Songklanakarin J. Sci. Technol.
44 (2), 408-414, Mar. - Apr. 2022

http://www.sjst.psu.ac.th

Original Article

Examination of interrelationships of key construction performance factors utilizing structural equation modeling

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Received: 24 June 2021; Revised: 15 August 2021; Accepted: 26 September 2021

Abstract

Thai construction industry faces several problems while trying to improve its performance. This study utilizes structural equation modelling to examine inter-relationships among 10 key performance factors, namely 1) time, 2) cost, 3) quality, 4) safety and health, 5) client satisfaction, 6) environment, 7) financial performance, 8) internal stakeholder, 9) external stakeholder, and 10) information, technology, and innovation. The final model confirms strong relationships among the traditional performance indicators: time, cost, and quality. Apart from that, also emerging concepts of performance measurement are assessed, especially in the areas of stakeholders and environmental management. Additional support is needed to improve the environmental standards, so that Thai construction companies can enhance their competitiveness in the global market. New technologies and innovative ideas should be encouraged in the real practices. It is expected that the final model of construction performance assists construction companies to better understand key performance factors, as well as their relationships, and effectively plan for their performance improvement.

Keywords: construction performance, relationships, structural equation modelling, Thai construction industry

1. Introduction

The development of the construction industry leads the development of other industries. In Thailand, the construction industry contributed 6% of the national GDP in 2020 (National Statistical Office, 2016). The industry, however, faces several problems while trying to improve its performance. Koushki, Al-Rashid, and Kartam (2005), for example, mentioned that low quality work causes low performance. Mansfield, Ugwu, and Doran (1994) stated that financial and payment arrangements, poor contract management, and overall price fluctuations are closely associated with low construction performance.

The above studies pinpointed various factors in measuring and improving construction performance. To enhance performance, however, it is necessary to establish a set of indicators that match a company's strategies. The selected criteria may differ from firm to firm, and also by country. However, they should be able to determine the overall success of an organization. Traditionally, the industry evaluates its performance using traditional indicators, including time, cost, and quality. Nevertheless, real practices have deviated from this iron triangle, as many direct and indirect factors may affect construction performance. Toor and Ogulana (2009), for example, proposed six additional key performance indicators, apart from time, cost, and quality, for large-scale construction projects in Thailand. Wang and Yuan (2011), on the other hand, listed seven factors influencing construction performance, such as quality, client satisfaction, and reliability. Soewin and Chinda (2018) examined key performance indicators for Thai construction contractors and listed 10 indicators for enhancing construction performance.

It is necessary to understand the key factors affecting construction performance as well as their interrelationships, so that a construction company can better plan for its performance enhancement. This study, therefore, aimed at utilizing structural equation modelling (SEM) together with 10 factors extracted from Soewin and Chinda (2018) to examine causal relationships among 10 key performance factors. It is expected that the study results

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summarize positive and negative relationships among key performance factors to be used for performance enhancement in the future.

2. Materials and Methods

2.1 Factors and items affecting construction performance

Soewin and Chinda (2018) developed a multi-dimensional performance evaluation framework for effective measurement of the construction performance. It consists of 10 key factors and a total of 57 associated items, as shown in Table 1. They are supported with a number of literature citations. Jiang and Chen (2009), for example, claimed that proper contract periods (an item in the TM factor) are needed to complete construction projects on time. Ngacho and Das (2015), on the other hand, mentioned that it is important for organizations to focus on safety during construction (an item in the SH factor) because if accidents occur, both contractors and clients may be subjected to legal claims (an item in the TM factor), financial loss (an item in the FP factor), and delay in the overall completion time.

The 10 key performance factors form a conceptual model of construction performance (Figure 1) and were used to develop a questionnaire survey. In Figure 1, the oval symbols represent key performance factors (or dependent variables), while the rectangle symbols represent the associated performance items (or independent variables).

