Construction Management and Economics

ISSN: 0144-6193 (Print) 1466-433X (Online) Journal homepage: https://www.tandfonline.com/loi/rcme20

Measuring effectiveness of safety programmes in the Thai construction industry

Thanet Aksorn & Bonaventura H. W. Hadikusumo

To cite this article: Thanet Aksorn & Bonaventura H. W. Hadikusumo (2008) Measuring effectiveness of safety programmes in the Thai construction industry, Construction Management and Economics, 26:4, 409-421, DOI: 10.1080/01446190801918722

To link to this article: https://doi.org/10.1080/01446190801918722

Published online: 01 Sep 2010.

Construction Management and Economics (April 2008) **26**, 409–421

Measuring effectiveness of safety programmes in the Thai construction industry

THANET AKSORN* and BONAVENTURA H. W. HADIKUSUMO

School of Engineering and Technology, Asian Institute of Technology, PO Box 4, Klong Luang, 12120 Thailand

Received 19 June 2007; accepted 15 January 2008

Some safety programmes are more effective than others in improving safety performance at the project level. The effectiveness of safety programmes was evaluated by studying 70 construction projects in the Thai construction sector, examining the relationship between their actual status and associated site safety performance. The actual status was assessed by using an evaluation tool developed in compliance with Thai safety legislation and validated by safety experts. Safety performance was assessed by using reactive and proactive measures. Particularly, the accident rate was used as a reactive indicator, while the unsafe act index and the unsafe condition index were used as proactive indicators. The results demonstrated that safety performance was influenced by the nature of implemented safety programmes. First, safety programmes which positively affect accident rates include accident investigations, jobsite inspections, control of subcontractors and safety incentives. Secondly, five programmes, namely jobsite inspections, accident investigations, job hazard analysis, safety committees and safety record keeping, were found to have the most contributions to fewer unsafe acts. And thirdly, accident investigations, jobsite inspections, job hazard analysis, safety inductions and safety auditing were the most effective programmes in reducing unsafe conditions.

Keywords: Accident, safety, health and safety, performance improvement, Thailand.

Introduction

In Thailand, the construction industry has been experiencing an expansive and increasing volume of market demand in accordance with the high economic growth of the country following its recovery from the financial crisis in 1997. The aftermath of this development has however had an adverse impact on the well-being of workers as evidenced by poor safety records at construction sites. This relatively high and stable economic growth in Thailand has led to a rapid increase in construction work and consequently an influx of unskilled workers to the major cities. Most workers currently hired in the construction industry are originally from the agricultural areas and provinces, with a low level of education and skills. In addition to the temporary nature of both construction and agricultural work, many of these workers engage themselves seasonally and tend to split their time between agricultural production and construction works. Such factors therefore make it difficult for the construction industry to maintain high safety standards. According to the Social Security Statistics of Thailand (2004 cited in ILO, 2005), the construction industry has the highest rate of deaths, accounting for close to 100 workers per year. In addition, up to 20 000 workers have suffered minor injuries on jobsites every year. Therefore, there has been a growing awareness within the government and private sectors towards improving construction site safety in order to provide better protection and safety to workers. In order to reduce the unacceptable statistics of accidents and injuries in the Thai construction industry, the Ministry of Labour and Social Welfare launched a basic safety management framework at the enterprise level wherein the implementation of safety programmes was promoted. Given that the personal safety and health of each employee is of primary concern, the prevention of occupational accidents and injuries is of such consequence that it will be given precedence over operational productivity. On the other hand, according to Siriruttanapruk and Anantagulnathi (2004), improving construction site safety in Thailand still remains a

*Author for correspondence. E-mail: artty_th@yahoo.com

Construction Management and Economics
ISSN 0144-6193 print/ISSN 1466-433X online
http://www.tandf.co.uk/journals
DOI: 10.1080/01446190801918722

formidable problem due to limited resources available to governmental and non-governmental safety institutions to carry out inspections and to give advice and guidance for implementing safety programmes effectively. From a global perspective, to assist the construction industry in improving its safety performance, several studies (Tam and Fung, 1998; Sawacha *et al.*, 1999; Poon *et al.*, 2000; and Hinze and Gambatese, 2003) have been conducted to identify appropriate safety strategies on jobsites. Research has shown that the development and implementation of an effective safety programme can reduce site accidents (Liska *et al.*, 1993; Findley *et al.*, 2004). However, it is unclear which policies are the most effective programmes in achieving improved safety performance.

A closer look at the methodologies used in the previous studies reveals that effectiveness is commonly measured by correlating the safety programmes with reactive safety indicators (i.e. lost time injury rates, frequency and severity rates, fatalities, first aid cases). However, there are very few studies which measure the effectiveness of safety programmes by using proactive indicators of safety performance. The proactive approach is considered a new measurement paradigm, which can be used to assess the current state of safety level, for example, workers' attitudes (i.e. unsafe acts) and working conditions (i.e. unsafe conditions). The proactive approach can identify such factors that can contribute to future accidents and meaningfully provide the necessary feedback to management to provide more appropriate preventive measures (Cantarella, 1998; Mohamed, 2003).

In response to the consistently poor safety performance of the construction industry, this study was conducted with construction projects in Thailand and aimed at identifying safety programmes that are clearly proven to be effective in reducing accidents (reactive safety performance indicators) and decreasing unsafe acts and unsafe working conditions (proactive safety performance indicators). The results of the study provide management with practical guidelines for implementing safety programmes more effectively.

