Journal of Construction in Developing Countries, Vol. 12, No. 2, 2007

Construction Safety and Health Factors at the Industry Level: The Case of Singapore

Charles Y.J. Cheah

Abstract: The construction industry is one of the most hazardous industries due to the unique nature of its products and the processes involved. Recent occurrences of highly publicized construction site accidents in Singapore have highlighted the immediate need for the local industry to address safety and health (S&H) hazards. In the past, S&H were considered as isolated aspects on site, but today they have emerged as systemic issues that warrant serious attention at the industry level. The objective of this paper is to examine issues and critical factors affecting S&H standards in Singapore. Clearly, collective efforts should be pursued at the industry level as the country moves towards the ultimate safety management strategy of self-regulation. The findings also indicate that the challenge of making worksites safe should not be placed solely on the contractors, but should be shared by all parties affecting the value chain of construction, including the developers, the consultants and the government. The factors identified through factor analysis may inform legislators and industry practitioners in terms of the sources of problems and help develop effective strategies for improvement. Some of the experiences mentioned in the paper could also be relevant to other countries facing similar circumstances.

Keywords: Construction site accidents, Inter-agency cooperation, Safety factors, Singapore

INTRODUCTION

Worldwide, construction is one of the most hazardous industries due to its unique nature (Jannadi and Bu-Khamsin, 2002). Firstly, the industry is highly fragmented, which marginalizes efforts to safeguard safety and health (S&H) standards. Secondly, unlike manufacturing, construction site activities are physically dispersed across various locations; thus supervising and monitoring S&H issues in the workplace is much more challenging. Compared with other industries, construction is often classified as high risk because historically it is plagued with higher and unacceptable injury rates. Two highly publicized cases in 2004 – the collapse of Nicole Highway (*Straits Times,* 2004a) and the Fusionpolis incident (*Straits Times*, 2004b), have placed this issue in the limelight. Based on the statistics published by Singapore's Ministry of Manpower (MOM), in 2006 alone, accidents in the

School of Civil and Environmental Engineering, Nanyang Technological University, SINGAPORE 639798. Corresponding author: cyjcheah@ntu.edu.sg

construction industry had caused 24 deaths, compared to 10 in shipbuilding and ship repairing, 7 in manufacturing and 21 in other sectors. The accident frequency rate for construction was recorded as 3.5 workplace accidents per million man-hours worked. This is compared to 2.2 for shipbuilding and ship repairing, 2.6 for manufacturing, and 1.3 for other sectors. Not surprisingly, the construction industry has received plenty of negative publicity when it comes to S&H issues.

The primary legislation in Singapore used to govern safety matters on construction sites is Chapter 104 of the Factories Act and Sections 68 and 77 of the Building Operations and Work of Engineering Construction (BOWEC) Regulations. However, ailing safety records indicated that legislation did not seem to fulfil its cause. On 1 March 2006, the Factories Act was repealed and replaced by the Workplace Safety and Health Act. With the introduction of the new act, the safety framework is shifting from one that is highly prescriptive (rule-based) to being more descriptive (principle-driven). According to the previous Factories Act, industry players were expected to follow a fixed set of safety guidelines. There is now a paradigm shift, as the new act is founded on three guiding principles – reduce risk at source, instil greater ownership of safety and health outcomes by industry, and impose higher penalties for poor safety management. According to this new act, every industry player in the construction process value chain will be held responsible for safety. The act also calls for a greater level of self-regulation and imposes more responsibilities on companies to determine their in-house S&H standards and practices. Violators of S&H practices will be fined even if no accident has occurred.

While more time is required to observe the effectiveness of the new act, the intention of this current study is to examine the issues and critical factors affecting S&H standards at the industry level. The burden of safety has traditionally been rested on the shoulders of the contractors, but it is felt that safety should be a shared responsibility among all industry players and the government. In short, the objectives of this study are:

1. To seek the view of the various industry players on the current status of S&H standards in Singapore.

2. To investigate whether there is a common agreement among the industry players on their roles and responsibilities in the area of S&H.