Table 1. Construction performance factors with their items

Factor	Associated item	Abbreviation
Time (TM)	Time Taken for Approvals	APD
	Contract Duration	CTD
	Time Taken for Environmental Issues	EVS
	Litigation	LTG
	Procurement Duration	PCD
	Resource Availability On-Time	RAV
Cost (CT)	Accuracy of Estimation	AES
	Cost Pressure	CTP
	Design Change	DSC
	Estimator Bias	ESB
	Payment Term	PAT
	Performance Bond	PFB
Quality (QT)	Cost of Quality	CTQ
	Quality Control	QTI
	Quality Policy	QTP
	Resource Quality	RQT
Safety and Health (SH)	Health & Safety Regulation	HSC
	Safety Awareness	SHA
	Safety Committee Policy	SHC
	Availability of Safety Equipment	SHE
	Safety Manual	SHM
	Site Conditions	STC
Client Satisfaction (CS)	Clear Problem Solutions	CPS
	Client Requirements	CRS
	Periodic Listings of Milestones	PMS
	Prompt Reactions	PTR
	Specifications Fulfillment	SPF
Environment (EV)	Compliance to Environmental Regulations	EVC
	Improving Corporate Environmental Image	EVI
	Natural Resource Usage	NRS
	Pollution Control	POC
	Reduction, Reuse & Recycling	RSC
	Site Waste Management	SWM
Financial Performance (FP)	Contract Realistic	COR
	Financial Indices	FPI
	Financial Strategy	PFT
Internal Stakeholder (IS)	Attitude of Stakeholders	ATT
	Communication between Stakeholders	COM
	Stakeholders' Competence	CPT
	Education & Training	ETG
	Job Assignment	JAS
	Job Security	JSE
	Monitoring	MNT
	Moral	MOR
	Labor Productivity	PDT
	Stress	STS
	Teamwork	TWK

Table 1. Continued.

Factor	Associated item	Abbreviation
Internal Stakeholder (IS)	Work Behavior	WBV
	Work Commitment	WCT
	Working Environment	WEV
External Stakeholder (ES)	External Stakeholders' Satisfaction	ESF
	Nominated Stakeholders' Selection Criterion	NST
	Sub-Contractors' Selection Criterion	SCC
	Suppliers' Selection Criterion	SRC
Information, Technology & Innovation (IT)	Innovation	INN
	Technology Support	TES
	Availability of Timely Data	TMD

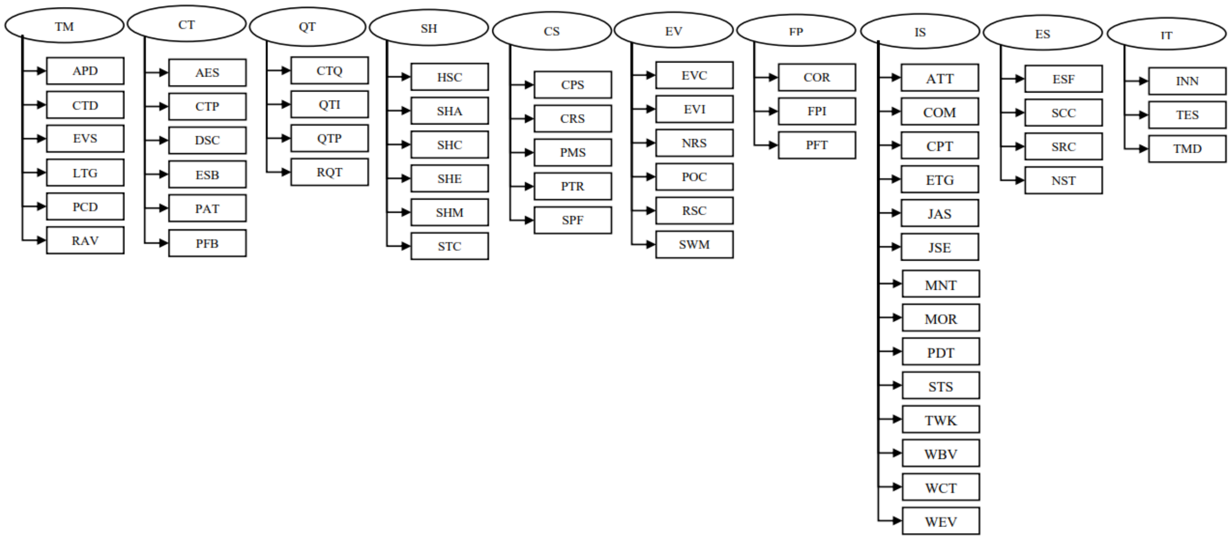

Figure 1. Conceptual model of construction performance

2.2 Questionnaire survey development, data collection, and data screening

2.2.1 Questionnaire survey

A questionnaire survey was used in this study for data collection. The respondents were asked to rate their agreement on 57 statements relating to items affecting construction performance using a 5-point Likert scale, ranging from 1 = strongly disagree to 5 = strongly agree. The target group was medium- and large-sized building construction contractors, located in Bangkok, Thailand, as they contribute about 60% of the total industry's GDP (National Statistical Office, 2016). A list of 150 medium to large construction organizations, with more than 100 staff, was prepared and used as the sampling frame. To capture macro-level perspectives, targeted respondents were those in senior positions, including project engineers, project managers, and executives with experience in various types of decision making, such as budget allocations, policy, and strategy planning.