Literature review

Several researchers have proved that there is a strong positive association between safety programme implementation and improved safety performance. For example, Jaselskis *et al.* (1996) investigated strategies for achieving better construction safety performance and established several important factors such as project manager experience and level, supportive upper management attitude, time devoted to safety for project safety representatives, safety meetings, frequency of site inspections and budget allocation for safety awards. Tam and Fung (1998) conducted a quantitative study to investigate relationships between safety practices and safety performance on construction sites in Hong Kong and revealed that improved site safety was associated with involvement of top management, safety orientation for new workers, safety awards or incentive schemes, use of post-accident investigation, safety training, safety committees and level of subcontracting. Similarly, Sawacha *et al.* (1999) uncovered that a safety programme that has the most effect on site safety consists of management talks on safety, provision of safety booklets, provision of safety equipment, providing a safe environment and appointing a trained safety representative on site.

Poon *et al.* (2000) recommended that post-accident investigation is the most effective task for reducing site accidents. They concluded that accident investigation can trace the causes of accidents and as such, appropriate preventive measures can be taken accordingly. Findley *et al.* (2004) proved that the employment of full-time safety managers and presentation of pre-job safety briefs are the key elements of superior safety performance. Their studies pointed out that safety functions cannot be run smoothly without appointment of onsite full-time safety managers who can provide the required and necessary leadership to facilitate preventive and corrective guidance.

In conclusion, these previous studies provide a useful guideline on the subject of construction site safety. The authors summarized the key elements of an effective safety programme based on previous research (e.g. Tam and Fung, 1998; Poon *et al.*, 2000; Goldenhar *et al.*, 2001; Hinze and Gambatese, 2003; and Findley *et al.*, 2004). These studies were conducted to evaluate the influence of safety programmes on improved construction safety performance and revealed that successful safety programmes, however, do not need extensive elements, but should at least include the critical elements including safety policy, safety committees, safety inductions, safety training, safety inspections, accident investigations, first aid programmes, in-house safety rules, safety incentives, control of subcontractors, selection of employees, personal protection programmes, emergency preparedness planning, safety-related promotions, safety auditing, safety record keeping and job hazard analysis. These safety programmes were used as research variables in this study.

Defining safety programme effectiveness

Prior to elaborating on this research on construction safety programmes, it is essential to understand what is meant by the term 'safety programme effectiveness'. Wojtczak (2002) defined effectiveness as a measure of the extent to which a specific intervention, procedure or service, when deployed in routine circumstances, does what it is intended to do. Erlendsson (2002) defined effectiveness as the extent to which objectives are achieved or 'doing the right things'. Furthermore, Collins (2005) offered a rather helpful explanation by declaring that managers typically either 'do things right' or 'do the right things'. Doing things right means efficiency, which refers to getting the best output from available resources. Doing the right things means effectiveness, which refers to setting the right goals and objectives and then ensuring they are accomplished. In this study, the effectiveness of safety programmes is defined as the extent to which the implemented safety programmes achieve the intended outcomes. The outcomes were expected to be highly related to improved construction safety performance including the reduction of work-related accidents, unsafe practices and unsafe working conditions.

Research method

The sample

In total, 70 construction projects, selected from 35 medium-scale projects and 35 large-scale projects, took part in this study. The sizes of the projects were differentiated based on total project cost. They were classified as 'medium' when total project cost ranged between 20 million baht (approx. US$600 000) to 100 million baht (approx. US$3 million) with a total employed workforce of 50 to 200 workers, and 'large' when total project cost was greater than 100 million baht (approx. US$3 million) with a workforce larger than 200 workers. For each visited project, an informant was required to participate in the data gathering. Thus, a total of 70 key informants were involved in the study. All the informants from participating projects were experienced construction safety personnel. More specifically, construction safety personnel are defined as those individuals such as safety managers, safety officers or safety inspectors, who are responsible for overall safety of construction sites.

Data collection

For each construction project, a considerable amount of data had to be collected in order to achieve the research objective. Several data collection techniques were therefore utilized, and these are elaborated in the following sections.

In-depth interview for evaluating actual status of safety programmes

Based on reviews of Thai safety standards and previous safety-related research, 17 safety programmes with the following elements were identified for evaluation of their actual status: (1) safety policies; (2) safety committees; (3) safety inductions; (4) safety training; (5) safety inspections; (6) accident investigations; (7) first aid programmes; (8) in-house safety rules; (9) safety incentives; (10) control of subcontractors; (11) selection of employees; (12) personal protection programmes; (13) emergency preparedness planning; (14) safety-related promotions; (15) safety auditing; (16) safety record keeping; and (17) job hazard analysis.

A one-hour interview was conducted with each informant. During the interview, an informant was requested to describe the extent of implementation of the above-listed 17 safety programmes within his or her project. Then, their narratives were measured against descriptive criteria in the evaluative tool to award scores for actual status of safety programmes (scores were awarded on a scale of 1 to 4, or poor to excellent). Descriptive criteria for the four awarded scales were developed in accordance with the Labour Protection Act 1998 (BE 2541), Notifications of the Ministry of Labour and Social Welfare, Notifications of the Ministry of Interior, and Guidelines for Safety Management System in Construction issued by the National Institute for the Improvement of Working Conditions and Environment (NICE) in 1999 and 2002. The descriptive criteria were developed based on the following definitions:

(1) The criterion for 'poor level' was established in the sense that the safety programme is not implemented, documented or maintained.
(2) The criterion for 'fair level' was established in the sense that the safety programme is partially implemented but not effective.
(3) The criterion for 'good level' was established in the sense that the safety programme is being implemented as required by relevant safety legislation and standards.
(4) The criterion for 'excellent level' was established in the sense that the safety programme element is implemented exceeding the minimum requirement of safety legislation and standards.