3. To identify the underlying factors that affect construction S&H standards.

The findings gathered in this study may be informative for legislators and industrial practitioners to understand the

source of problems affecting construction safety and strategize improvement measures accordingly. Furthermore, some of the experiences mentioned in the paper could also be relevant to other countries facing similar circumstances.

RESEARCH METHODOLOGY AND LITERATURE REVIEW

The research started with gathering information through literature review, in which factors that might affect the S&H standards of construction industry in general were identified. A pilot study questionnaire was then prepared based on this preliminary list of factors. The pilot questionnaire was first sent to various industrial practitioners for review and comment. Feedback sessions were then conducted with these participants to refine the questionnaire. The modified version was sent out via post and electronic mail to suitable respondents for filling out. The sampling technique for each respondent group is largely random. Quantitative techniques were subsequently employed to analyze the feedback before the research findings were organized and concluded in a more meaningful manner.

The study was inclined towards the management aspects of S&H issues, rather than the scientific and technological facets. Literature related to this research topic was identified for a more in-depth review. The following papers provided insights into the appropriate research methodology, design of the questionnaire and analytical techniques. However, the methodology and findings of these papers should be referenced with caution, since they were designed to suit the localities and conditions of the countries where the research were conducted. The industrial context of Singapore construction must be duly considered.

Sawacha et al. (1999) studied the attitudinal aspects of safety among workers in the UK construction industry. The specific objectives were to correlate the workers' background and attitude towards safety with their accident records and also to determine the group of factors that have the most impact on site safety. The information and data necessary for the research study was collected through a questionnaire survey. The top five issues found to be associated with site safety are: (i) management talk on safety, (ii) provision of safety, booklets, (iii) provision of safety equipment, (iv) provision of a safe working environment, and (v) appointment of a trained safety representative on site.

Effectively, site managers and supervisors must engage in regular talks with the workers on site in order to have better safety. The importance of providing workers with a safety booklet or manual when joining a company

was also emphasized and verified. Sawacha et al.'s (1999) research also indicated that the provision and use of the correct type of protective equipment and clothing are only the pre-requisites for improving safety performance. The workers should also be trained for the correct trades or construction tasks. The importance of a clean and tidy site as a factor that improves safety performance cannot be overlooked. Finally, a well-trained safety representative on site can improve safety performance by undertaking fault spotting and insisting on corrective actions being taken.

Zeng et al. (2004) discussed factors that affected safety in the construction industry in China. Their research methods consisted of a structured questionnaire survey and interviews. The questionnaires were sent to safety representatives of the Chinese construction firms, whereas the interviews were conducted with Chinese government officials in charge of safety. The main factors affecting safety performance in China were identified as poor safety awareness of top management, lack of training, poor safety awareness of project manager, reluctance to input resources to safety, and reckless operation.

Zeng et al. (2004) concluded that safety awareness of the top management and project managers in most Chinese construction firms was of grave concern. Apparently, most contractors did not implement the proper system as laid down in the safety manual. Only a small percentage provided adequate personal protective equipment for their workers and offered systematic safety training. Essentially, the management lacked emphasis on safety, as revealed by their infrequent attendance at safety meetings. The percentage of workers being trained was also found to be very low in China. The reluctance to invest resources in safety was closely associated with the operating nature of construction firms in China. When firms of different sizes competed for the same jobs, it resulted in excessive competition, thin profit margins and a compromise in safety standards. Finally, it was suggested that the Chinese government should play a more critical role in stricter legal enforcement of safety legislation and organization of safety training programmes.

Kartam et al. (2000) evaluated existing safety regulations and procedures adopted by owners, designers, contractors and insurance companies in Kuwait. Different research activities, such as field visits, questionnaires and interviews, were used to collect the necessary information and data. The factors that contributed to poor safety standards were compiled as disorganized labour, poor accident record keeping and reporting systems, extensive use of foreign labour, extensive use of sub-contractors, lack of safety regulations and legislation, low priority given to safety, small size of most construction firms, competitive tendering, and severe weather conditions during the summer.