2.2.2 Data collection

A total of 720 sets of questionnaire were distributed from June, 2016 to September, 2016, with 345 responses returned, representing 47.9% response rate. According to Adams, Khan, Raeside, and White (2007), a minimum of 20% response rate is considered adequate. More than 70% of the respondents were in above-senior positions, with the majority of them having more than 5 years of work experience in the construction industry and in their respective companies. More than half of the respondents were also involved in decision making, for example on safety policies and environmental performance policies. These prove the appropriateness of the respondents in providing information for the analyses.

The majority of the respondents ranked time, cost, and quality factors as the top three factors affecting construction performance. This may be because most of Thai construction performance are still adhering to traditional performance measurement.

2.2.3 Data screening

The total of 345 responses were screened using a number of analyses. Normality test was performed to confirm normally distributed of variables. The results show that all data follow normal distributions, with all the skewness and kurtosis values in acceptable ranges of < ±2 and < ±7, respectively (Hox, Moerbeek, & Van De Schoot, 2017).

Outlier test was conducted to screen out cases with extreme values, or two or more variables that have strange combinations of scores. The results confirmed no outliers in the 345 responses, as the z-scores did not exceed the acceptable level of 3 (Hox *et al*., 2017).

Reliability test was also performed with 10 key performance factors using the Cronbach's alpha coefficient. The results show that alpha values of 10 key factors were above the minimum acceptable level of 0.70, suggesting a satisfactory level of internal consistency reliability (Hox *et al*., 2017).

3. Results and Discussion

There are a number of methods that can be used to examine relationships among the construction performance factors. Mahamid (2019), for example, utilized regression models to describe the relation between rework and labor productivity on construction sites. Lofgren and Eriksson (2021) investigated how collaborative tools affect collaboration, and further collaboration's effects on project performance using hierarchical regression analysis.

In this study, the conceptual model of construction performance is chosen in SEM form to examine relationships and their directions. The AMOS software was utilized in this study, as it has an excellent graphical interface, is well organized, has quickly accessible outputs, and outperforms the other packages (Narayanan, 2012).

There are two models involved in an SEM analysis: measurement and structural models (Mcdonald & Ho, 2002). Measurement model identifies how factors are measured in terms of their associated items, and how they correlate with each other. Structural model, on the other hand, specifies directions of relationships among the factors.

To accept the measurement and structural models, this study utilizes the CMIN/df, RMSEA, and CFI values, as they are common indices in the construction industry studies. The CMIN/df of lower than 2, RMSEA of less than 0.06, and CFI value of at least 0.80 are considered acceptable (Shadfar & Malekmohammadi, 2013).

Model adjustment may be needed if the fit indices of a model are not in acceptable ranges. Modification index (MI) is commonly used to improve the model fit. According to Hox and Bechger (1998), path coefficients with high MI values should be added to improve the model fit. Paths with low coefficients, on the other hand, should be removed from the model.

3.1 Measurement model of construction performance

The conceptual model of construction performance is decided with the measurement model. A total of 45 correlations are hypothesized and examined with the measurement model. The fit indices of the first run results are as shown in Table 2.

The results revealed a need to modify the model to achieve a better fit. To improve the model fit, MI values are considered (Table 3). The suggested correlations are presented by high MI values. As a result, seven correlations were added, including TWK ↔ WCT, COM ↔ TWK, ATT ↔ MOR, JSE ↔ WBV, WBV ↔ WEV, RSC ↔ SWM, and SHM ↔ SHC. Wang and Yuan (2011), for example, concluded that one's moral may influence his/her attitude towards work (ATT ↔ MOR). Choudhry and Fang (2008) commented that work pressure may create unsafe work behavior (WBV ↔ WEV).