Thereafter, all newly developed criteria were incorporated into a preliminary questionnaire and distributed to a panel of 70 construction safety experts to assess their validity. In this study, these criteria were validated by using Lawshe's (1975) content validity technique. The raw data gathered from the experts were used to compute the content validity ratio (CVR). The results showed that the computed CVR values for all descriptive criteria highly exceed the minimum requirement, and thus, it was concluded that those criteria are strongly applicable. In addition, Cronbach's alpha coefficient (α) was computed for the entire dataset with the aim of providing a measure of reliability. The value of the alpha coefficient was 0.910 which therefore suggested that the reliability of this survey's validity was highly acceptable. An example of the valid evaluation criteria for evaluating the actual status of safety training, which is one of 17 safety programmes used in this study, is shown in Figure 1.

Review of accident statistics for calculating accident rate

The measurement of safety performance by using accident statistics is a traditional approach. It implies that the success of safety programme implementation results in the absence of accidents or injuries rather than an occurrence. In 1997, the Ministry of Labour and Social Welfare of Thailand announced a notification requesting all safety officers at construction sites to submit a progress report of their safety activities undertaken to prevent accidents and injures and to resubmit updated editions every three months. In such progress reports, accident records and associated information must be included as legally required. Consequently, each construction project has safety records available for accident rate computation. The necessary data required from the sites included the number of accidents and total working hours of the employees during the entire construction period. The accident rate was calculated as follows:

$$\textit{Accident rate} = \frac{\textit{Number of accidents}}{\textit{Total man hours worked}} \times 1\,000\,000$$

Observation method for quantifying unsafe acts and unsafe conditions

According to Laitinen *et al.* (1999), unsafe acts and unsafe conditions are considered as the two major direct causes of accidents; therefore, observation of the workers' behaviours and working conditions at the

Safety programme evaluation score sheet				
Construction company:				
Site:		**Date:**		
Safety training				
0	**1**	**2**	**3**	**Evaluation score**
No training programmes are arranged for workers.	Some formal training is provided but without updated training programmes. The firm does not offer daily training to give direct instructions to the workers before they perform their jobs or tasks.	Formal training is regularly organized covering topics in compliance with Thai OS&H standards. Updated training is occasionally provided. The firm offers daily training to give direct instructions to the workers before they perform their jobs or tasks.	In addition to 'good', formal training plans, schedules are also written. Special training sessions are conducted when a real need is apparent, such as when new equipment, processes or procedures are introduced to the workplace. The workers' understanding of each conducted training is evaluated and documented.	

Figure 1 Sample of safety programme evaluation criteria

jobsite is another possible method to estimate potential safety performance. The definitions of an *unsafe act* and *unsafe condition*, according to the American Society of Safety Engineers (ASSE), are as follows:

> … unsafe condition is defined as any physical states which deviate from that which is acceptable, normal or correct in terms of its past production of personal injury and/or damage to property or things; and also defined as any physical states which result in a reduction in the degree of safety normally present … (Michaud, 1995, p. 9).

> … unsafe act is the behavior which departs from an accepted, normal, or correct procedure or practice which has in the past actually produced injury or property damage or has the potential for producing such a loss in the future; an unnecessary exposure to a hazard; or conduct reducing the degree of safety normally present … (Michaud, 1995, p. 10).

The observation of unsafe acts and unsafe conditions is a proactive approach to safety performance measurement. The results of observation can predict the potential possibilities of future accidents. The observation method produces a safety index which may vary from 0 to 100%. For instance, an observation index of 60% means that 60 out of every 100 observed units are not in accordance with the specified safety standards or safety practices. The basic equations used to compute safety index are as follows:

$$\textit{Unsafe act observation index} = \frac{\textit{unsafe acts}}{\textit{unsafe acts} + \textit{safe acts}} \times 100$$

$$\textit{Unsafe condition observation index} = \frac{\textit{unsafe conditions}}{\textit{unsafe condition} + \textit{safe condition}} \times 100$$

In this study, an observation checklist was used as a supportive tool. A checklist, which includes observed items and criteria for an unsafe score, was developed in compliance with the Labour Protection Act 1998 (BE 2541), Ministerial Regulations and Notifications of the Ministry of Labour and Social Welfare, Ministerial Regulations and Notifications of the Ministry of Interior, and the two editions of guidelines for safety management system in construction developed by the National Institute for the Improvement of Working Conditions and Environment (NICE) in 1999 and 2002.

According to WorkCover New South Wales (2001), the observation was conducted by dividing a workplace into 'areas' or 'squares', where the observer could walk and/or stand to observe workers and/or the working environment. For example, on a high rise construction project, this could include individual floors or parts thereof. On a single floor building site, it could be work areas defined by visible boundaries.

The observation of workers' practices in the sampling area was conducted first. The observer at his own convenience selected some workers to be observed. The observer took adequate time to make an evaluation or required judgement of each worker (i.e. 10–15 minutes). If the observation indicated that a worker was performing his or her task unsafely, a check was made at the appropriate column of the observation scoring sheet (see Figure 2). An 'unsafe act' was marked if the observed element did not fully comply with safe practice standards. For example, if the worker used required personal protective equipment and did not take any risk during observation, the 'safe acts score' was marked. Thereafter, observations were made of unsafe conditions in the same sampling area. Similarly, each one was scored as 'safe condition' if it complied with acceptable standards. For example, a walkway at an observed area was scored as 'safe condition' if it was clean and tidy and there were no unnecessary remnants on the floors.

It is worth noting that the criteria for an unsafe score were only used as a guideline on scoring for unsafe acts and unsafe conditions. If the observer who was conducting the measurement was uncertain of assigning a score, then the item was not scored at all. According to Sikiö and Laitinen (1999) and WorkCover New South Wales (2001), for each sampling project, a minimum of 100 samples across all observed items was preferred in order to provide an appropriate measurement.