Employment of migrant labour was quite common on the construction sites in Kuwait (and in many ways, this is similar to the situation in Singapore where many workers originate from Bangladesh, India, Sri Lanka, Myanmar, and China). The differences in labour cultures and traditions reflected on human relations and work habits and caused difficulty in communications. These gave rise to safety issues. There was also a lack of official safety data and records of construction accidents on site, which resulted in a lack of awareness among contractors and owners on the importance of safety. In addition, the foreign labour force had no union or community to defend their rights. The main concern of most contractors was cost reduction. Many contractors felt that their bids would be considered even if they did not make proper provisions for safety during competitive tendering, unless these were explicitly itemized in the contract documents. S&H hazards in Kuwait were also exacerbated by extreme weather conditions in the summer, with the temperature exceeding 110°F, thereby adversely affecting the workers' state of mind and attention.

Finally, the literature review process also included most of the construction safety incidents that occurred over the past three years in Singapore. A search was conducted over the archived news of local newspapers and news stations. The safety system implemented and the trend in S&H standards in Singapore were also studied through information published by MOM, Building and Construction Authority (BCA), Statistics Singapore (SingStat), and other non-governmental bodies that are involved in construction S&H issues.

QUESTIONNAIRE DESIGN AND PRELIMINARY ANALYSIS

Sample Size

The objective of the use of a questionnaire was to develop an appropriate framework to extract critical factors for the research topic. The targeted respondents of the survey were middle management, professionals and executives from the construction industry. The middle management comprised project managers and assistant managers. Professionals and executives included architects, engineers, quantity surveyors, project coordinators, government registered safety officers and site supervisors. Table 1 gives a summary of the responses from each group.

Content of the Questionnaire

There are three sections in the questionnaire:

1. Section I – Background information about the respondent.

Table 1. Summary of Questionnaire Responses

Respondent Groups	Questionnaires Sent Out	Replies Received	Response Rate (%)	Usable Responses	Usable Rate (%)
Government agencies	25	8	32	7	28
Developers/ property managers	25	10	40	9	36
Consultants	40	20	50	18	45
Contractors/ sub-contractors	50	44	88	37	74
Suppliers	10	0	0	0	0
Non-govern-mental safety personnel	20	9	45	9	45
TOTAL	**170**	**91**	**54**	**80**	**47**

2. Section II – General opinions on safety issues.

3. Section III – Specific questions for factor analysis.

Section I contains questions on the general information of the respondents, such as the respondent's job designation, profession and company information. Section II seeks the respondents' opinions on general construction industry S&H issues. The respondents were asked to rate the S&H standards in terms of the frequency of injuries/deaths/accidents, and to give their views on the S&H responsibilities among various groups of industry players.

Section III compiles significant issues that were identified in the previous literature review and feedback sessions. These issues can be categorized intuitively into eight categories: (i) industrial issues, (ii) competitive tendering, (iii) role of government, (iv) non-governmental safety personnel-related issues, (v) main contractor-related issues, (vi) developer/property manager-related issues, (vii) consultant-related issues, and (viii) worker-related issues. Each category of issues is further described by several sub-factors. For example, under "competitive tendering", the following issues or sub-factors were identified:

1. Safety is seldom considered, as low price is the primary consideration.

2. Standardized clause for allocation of safety budget is absent in most contracts.

3. There is no system to reward contractors who achieve good safety performance; hence a lack of incentives.

In total, there are 45 of these sub-factors compiled in Section III. For each sub-factor, the respondents were asked to rate its level of impact on S&H standards along a 5-point Likert scale, ranging from "lowest impact" to "highest impact".

Preliminary Analyses

Reliability analysis studies the properties of measurement scales and the items that make up the scales. One of the most widely used measures is the Cronbach's alpha. Ranging from 0 to 1, a higher value of Cronbach's alpha is usually more desirable. In this case, this was determined as 0.9022. Consequently, the research data was deemed satisfactory for further statistical analysis.