After the modifications, the model was re-analyzed, and the best fit measurement model was achieved (Tables 2 and 4). According to Shadfar and Malekmohammadi (2013), path coefficients between two factors of less than 0.3, between 0.31 - 0.7, and more than 0.7 are considered as weak, medium, and strong relationships, respectively.

The best fit measurement model reveals seven strong correlations. The strong correlations between the TM and CT factors, and the CT and QT factors align with the traditional triangle of performance measurement. This may be because Thailand is a developing country, and issues related with time, cost, and quality are still listed in the contracts. Interestingly, strong correlations are also found between the TM and IS factors, and the CS and IS factors, respectively. These show importance of stakeholders in successfully completing the work on time, thus enhancing customer satisfaction.

The IS and CS factors, the EV and FP factors, and the SH and CS factors also have strong correlations. These are confirmed by, for example, in Choudhry and Fang (2008) stating that great teamwork (an item in the IS factor) can allow quickly responding to customer queries, leading to great work performance (an item in the CS factor). The economic benefits (an item in the FP factor) gained from waste minimization and recycling (an item in the EV factor) are enormous (Begum, Siwar, Pereira, & Jaafar, 2006).

Table 3. MI values of the first run measurement model results

Correlation			M.I.
TWK	↔	WCT	45.77
COM	↔	TWK	41.42
ATT	↔	MOR	36.56
JSE	↔	WBV	32.42
WBV	↔	WEV	31.54
RSC	↔	SWM	28.51
SHM	↔	SHC	24.96
CTQ	↔	STS	24.31
POC	↔	COR	21.00
RSC	↔	FPI	20.27

Table 2. Fit indices results

Fit index	Acceptable value	Base measurement	Best-fit measurement	Base structural	Best-fit structural
CMIN/df	≤ 2.00	1.96	1.80	1.80	1.79
RMSEA	≤ 0.06	0.06	0.06	0.06	0.06
CFI	≥ 0.80	0.78	0.82	0.82	0.83

Table 4. Correlation coefficients of the best fit measurement model

Hypothesis	Description			Decision	Correlation coefficient
H1	CS	↔	ES	Medium	0.54
H2	CS	↔	EV	Medium	0.61
H3	CS	↔	FP	Medium	0.68
H4	CS	↔	IS	Strong	0.80
H5	CS	↔	IT	Medium	0.54
H6	CT	↔	CS	Medium	0.69
H7	CT	↔	ES	Medium	0.56
H8	CT	↔	EV	-	-
H9	CT	↔	FP	-	-
H10	CT	↔	IS	Medium	0.65
H11	CT	↔	IT	Medium	0.60
H12	CT	↔	QT	Strong	0.85
H13	CT	↔	SH	Medium	0.69
H14	ES	↔	IT	Medium	0.64
H15	EV	↔	ES	-	-
H16	EV	↔	FP	Strong	0.80
H17	EV	↔	IS	Medium	0.53
H18	EV	↔	IT	-	-
H19	FP	↔	IT	-	-
H20	FP	↔	ES	-	-
H21	FP	↔	IS	-	-
H22	IS	↔	ES	Medium	0.54
H23	IS	↔	IT	Medium	0.64
H24	QT	↔	CS	Medium	0.59
H25	QT	↔	ES	-	-
H26	QT	↔	EV	Medium	0.53
H27	QT	↔	FP	-	-
H28	QT	↔	IS	Medium	0.60
H29	QT	↔	IT	Medium	0.64
H30	QT	↔	SH	Medium	0.64
H31	SH	↔	ES	-	-
H32	SH	↔	FP	-	-
H33	SH	↔	EV	Medium	0.55
H34	SH	↔	IT	Medium	0.57
H35	SH	↔	IS	Medium	0.60
H36	SH	↔	CS	Strong	0.77
H37	TM	↔	CS	Strong	0.71
H38	TM	↔	CT	Strong	0.84
H39	TM	↔	ES	Medium	0.57
H40	TM	↔	EV	-	-
H41	TM	↔	FP	-	-
H42	TM	↔	IS	Strong	0.72
H43	TM	↔	IT	Medium	0.59
H44	TM	↔	QT	Medium	0.56
H45	TM	↔	SH	Medium	0.57

3.2 Structural model of construction performance

The structural model is used to examine the directions of relationships among 10 key performance factors. In the structural model, one-headed arrows replace two-headed arrows, showing directions of relationships. A total of 32 directions were hypothesized (Table 5). For instance, delay causes high overhead costs (TM → CT) (Faridi & El-Sayegh, 2006). Kannan and Tan (2005) mentioned that time pressure forces construction companies to use new technology and innovative ideas (TM → IT).