Results and discussion

Results of safety performance measurement

A total of 70 construction projects were involved in the data collection process. As clearly discussed above, safety performance was measured by using three safety indicators: accident rate, unsafe act index and unsafe condition index. Table 1 presents the results of these three measurements of safety performance for the whole sample and the breakdown of the results for large-scale and medium-scale projects. To provide an understandable presentation, the measurement results are provided at predetermined intervals. In addition, the mean score, minimum score and maximum score of the results are also provided.

The table indicates that the means of accident rate for large and medium projects are 45.15 and 107.73 respectively. Nearly 28% on average of observed activities of workers in large projects were found unsafe while about 31% on average were found in medium projects. In addition, the table points out that

Construction company:					
Project:		**Visited date:**			
Unsafe act observation					
Observed item	**Scoring criteria**	**Safe**	**Total**	**Unsafe**	**Total**
Improper lifting and handling of objects	Insecure grip of the object, carrying heavy load without lifting equipment, or observing unsafe lifting postures (e.g. failure to use sit-down position and maintain straight backs)	/////////////////// /////////////////// ////////////	50	///////////////	15
Violation of safe procedures	Servicing equipment in operation, or taking short-cut methods (e.g. jumping, climbing)	////////////////////	20	///	3
Throwing objects from height	Careless throwing or dropping of objects from a height	/////	5	////////	8
Removing safety guards	Removing safety guards from tools or set-up of safety guards in inoperative condition	//////////	10	///////////////	15
Failure to wear PPE	Failure to wear personal protective equipment (PPE) suitable to the job	///////	7	///////	7
Improper dressing	Wearing unsafe personal attire (e.g. wearing shorts)	///////////////	15	///////////////	15
		Total safe	107	**Total unsafe**	63
Safety index = (total unsafe x 100) / (total safe + total unsafe) = 37.10%					
Unsafe condition observation					
Observed item		**Safe**	**Total**	**Unsafe**	**Total**
Stairways	Guardrails are not installed or installed but not securely fixed, unnecessary objects are not removed from the steps, or spill or wet spot is not cleaned up	/////////////////// ////////////	31	////////	8
Lighting system	Insufficient level of lighting, appearance of harmful glare, or ineffective sources of lighting (e.g. unclean lamps, obstructed windows and skylights)	/////////////////// /	20	////////////// /	15
Scaffolding	Scaffold is not made of strong materials, point of connection is not securely fixed, standing platform is not properly provided, footing is not placed on the firm ground, a safe access way is not provided, or guardrail and toe-board is not installed	/////////////////// /	20	////////////// /	15
Ladder	Ladders are not placed on firm ground, or the ladders' components are not in a good condition (e.g. cracked)	///////	7	///	3
Work bench	Working surface is not clean and tidy, the component is in poor condition (e.g. broken), or footing is not properly positioned	///////	7	///	3
Hand tool	Power tools are not grounded and not kept away from heat and water, or defective or damaged power tool is in use for job (e.g. cracked cables, fraying cords)	//////////	10	//////////	10
		Total safe	95	**Total unsafe**	54
Safety index = (total unsafe × 100) / (total safe + total unsafe) = 36.20%					

Figure 2 Sample of observation scoring sheet

approximately 35% of observed working conditions of large projects were found dangerous to workers whereas approximately 38% of observed working conditions of medium projects were unsafe.

Discussion on safety performance in medium-sized and large-sized construction projects in Thailand

According to Table 1, it can be seen from the results that the level of safety performance on construction sites is found to be dependent on project size. The findings inevitably signify that large-sized construction projects have better safety records than smaller projects, fewer unsafe practices as well as a smaller number of dangerous conditions exposed to the workers. In other words, the large construction sites have a tendency to provide more safe working conditions than smaller sites do and its workers incline to perform their assigned tasks more safely than their counterparts in smaller projects.

Ranking of actual status of safety programmes

Table 2 shows the overall mean ranking of the actual status of each of the 17 safety programmes investigated during the survey of 70 construction projects. Overall, five safety programmes, namely safety record keeping (mean=3.41), safety inductions (mean=3.37), control of subcontractors (mean=3.33), safety committees (mean=3.19) and safety training (mean=3.16) were rated very highly. Table 2 exhibits five factors, namely job hazard analysis (mean=2.43) emergency preparedness planning (mean=2.37), first aid programmes (mean=2.34), safety incentives (mean=2.03) and selection of employees (mean=2.00) that have the lowest mean scores.

Table 2 also provides a detailed breakdown of the mean rankings of the large-scale and medium-scale construction projects. The evaluation of safety programmes implemented in large-scale projects indicates that the following five safety programmes have highest mean scores: control of subcontractors (mean=3.63), safety inductions (mean=3.46), safety record keeping

Table 1 Survey results of safety performance in construction projects

Safety performance		Types of project		
Indicators	Results	Large-scale projects	Medium-scale projects	Overall
Accident rate	0–20	8	–	8
	20–40	6	10	16
	40–60	15	1	16
	60–80	1	9	10
	80–100	5	–	5
	>100	–	15	15
	Total	35	35	70
	Mean	45.18	107.73	76.46
	Min.	8.06	32.22	8.06
	Max.	99.64	198.77	198.77
Unsafe act index	<20%	7	–	7
	20%–25%	10	11	21
	26%–30%	3	9	12
	31%–35%	6	1	7
	36%–40%	8	14	22
	>40%	1	–	1
	Total	35	35	70
	Mean	27.97	30.83	29.40
	Min.	15.80	22.00	15.80
	Max.	41.90	39.60	41.90
Unsafe condition index	<20%	–	–	–
	20%–25%	–	–	–
	26%–30%	2	–	2
	31%–35%	17	9	26
	36%–40%	11	18	29
	>40%	5	8	13
	Total	35	35	70
	Mean	35.08	37.53	36.32
	Min.	29.60	31.30	29.60
	Max.	43.40	43.50	43.50

(mean=3.43), accident investigations (mean=3.40) and safety-related promotions (mean=3.34). Similarly, the evaluation results of medium-scale projects showed that safety record keeping (mean=3.40), safety inductions (mean=3.29), in-house safety rules (mean=3.23), safety committees (mean=3.20) and safety inspections (mean=3.09) are the five factors with the highest mean scores.