Factor analysis was a key statistical technique used to identify the underlying cluster of factors affecting S&H performance. This was performed using Section III of the survey data. Before the data could be used, it should be assessed for the KMO (Kaiser-Meyer-Olkin) measure of sampling adequacy and the Bartlett's test of sphericity. The result of the KMO test for all the variables was 0.662; usually, a KMO measure greater than 0.5 is deemed satisfactory for factor analysis. The null hypothesis of the Bartlett test was also rejected at the 5% level of significance, indicating that the correlation matrix is not an identical matrix.

Collectively, the results of the preliminary analyses supported that the data was satisfactory for factor analysis. Readers who are interested in the details of the above tests may refer to Bryman (2005).

RESULTS AND DISCUSSIONS

General Outlook of S&H Standards in Singapore

In Section II of the questionnaire, respondents from the different groups were asked to rate the S&H standards of Singapore construction industry in terms of the frequency of injuries/deaths/accidents. The evaluation was based on a scale ranging from "very bad (1)" to "very good (5)". The average feedback from each group is tabulated in Table 2.

At first sight, the non-governmental safety personnel seemed to adopt the most sceptical view concerning the S&H standards. A one-way ANOVA test however confirmed that the means of all five groups were not statistically different from one another, even at the 10% level of significance. Therefore, one could only say that all groups generally felt neutral about the issue, given that the means

hovered around 3.00. Still, it would be useful to consider other facts and statistics described below.

Table 2. Average Feedback on S&H Standards Given by Various Groups

Government Agencies	Developer/ Property Managers	Consultants	Contractors/ Sub-contractors	Non-governmental Safety Personnel
3.00	3.00	3.17	3.24	2.56

Note: These figures represent the mean values of feedback given by different groups of respondents, which are measured along a scale of 1 (very bad) to 5 (very good)

The rate of accidents in the Singapore construction industry had not improved much even after the Safety Management System was implemented in 1994. One useful yardstick is the number of accidents per million man-hours worked published by MOM. Although a downward trend was generally observed since 1994 – suggesting an improvement in S&H standards – further scrutiny indicated otherwise. A comparison was made between the value of construction contracts and the number of workers employed against the number of construction accidents for the period of 1997–2004. This is tabulated in Table 3.

Table 3. Comparison among Value of Contract, Number of Workers Employed and Number of Accidents

Period	Percentage Change using 1997 as Benchmark		
	Value of Contract (%)	No. of Workers Employed	No. of Accidents
1997–1998	3.08	–0.60	–0.39
1997–1999	–10.32	–7.96	–2.21
1997–2000	–6.06	–6.39	–9.30
1997–2001	–17.45	–14.07	–5.40
1997–2002	–31.06	–19.57	–13.07
1997–2003	–36.48	–27.21	–22.43
1997–2004	–40.75	–30.77	–20.94

In Table 3, the drop in number of workers employed was in tandem with the decrease in value of construction contracts. However, the rate of accidents had not reduced by the same proportion. In 1997, the total value of construction contracts was approximately S$19.2 billion and in 2004, the value was approximately S$11.4 billion; the drop was, therefore, about 41%. During the same period, the number of workers employed fell from approximately 214,000 to 148,000; the drop was, therefore, about 31%. There was also a fall in accidents from 1538 cases to 1216 cases; the drop was only about 21%. Thus, the lower number of construction fatalities from 1994 to 2004 might

not be attributed to the improvement in S&H standards, but merely due to fewer construction projects and workers.

Feedback on Safety Responsibilities

The respondents were also asked to rank the level of safety responsibilities that should be assumed by the various players in the industry. The evaluation was based on a scale ranging from "most responsible (1)" to "least responsible (6)". For each row of entries in Table 4, the relative rankings in the columns were based on the average responses gathered from the corresponding group. The final rankings were then worked out by summing vertically the average rankings computed.