The structural model was run and the results (Tables 2 and 5) suggested seven hypotheses to be removed due to low path coefficients, namely CT → CS, QT → CS, IS → ES, IS → EV, IS → QT, IS → SH, and ES → CS. After the modification, the best fit structural model, or the final model of construction performance, was achieved.

Table 5. Path coefficients of the final model

Hypothesis	Description			Decision	Path Coefficient
H1	TM	↔	CT	Strong	0.91
H2	TM	↔	SH	Weak	-0.24
H3	TM	↔	CS	Weak	0.17
H4	TM	↔	ES	Medium	0.30
H5	TM	↔	IT	Medium	0.58
H6	CT	↔	QT	Strong	0.84
H7	CT	↔	SH	Medium	0.65
H8	CT	↔	CS	-	-
H9	QT	↔	TM	Strong	-0.71
H10	QT	↔	SH	Weak	-0.15
H11	QT	↔	CS	-	-
H12	QT	↔	EV	Medium	0.46
H13	SH	↔	CS	Medium	0.49
H14	CS	↔	IS	Medium	0.64
H15	CS	↔	IT	Weak	-0.26
H16	EV	↔	SH	Medium	0.32
H17	EV	↔	CS	Weak	-0.10
H18	EV	↔	FP	Strong	0.78
H19	FP	↔	CS	Medium	0.41
H20	IS	↔	TM	Strong	0.89
H21	IS	↔	CT	Medium	-0.34
H22	IS	↔	QT	-	-
H23	IS	↔	SH	-	-
H24	IS	↔	EV	-	-
H25	IS	↔	ES	-	-
H26	IS	↔	IT	Medium	0.34
H27	ES	↔	CT	Weak	0.13
H28	ES	↔	CS	-	-
H29	IT	↔	CT	Weak	0.26
H30	IT	↔	QT	Weak	0.22
H31	IT	↔	SH	Weak	0.26
H32	IT	↔	ES	Medium	0.44

The final model shows relationships among 10 key factors with different degrees of relationships. Medium and strong relationships are considered in the final model. As a result, five strong relationships and 11 medium relationships are found in the final model, with path coefficients ranging from 0.30 to 0.91 (Figure 2).

The final model reveals a number of direct and indirect relationships. It is found that some factors directly influence the other factors, while some factors have indirect relationships with each other through intermediaries. A strong positive relationship between the TM and CT factors, with the path coefficient of 0.91, indicates that whenever the TM factor is improved by one unit, the CT factor increases by 0.91 unit. This is consistent with Faridi and El-Sayegh (2006), in that long procurement and materials approval time (an item in the TM factor) leads to extra costs (an item in the CT factor). With better cost performance, better quality performance is achieved; this is shown by a strong positive relationship between the CT and QT factors. Interestingly, focusing more on quality performance might decrease time performance, as more time is taken to ensure quality work (Kannan & Tan, 2005). This is confirmed with a strong negative relationship between the QT and TM factors.

The final model also reveals emerging concepts of performance measurement. A strong relationship, for example, is found between the EV and FP factors. Begum *et*