In addition, Table 2 shows the results of the *t*-test analysis which was conducted to investigate whether the means for actual status for each safety programme between large-sized and medium-sized projects are significantly different from each other. The analysis showed that eight of 17 factors are significantly different at 95% level of confidence, namely safety policies, accident investigations, job hazard analysis, in-house safety rules, safety auditing, safety incentives, safety-related promotions and control of subcontractors. By taking a closer look, it can be seen that the large construction projects have the mean scores for those safety programmes, excluding in-house safety rules, higher than the smaller projects.

In order to examine the general similarities between rankings of the large-scale projects and medium-scale projects, the Spearman's rank correlation test was carried out to determine whether or not such similarities are significant. The association between rankings of the two respondent groups was then verified at the 5% significance level. The results indicate that the Spearman's rank correlation coefficient was 0.649 and the correlation was statistically significant at the 5% level.

Discussion on the current practices towards safety programme implementation in the Thai construction industry

The results of this study showed that, overall, five safety programmes, namely safety record keeping, safety inductions, control of subcontractors, safety committees and safety training have the best actual status. This implies that these programmes have been given appropriate consideration for implementation on the sites. However, more emphasis needs to be placed on those factors with an unsatisfactory status characterized by low mean scores, namely job hazard analysis, emergency preparedness planning, first aid programmes, safety incentives and selection of employees. By conducing *t*-test analysis, it can be seen that the means for eight safety programmes between large-sized and medium-sized projects are significantly different. This implies that these programmes were implemented in a different quality. As shown in Table 2, the large projects tend to operate these programmes, excluding in-house safety rules, in better quality than the medium projects. It was suggested that management of smaller projects should pay greater attention to implementing these programmes to improve their actual status up to a

Table 2 Ranking of the actual status of safety programmes

Safety programmes	Overall (1)		Large-scale projects (2)		Medium-scale projects (3)		*t*-test (p-value)
	Mean	Rank	Mean	Rank	Mean	Rank	
P1: Safety policies	3.06	9	3.29	6	2.83	10	0.004*
P2: Accident investigations	3.10	8	3.40	4	2.80	11	0.002*
P3: Safety inspections	3.14	7	3.20	8	3.09	5	0.462
P4: Selection of employees	2.00	17	2.00	17	2.00	16	1.000
P5: Job hazard analysis	2.43	13	2.66	13	2.20	15	0.001*
P6: Safety training	3.16	5	3.26	7	3.06	6	0.216
P7: Safety inductions	3.37	2	3.46	2	3.29	2	0.210
P8: Safety committees	3.19	4	3.17	9	3.20	4	0.829
P9: Emergency preparedness planning	2.37	14	2.49	15	2.26	14	0.177
P10: In-house safety rules	3.04	10	2.86	11	3.23	3	0.033*
P11: Personal protection programmes	3.00	11	2.91	12	3.09	7	0.296
P12: First aid programmes	2.34	15	2.34	16	2.34	12	1.000
P13: Safety auditing	2.60	12	2.89	10	2.31	13	0.001*
P14: Safety incentives	2.03	16	2.51	14	1.54	17	0.000*
P15: Safety-related promotions	3.16	6	3.34	5	2.97	9	0.033*
P16: Safety record keeping	3.41	1	3.43	3	3.40	1	0.860
P17: Control of subcontractors	3.33	3	3.63	1	3.03	7	0.000*
Value of Spearman's rank correlation coefficient between (2) and (3)=0.649							

Notes: Mean scores 1.00–1.50, 1.51–2.50, 2.51–3.50 and 3.51–4.00 are defined as poor, fair, good and excellent status respectively. * denotes that the value is significantly different at 95% level of confidence.

satisfactory level so that significant improvement of safety performance could be achieved.

Furthermore, more in-depth analysis indicated that the priorities for implementation of safety programmes among large-sized and medium-sized projects are similar.

Multiple regression analysis to investigate the relationships of safety programmes on safety performance

Multiple regression analysis is a statistical technique widely used to create a model which indicates the combined effects of several independent variables on one dependent variable. In this study, three indicators of safety performance, namely accident rates, unsafe act indices and unsafe condition indices, were used as dependent variables, and 17 safety programmes were used as independent variables. In order to obtain the best predictors from a set of independents, a stepwise approach was employed to eliminate insignificant variables from the model. The results of stepwise regression analysis yield a model that reflects a set of the most effective safety programmes for safety performance improvement. The results of the analysis are tabulated in Table 3 and discussed below.

The results of stepwise multiple regression analysis created three models as illustrated in Table 3. First, a model signifying the influence of safety programmes on the accident rate can be expressed by:

$$\begin{aligned} \text{AR [accident rate]} = &\ 328.801 - 32.535\text{P2 [accident investigations]} - \\ &37.448\text{P3 [safety inspections]} - 20.225\text{P14} \\ &\text{[control of subcontractors]} - 12.603\text{P17} \\ &\text{[safety incentives]} \end{aligned}$$

Four of the 17 safety programmes, namely accident investigations, safety inspections, control of subcontractors and safety incentives, were found to be the most effective in improving the accident rate at construction sites. The value of R^2 of the model reached 0.853 thus indicating that the regression was considerably high as approximately 85% of the variation in accident rates could be accounted for by these four safety programmes.

Discussion on the contribution of four effective safety programmes on accident prevention

From the results obtained, accident investigations had the highest value of the standardized regression coefficient (β) of -0.455 with a significance level at $p \leqslant 0.000$, and consequently, this factor was considered the most effective contributor to reducing the accident rate. Accident investigations are pertinent to an improved safety level as they can correctly identify the actual causes of accidents and provide corrective measures to prevent their recurrence (Tam and Fung, 1998).