The chief causes of industrial accidents are well known – an unsafe act coupled with unsafe conditions and a lack of coordination of work processes. Indirectly, the results of Table 4 support this proposition. Workers who are executing the physical work at construction sites should be held as the most responsible party for their own safety. These workers have gone through a fair amount of safety training and have been provided with personal protective equipment. However, this does not ensure that they will put their training into practice and many are still found to indulge in unsafe acts, therefore leading to worksite accidents. Contractors are ranked second in Table 4. As direct employers of the workers, they have moral and legal duties to provide the workers with a safe working environment. They must also coordinate their work processes to eliminate any potential S&H hazards. The third S&H measures despite the importance of human life and the incurrence most responsible party is the government. Some managers, supervisors and workers continue to ignore and neglect S&H measures despite the importance of human life and the incurrence of financial losses due to accidents. It is essential that the government puts in place a strong regulatory framework.

The ability of developers to assume safety responsibilities depend on the procurement arrangements and their level of technical expertise. Some developers have in-house technical experts who are actively involved in every stage of the project; others who do not will tend to leave the project management function to its consultants and adopt a "hands-off" approach. Undoubtedly, developers do not create any S&H hazards directly at the worksites (unlike the contractor, consultants and workers). However, their stand on S&H issues, particularly on promoting a safety culture, does have a direct impact on the contractors and consultants and indirectly, the workers. For example, in one real project, the client was willing to allocate a reasonable sum of money towards promoting S&H awareness on site and it challenged the contractor to match its funds. The total pool of money was then

Table 4. Ranking of Safety Responsibilities among Various Industry Players

Responses from	Safety Responsibilities of					
	Gov. agencies	**Developers/ property managers**	**Consultants**	**Contractors/ sub-contractors**	**Non-gov. safety personnel**	**Workers**
Government agencies	3	6	5	2	4	1
Developers/property managers	3	2	4	1	5	1
Consultants	4	5	6	2	3	1
Contractors/ sub-contractors	4	3	6	2	5	1
Non-governmental safety personnel	4	3	5	1	6	2
Total Score	18	19	26	8	23	6
SAFETY RANK	**3**	**4**	**6**	**2**	**5**	**1**

distributed as safety awards that were handed out weekly. This incentive scheme strongly motivated the workers to pay more attention to safety and the 10-month project enjoyed a zero-incident record.

In Table 4, the least responsible party for safety based on the survey results is the consultants. However, it should be mentioned that the design of a structure has a direct impact on the safety of a project. In fact, recent literature had recommended for an increased level of design professionals' safety obligations. Specifically, designers should proactively consider site safety during the design stage (Hinze and Wiegand, 1992; Gambatese, 1998, 2000; Gambatese et al., 1997). This, however, is a paradigm shift for most consultants since they are traditionally not responsible for safety. The shift infers a natural extension to their legal liability on construction safety and also duties on safety during physical construction activities. In the UK, the principles of having consultants to design structures that can be built, maintained, operated and demolished safely were first enshrined in the *Construction (Design and Management) Regulations 1994*. It was realized that reputable contractors indeed had expertise in constructing structures safely, but were sometimes given dangerous designs to build. In fact, the performance of consultants had been so poor that a new set of regulations have been enacted in 2007 with the aim to improve the safety performance of the consultants.

The Latham Report, a study conducted by Sir Michael Latham and commissioned by the UK government in 1994, painted a picture of distrust and conflict – not just between developer and contractor, but also between the design and construction team and within the construction team itself. Latham (1994) described a debilitating culture of conflict:

> ...The industry has deeply engraved adversarial attitudes. The culture of conflict seems to be embedded, and the tendency towards litigiousness is growing...disputes and conflicts have taken their toll on morale and team spirit. Defensive attitudes are a common place.