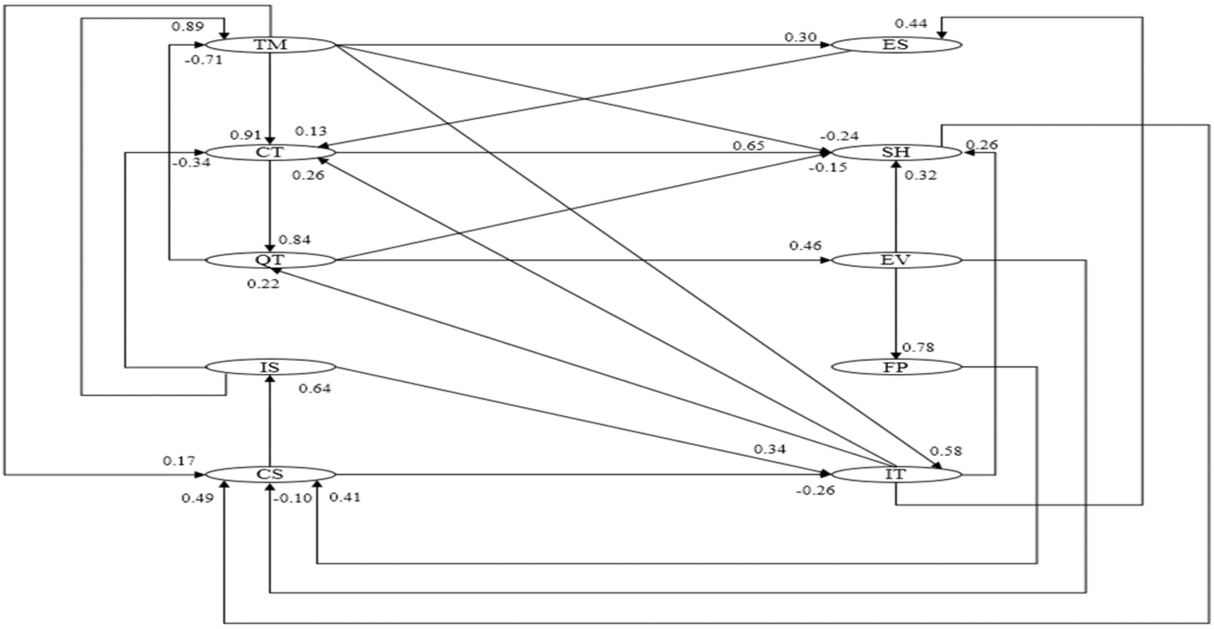

Figure 2. Final model of construction performance

al. (2006) stated that improving environmental performance creates special leverage for Thai construction companies to compete in global markets. The EV factor is closely related with the SH factor. Site management, in terms of wastewater management and dust control improve health and safety of workers (Kaming, Olomolaiye, Holt, & Harris, 1997). The improvement of financial competitiveness (the FP factor) and safety and health (the SH factor), as a result of the environmental improvement (the EV factor), leads to high customer satisfaction (the CS factor). This is seen as an indirect relationship between the EV and CS factors through the FP and SH factors (Figure 2).

According to Bowen and Shoemaker (2003), client satisfaction is a fundamental issue for construction contractors to survive in the global market. This is confirmed by a strong relationship between the CS and IS factors. To achieve high customer satisfaction, Thai construction companies need to focus on their stakeholders (the IS factor), as they highly influence time, cost, and quality performance. Providing good teamwork and work environment (items in the IS factor) reduces design changes (an item in the QT factor), resulting in accurate cost estimate (an item in the CT factor). This also helps to reduce delays (an item in the TM factor), leading to high client satisfaction and better work performance.

To achieve a better work performance, new technology should also be introduced to assist in, for example, enhancing communication between internal and external stakeholders, facilitating the cost estimation and design development processes, and initiating innovations to ease work processes. These are confirmed by direct and indirect relationships among the IS, IT, and ES factors.

4. Conclusions and Limitations

It is necessary to understand the key factors affecting construction performance as well as their interrelationships, so that construction companies can better plan for their performance enhancement. This study utilized the SEM approach to examine relationships among 10 key performance factors. The results revealed five strong relationships and 11 medium relationships among those 10 key factors. Strong positive and negative relationships were found among time, cost, and quality factors. In improving construction performance, therefore, it is unavoidable to ensure that work is finished on time, within the budget, and in the quality standard. Focusing more on quality performance, however, may decrease time performance, as more time is spent to ensure quality work.

The analysis results also revealed new findings in key factors influencing performance enhancement. A strong relationship, for example, was found between the environment and the financial factors. To be competitive in the global market, it is necessary for Thai contractors to focus on international environmental standards, as they are compulsory in many countries, and are emphasized by foreign direct investors. The use of information, technology, and new innovations is also important in increasing companies' competitiveness in the global market and in enhancing overall performance of the companies.

The study results pinpoint the importance of the internal and external stakeholders, and that their cooperation in safety and health and environmental issues is needed to enhance the construction performance. With good attitude, teamwork, and management support, customers' requirements could be fulfilled, prompt reactions are used to solve problems, construction site is properly managed, and quality work is attained, and finally, a high work performance is achieved.

This study has a number of limitations. Data collection was done in Bangkok, Thailand and in its vicinity. The results, therefore, may not generalize to other regions or countries. Targeted respondents were only in management positions. Operational level may be included in future studies to elaborate the findings in the context of a real implementation.

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