The second most effective factor was safety inspections ($\beta = -0.405$). Hinze and Gambatese (2003) pointed out that construction projects have improved safety records when the supervisors regularly conduct jobs inspections in their respective areas. Safety inspections can discover potential hazards and enable corrective measures to remove such hazards before they cause accidents and injuries (Michaud, 1995).

The third factor was control of subcontractors ($\beta = -0.251$). It is well known that the high mobility of subcontractors contributes to the poor accident records. Tam and Fung (1998) claimed that a general contractor may encounter poor subcontractors' safety performance because those subcontracted workers are highly mobile, and are paid according to the work done, thus they lack loyalty to main contractors. To maintain good safety records on site, the main contractor must ensure that subcontractors are implementing their own safety programmes, and assigning full-time safety staff to be in charge of workplace safety.

The fourth factor was safety incentives ($\beta = -0.191$). Incentive programmes are rewarding techniques applied to raise safety awareness, reinforce safe behaviours and counteract unsafe worker behaviour for the purpose of eliminating accidents and injuries (Hinze and Gambatese, 2003). In fact, the workers who want to be safe are self-motivated to safety and usually perform their work to comply with acceptable safety standards, while others may take short cuts in order to get the job done faster, but sooner or later they will suffer an accident. To overcome safety problems, incentive programmes should be applied because people usually expect something from the results of their good performance.

Secondly, the regression analysis created a model showing the effect of safety programmes on the occurrence of unsafe acts as follows:

$$\begin{aligned} \text{UA [unsafe acts]} = &\ 70.390 - 3.654\text{P3 [jobsite inspections]} - \\ &2.785\text{P2 [accident investigations]} - 3.660\text{P5} \\ &\text{[job hazard analysis]} - 2.176\text{P8 [safety} \\ &\text{committees]} - 1.474\text{P16 [safety record} \\ &\text{keeping]} \end{aligned}$$

Table 3 shows the five significant safety programmes implemented to minimize the occurrences of unsafe

Table 3 Regression results of the effects of safety programmes on safety performance

Independent variables (safety programmes)	Dependent variables (safety performance)								
	AR: Accident rate			UA: Unsafe acts			UC: Unsafe conditions		
	Unstandardized coefficients (B)	Standardized coefficients (β: Beta)	Ranking	Unstandardized coefficients (B)	Standardized coefficients (β: Beta)	Ranking	Unstandardized coefficients (B)	Standardized coefficients (β: Beta)	Ranking
P1: Safety policies	–	–	–	–	–	–	–	–	–
P2: Accident investigations	−32.353	−0.455	1	−2.785	−0.321	2	−1.952	−0.426	1
P3: Safety inspections	−37.448	−0.405	2	−3.654	−0.324	1	−1.499	−0.257	2
P4: Selection of employees	–	–	–	–	–	–	–	–	–
P5: Job hazard analysis	–	–	–	−3.660	−0.292	3	−1.618	−0.250	3
P6: Safety training	–	–	–	–	–	–	–	–	–
P7: Safety inductions	–	–	–	–	–	–	−0.829	−0.126	5
P8: Safety committees	–	–	–	−2.176	−0.164	4	–	–	–
P9: Emergency preparedness planning	–	–	–	–	–	–	–	–	–
P10: In-house safety rules	–	–	–	–	–	–	–	–	–
P11: Personal protection programmes	–	–	–	–	–	–	–	–	–
P12: First aid programmes	–	–	–	–	–	–	–	–	–
P13: Safety auditing	–	–	–	–	–	–	−0.722	−0.141	4
P14: Safety incentives	−12.603	−0.191	4	–	–	–	–	–	–
P15: Safety -related promotions	–	–	–	–	–	–	–	–	–
P16: Safety record keeping	–	–	–	−1.474	−0.136	5	–	–	–
P17: Control of subcontractors	−20.225	−0.251	3	–	–	–	–	–	–
Constant		328.801			70.390			55.681	
Adjusted R^2		0.853			0.877			0.823	

Note: – denotes that the relationship between dependent variable and independent variable is not significant.

acts at construction sites including: safety inspections, accident investigations, job hazard analysis, safety committees and safety record keeping. The value of R^2 of the model was 0.877 demonstrating that the regression was significantly high, as about 88% of the variations in the level of occurrence of unsafe acts can be explained by these five programmes.

Discussion on the contribution of five effective safety programmes on unsafe acts prevention

From the results of regression analysis, safety inspections had the highest value of the standardized regression coefficient (β) of -0.324 with a significance level of $p \leqslant 0.000$; as such, this factor has offered the greatest contribution to the level of unsafe acts. Given the evidence that a lower accident rate can be achieved if workers perform their jobs safely, routine safety inspections need to be scheduled and carried out to discover unsafe practices in order to provide recommendations to control and prevent them accordingly (Michaud, 1995; Goetsch, 2005).

The second most effective factor influencing unsafe acts was accident investigations ($\beta = -0.321$). Accident investigations typically address the issues specifically related to each particular accident. They enable the identification of substandard working practices which predominantly cause near-misses, accidents or injuries, and recommend the corrections necessary to prevent future accidents (Poon *et al.*, 2000).

The third factor was job hazard analysis ($\beta = -0.292$). The aim of job hazard analysis is to identify possible hazards and exposure of the workers to risks for particular jobs and to establish safe working methods enabling the workers to perform their jobs more safely (Carter and Smith, 2006).