This problem of uncertainty and adversity inherent in the construction industry still holds true until today, which is largely caused by a lack of both trust among the various players. Typically, there are no detailed specifications about safety responsibilities in contracts and even governmental standards. The only portion in a contract that typically mentions about site safety is General Conditions under the Preliminary Section. The General Conditions, however, do not clearly establish the safety responsibilities of the developer, the consultant, the contractor, the non-governmental safety officer and the workers. For moral reasons and practical financial risk management, construction S&H issues should be the

concern of all individuals and organizations involved in a construction project.

In a way, in Table 4, there is a lack of uniform agreement on the degree of responsibilities that should be assumed by certain groups. This disparity in opinions on safety responsibilities can be represented graphically. In Figure 1, the role of safety assigned to the three most responsible parties – workers, contractors and government – fluctuate within a narrow band. It shows that relatively higher consensus is met for these three parties. However, there is a larger disparity of views on the safety roles for developers, non-governmental safety personnel and consultants, which are potentially areas of debate when designing a holistic S&H management system governing all the industry players.

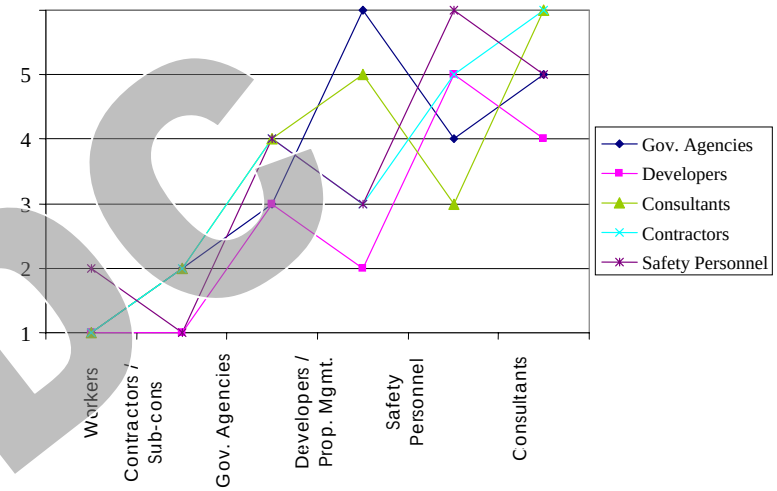

Figure 1. Measuring Disparity in Opinions on Safety Responsibilities of Each Party

Factor Analysis

Factor analysis was used to identify and interpret non-correlated clusters of routine variables that dominate construction S&H. It is a common technique adopted for reducing a large number of variables to a smaller number of more interpretable and significant factors. As mentioned, Section III of the questionnaire was designed for this purpose. The total percentage of variance explained by each principal factor was examined in order to determine the required number of factors to adequately represent the entire set of data. The extraction of principal factors was conducted using SPSS, a statistical package that is commonly used in academic and industrial studies.

A total of 13 principal factors had been extracted. These 13 factors accounted for approximately 73% of the variance in responses. All factor loadings were greater than 0.5 and 16 of them were greater than 0.7. To

introduce meaningful interpretations of the results, each principal factor was given an identifiable description. This could be normally achieved because a principal factor is essentially an aggregation of a number of correlated sub-factors.

The details are presented in Table 5. The sub-factors supporting most of the principal factors are in fact related to different industry stakeholders, which include the consultants, developers/clients, main contractors, government and workers. For example, for Factor 1, the first three sub-factors are consultant-related, the next two are developers/property managers-related, and the last is main contractor-related. This emphasizes the fact that solutions to improve S&H issues apparently require a holistic approach and joint efforts from various industry stakeholders.

Due to the limitation of space, only detailed interpretations of the first six factors, which account for more than 50% of cumulative variance explained, are discussed.

Factor 1: Lack of integration of safety considerations in the upstream construction activities

Clients and developers in Singapore can play a major role in promoting the safety culture of a project. Efforts from developers must come on board in the early stage of the project. This is because developers have the ultimate control over the consultants and contractors hired and even moral responsibilities for S&H. Developers can impose market pressure by making safety as a pre-qualified criterion. For example, only contractors with good safety records are allowed to bid for projects, and tender may not be awarded to the lowest bidder if the lowest bidder has a poor safety record. Thus, the "unsafe contractors" must change their ways of working or face the danger of being forced out of business in the long run.

