditions causes changes in scope of work and might eventually lead to job abandon. Owner-requested changes throughout the design and construction process can lead to budget and schedule overruns, as well as increased uncertainty for the project delivery team (Okada *et al*., 2017). Reginato and Alves (2012) suggested the use of lean techniques in the bidding phase to facilitate the screening of subcontractors in hard bid environments and contribute to reducing project risk and uncertainties.

The Design Management factor in the construction phase directly affects the Labour Capability factor in the construction phase. Design errors could lower labour productivity. Naoum (2016) added that factors associated with pre-construction activities, namely the experience of the selected site and project managers, design errors, buildability of the design, project planning, communication, leadership style, and procurement method influence labour productivity.

The Unclear Client Requirements factor in the construction phase directly affects the Site Management and Resources factors in the construction phase, and indirectly affects the Labour Capability factor through the Resources factor. Poor site management, resulting from poor resources management, can severely affect the project completion. This poor site management is affected by the unclear client requirements, design error, and lack of coordination in the pre-construction phases. Doloi (2013) stated that the client's responsibility in facilitating efficient design and effective site management within the project environment is crucial, as it might affect material and worker availability, resulting in schedule delay and cost overrun. Unclear client's requirement could lead to late identification of the type of materials needed, resulting in shortage of specific materials and skilled workers and time and cost overruns in construction projects (Rahman *et al.*, 2017).

Four factors in the construction phase are have direct and indirect relationships among them. Resources factor has direct relationships with the Site Management and Labour Capability factors, and indirectly influences the Contract Related factor through the Site Management factor. Shortages of materials and workers lead to poor site and safety management, resulting in changes in project schedules and scope of work, and eventually breach of contract of Thai construction industry (Toor & Ogunlana, 2008). Mentors should be considered for new employees so experienced and inexperienced people can join the companies and reduce the turnover rate (Kaewsri & Tongthong, 2012). Social impact, especially that relating to environmental issues, must be considered to avoid delay in the construction (Pronsirichotirat *et al*., 2018).

The study results contribute to the construction industry in many ways. Key factors affecting cost performance are extracted in pre-construction and construction phases. This provides a better understanding of factors affecting the construction cost in each phase of construction, so that the construction company can better plan for cost improvement. Relationships among the key factors in the pre-construction phase, construction phase, and between the pre-construction and construction phases, are clarified, thus providing insights into root causes of poor cost performance. It is important that project managers understand the relationships among key factors in the construction projects, so that an effective plan can be made on key influential factors and not on unimportant activities. For example, by focusing on improving communication among the stakeholders through different channels, such as face-to-face, email, and mobile communication, design errors and design changes may be minimized, thus reducing rework, schedule delay, and cost overrun of the construction projects. Cost improvement plan can then be established by focusing on key factors affecting cost in pre-construction phase, as they lead to cost improvement in construction phase.

There are limitations in this study. The data used for the analyses are collected from construction companies in Bangkok, Thailand. The results may be different in different geographical areas and working culture. For example, countries with strong law and regulation might not consider "breach of local regulations" item. The use of high technology equipment in Thailand is low, as labour cost is cheap and skilled workers are limited. Safety and health regulation in Thailand are weak compared with some other countries. This results in high sick and accident leaves and compensation cost, thus affecting the total construction cost. The study also focuses on pre-construction and construction phases. The post-construction phase could be investigated and compared with the study results. Construction companies can use this study's results to better understand the factors affecting cost performance and effectively plan for cost improvement.

ACKNOWLEDGEMENT

The author would like to thank Mr Supparoek Poojantr for his help with the data analysis.

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