The fourth factor was safety committees ($\beta = -0.164$). Safety committees are a well-proven tool in facilitating the reduction of workplace injuries, given that committees can assist in reviewing and updating workplace safety rules and initiating preventive control measures based upon accident investigation findings, inspection findings, employees' reports of unsafe practices, and accepting and addressing anonymous complaints and suggestions from employees (Stranks, 2000; Lin and Mills, 2001).

The fifth factor was safety record keeping ($\beta = -0.136$). Michaud (1995) confirmed that by having a good record keeping system, the unsafe practices leading to work-related accidents can be reviewed and identified correctly; therefore, effective corrective measures can be established.

And thirdly, the regression model that demonstrates the interrelated effect of safety programmes on the occurrence of unsafe conditions can be expressed as follow

$$\begin{aligned}\text{UC [unsafe conditions]} = {} & 55.681 - 1.952\text{P2 [accident investigations]} - 1.499\text{P3 [safety inspections]} \\ & - 1.618\text{P5 [jobhazard analysis]} - 0.829\text{P7 [safety inductions]} - 0.722\text{P13 [safety auditing]}\end{aligned}$$

As tabulated in Table 3, accident investigations, safety inspections, job hazard analysis, safety inductions and safety auditing were identified as the five most significant factors in alleviating unsafe conditions at a construction site. The value of R^2 of this model was 0.823 indicating that the regression model was relatively strong, as about 82% of the variations in the occurrence of unsafe conditions were associated with these five programmes.

Discussion on the contribution of five effective safety programmes on unsafe conditions prevention

According to the results of analysis, accident investigations had the highest value of the standardized regression coefficient (β) of -0.426 with a significance level of $p \leqslant 0.000$. It was determined that this factor has the most effect on the level of unsafe conditions on jobsites. Every accident is an indication that something is wrong in the system. Thus, accident investigation is a proven programme undertaken to discover hazardous working conditions or other inherent causes of work-related accidents and injuries in order to take effective corrections.

The second most effective factor was safety inspections ($\beta = -0.257$). Many construction operations expose workers to dangerous working conditions. Safety inspections can therefore be used to identify existing hazardous conditions and suggest appropriate corrective and preventive measures before such hazards cause accidents (Peterson and Cohen, 1996).

The third factor was job hazard analysis ($\beta = -0.250$). Carter and Smith (2006) stated that job hazard analysis is a process in which all of the various steps in a particular job are identified and listed in order to discover any potential hazards associated with them. The working procedures for reducing the degree of hazards associated with each respective step need to be developed accordingly (Tam *et al.*, 2002). Consequently, unhealthy work conditions would be corrected prior to start of works.

The fourth factor was safety inductions ($\beta = -0.126$). Safety performance can be improved through cooperative involvement of workers and the management team working together to eliminate safety problems in the workplace. To gain more workers' involvement, Goetsch (2005) suggested that before new employees are permitted to perform their assigned jobs, safety inductions should be provided to create safety awareness and educate those newcomers to work in a safe manner, and to report any unsafe conditions or other hazards encountered at work.

The fifth factor was safety auditing ($\beta = -0.141$). Flannery (2001) stated that a safety audit mainly focuses on the safety management systems which are developed to ensure that safety risks are properly managed. Holt (2001) also noted that an effective audit is capable of identifying deviations from general standards, analyse events leading to such deviations and highlight good practices, which in turn can serve as feedback to the company for providing corrective actions and improving existing safety systems.

Comparison of this study's finding and previous studies

It can be seen from a comparison of the findings of this study and some selected major studies (i.e. Tam and Fung, 1998; Poon *et al.*, 2000; Hinze, 2002; Findley *et al.*, 2004) that an effective safety programme does not need extensive elements, but should at least include the critical elements. It was also found that each study introduced its own unique elements of an effective safety programme. However, by taking a closer look at the result of each of the selected studies and this research's finding, the conclusion is inevitably that some elements of an effective safety programme are similar, as follows:

- The findings of this study, and the studies conducted in Hong Kong by Tam and Fung (1998) and Poon *et al.* (2000), and in the US by Hinze (2002) and Findley *et al.* (2004), all attest that accident investigations can effectively improve site safety performance.
- The results of this research, Poon *et al.* (2000)and Findley *et al.* (2004) provide similar conclusions, in which safety inspections and safety inductions are proven to be effective in improving construction site safety performance.
- In regard to careful consideration of the findings of this study, Tam and Fung (1998) and Hinze (2002), it can be seen that the elements of an effective safety programme must include control of subcontractors' safety, and safety incentives.
- The results of this research, Hinze (2002) and Findley *et al.* (2004) regard safety committees as an effective safety programme. A safety committee is a forum for workers and management working together in a non-adversarial, cooperative effort to improve safety in the workplace by planning, implementing and evaluating a comprehensive safety programme.
- The results of this research and Poon *et al.* (2000) found that safety record keeping is a key safety programmes. In Thailand, a safety record keeping programme has been legislatively required by Ministerial Regulation No.25 BE 2549 to implement on every jobsite.

Conclusions

The effectiveness of safety programmes in improving safety performance on construction sites in Thailand was investigated. More specifically, the relationship between the actual status of safety programmes and associated safety performance was examined. The results show that, overall, large-scale construction projects have better safety performance than medium-scale projects, as evidenced by having fewer accidents, unsafe acts and unsafe conditions.

Furthermore, the actual status of safety programmes implemented by participating projects was evaluated. It was found that five safety programmes, namely safety record keeping, safety inductions, control of subcontractors, safety committees and safety training, have very high average evaluation scores. Thus, it is implied that these five programmes are being given appropriate consideration by all construction projects to implement on jobsites.

A stepwise multiple regression technique was employed to create the models that explain the interrelated effects of safety programmes on safety performance. Consequently, three regression models were extracted from the analysis. First, four of the 17 safety programmes, namely accident investigations, safety inspections, control of subcontractors and safety incentives, were found to be the most effective in improving accident rates at construction sites. Secondly, the five most effective safety programmes in minimizing the occurrence of unsafe acts at construction sites were safety inspections, accident investigations, job hazard analysis, safety committees and safety record keeping. And thirdly, accident investigations, safety inspections, job hazard analysis, safety inductions and safety auditing were identified as the five most effective factors in decreasing unsafe conditions at construction sites.

In the light of this study, construction managers can use these quantitative results to establish an effective safety programme for achieving improved construction site safety performance.

References

Cantarella, A.F. (1998) Effectively measuring safety performance. *Professional Safety*, **43**(1), 1–3.

Carter, G. and Smith, D.S. (2006) Safety hazard identification on construction projects. *Journal of Construction Engineering and Management*, **132**(2), 197–205.

Collins, T. (2005) *Effectiveness versus Efficiency*, available at www.morepartnerincome.com/blog/_archives/2005/4/22/600001.html (accessed 16 December 2006).

Erlendsson, J. (2002) *Value for Money Studies in Higher Education*, available at www.hi.is/~joner/eaps/wh_vfmhe.htm (accessed 24 September 2006).

Findley, M., Smith, S.M., Kress, T., Petty, G. and Enoch, K. (2004) Safety program elements in construction: which ones best prevent injuries and control related workers' compensation costs? *Professionals Safety*, **49**(2), 14–21.

Flannery, J.A. (2001) *Safety Culture and Its Measurement in Aviation*, available at www.asasi.org/papers/other/safety_culture_measurement_aviation.pdf (accessed 26 December 2006).

Goetsch, D.L. (2005) *Occupational Safety and Health: For Technologists, Engineers, and Managers*, 6th edn, Prentice Hall, Upper Saddle River, New Jersey.

Goldenhar, L.M., Moran, S.K. and Colligan, M. (2001) Health and safety training in a sample of open-shop construction companies. *Journal of Safety Research*, **32**, 237–52.

Hinze, J. (2002) *Making Zero Accidents a Reality*, CII Report 160, The University of Texas at Austin, Austin, TX.

Hinze, J. and Gambatese, J. (2003) Factors that influence safety performance of specialty contractors. *Journal of Construction Engineering and Management*, **129**(2), 159–64.

Holt, J.A. (2001) *Principles of Construction Safety*, Blackwell Science, London.

ILO (International Labour Organization) (2005) *Thailand—Occupational Safety and Health in the Construction Industry*, available at www.ilo.org/public/english/region/asro/bangkok/download/background/osh/conth05.pdf (accessed 12 May 2006).

Jaselskis, J.E., Anderson, S.D. and Russell, J.S. (1996) Strategies for achieving excellence in construction safety performance. *Journal of Construction Engineering and Management*, **122**(1), 61–70.

Laitinen, H., Marjamäki, M. and Päivärinta, K. (1999) The validity of the TR safety observation method on building construction. *Accident Analysis and Prevention*, **31**, 463–72.

Lawshe, C.H. (1975) A quantitative approach to content validity. *Personal Psychology*, **28**(4), 563–75.

Lin, J. and Mills, A. (2001) Measuring the occupational health and safety performance of construction companies in Australia. *Facilities*, **19**(3), 131–8.

Liska, R.W., Goodloe, D. and Sen, R. (1993) *Zero Accident Techniques*, The Construction Industry Institute, Austin, TX.

Michuad, P.A. (1995) *Accident Prevention and OSHA Compliance*, CRC Press, Florida.

Mohamed, S. (2003) Scorecard approach to benchmarking organizational safety culture in construction. *Journal of Construction Engineering and Management*, **129**(1), 80–8.

Peterson, R.D. and Cohen, J.M. (1996) *The Complete Guide to OSHA Compliance*, Lewis Publishers, Boca Raton.

Poon, W.F., Ma, C.H. and Ho, K.L. (2000) Statistical analysis on factors in reducing construction site accident frequency rate in Hong Kong, in *Proceedings of the 6th Annual Conference of the Australian and New Zealand Association of Occupational Health and Safety Educators*, Hong Kong, pp. 341–55. Available at http://www.ic.polyu.edu.hk/oess/$publications.htm (accessed 20 October 2006).

Sawacha, E., Naoum, S. and Fong, D. (1999) Factors affecting safety performance on construction sites. *International Journal of Project Management*, **17**(5), 309–15.

Sikiö, A.L. and Laitinen, H. (1999) *A Workplace Safety and Health Observation Method for the Meat Industry*, Report for the Finish Institute of Occupational Health, available at www.ttl.fi/NR/rdonlyres/A1411CB8-94EA-4ABB-8A98-DBCDA03ACFF8/0/mebooklet.pdf (accessed 20 November 2006).

Siriruttanapruk, S. and Anuntagulnathi, P. (2004) Occupational health and safety situation and research priority in Thailand. *Industrial Health*, **42**, 135–40.

Stranks, J. (2000) *The Handbook of Health and Safety Practice*, 5th edn, Prentice Hall, London.

Tam, C.M. and Fung, I.W.H. (1998) Effectiveness of safety management strategies on safety performance in Hong Kong. *Construction Management and Economics*, **16**, 49–55.

Tam, C.M., Tong, T.K.L., Chiu, G.C.W. and Fung, I.W.H. (2002) Non-structural fuzzy decision support system for evaluation of construction safety management system. *International Journal of Project Managements*, **20**, 303–13.

Wojtczak, A. (2002) *Glossary of Medical Education Terms*, available at www.iime.org/glossary.htm (accessed 24 November 2006).

WorkCover New South Wales (2001) *Safety Meter: Positive Performance Measurement Tool*, available at www.workcover.nsw.gov.au/Publications/OHS/RiskManagement/safetymeterpositiveperformancetool.htm (accessed November 2006).