On the other hand, building design can bear an impact on the safety level of physical construction activities. Consultants should integrate safety considerations into their design process and actively involve in safety management during construction.

Contractors, like most business entities, are profit-driven. Their main emphases are cost, work progress and quality, instead of S&H issues. Some contractors adopt a "minimum compliance" mindset in fulfilling legislative requirements. They seldom go beyond what the legislation requires even when the situation calls for a better practice. Thus, integration of efforts among these three parties is vital in S&H planning and management.

Table 5. Results of Principal Components Analysis and Factor Structure

Descriptions of Sub-factors Supporting Each Principal Factors	Factor Loading	% of Variance Explained	Cum. % of Variance Explained
Factor 1 – Lack of integration of safety considerations in the upstream construction activities			
Lack of procedure to evaluate safety at various stages of feasibility study, planning, design, tendering and construction	0.828	27.737	27.737
Lack of involvement by consultants in contractors' safety activities, such as meetings and inspection	0.827		
Consultants' perception that safety is solely contractors' problem; not considered in design	0.778		
Lack of emphasis on safety by developers/clients; no external pressure on consultants and contracts to act on safety	0.566		
Lack of involvement by developers/clients in contractors' safety activities, such as meetings and inspection	0.566		
Contractors' safety practices aim only to satisfy minimum legislation requirements	0.522		
Factor 2 – Role of the government in designing a sound safety legislative framework			
Ineffectiveness of current safety policies	0.774	7.339	35.065
Insufficient promotion on safety awareness	0.768		
Insufficient intervention from government in contractors' in house safety programme; most contractors aim satisfy minimum requirements only	0.706		
Lack of access to safety record and performance of the contractor to evaluate their safety performance	0.698		
Officers sent to enforce safety are inexperienced	0.636		
Factor 3 – Poor chain of command and management within contractor's organization			
Poor safety awareness among supervisory staff of main contractor, such as project manager, supervisors, engineers, etc.	0.723	5.365	40.431
Safety policies of main contractor are not communicated well to staff, especially those at the lower level	0.696		
Poor housekeeping and site planning	0.617		
Workers themselves display personal risk behaviour	0.598		
Factor 4 – Problems with workers and insurance policies			
High turnover of labour	0.746	4.517	44.948
Insurers do not have evaluation procedure on contractors, who do not face rising premium even with bad safety records	0.564		
Workers do not know their rights at workplace	0.555		
Lack of union/community to defend theirs rights to fight for a safe working environment	0.516		

(continued on next page)

Table 5. *(continued)*

Descriptions of Sub-factors Supporting Each Principal Factors	Factor Loading	% of Variance Explained	Cum. % of Variance Explained
Factor 5 – Problems with contractors' fraudulent acts or negligence			
Main contractors not justly punished due to dishonesty in accident reporting	0.679	4.061	49.009
Safety programme shown on paper only and not practiced in reality	0.644		
Contractors not giving specific training to workers to perform their jobs safely	0.531		
Factor 6 – Pressure on workers and non-governmental safety personnel			
Workers under enormous pressure, fatigue and stress leading to accidents	0.825	3.908	52.917
Safety personnel not given sufficient budget and authority to execute safety duties effectively	0.538		
Factor 7: Structural factors of the industry	0.784	3.461	56.378
Harsh working environment as most activities are carried out under the sun and exposed to weather conditions			
Failure to identify safety hazards early since design and construction stages are separated	0.606		
Factor 8: Problem with extensive sub-contracting	0.748	3.371	59.749
Extensive subcontracting causing problems in safety, e.g., coordination, planning, allocation of duties, etc.			
Safety personnel of subcontractors not able to focus on safety as they are often asked to do multi-tasking, e.g., as site foremen	0.577		
Factor 9: Financial pressure			
Safety is often omitted in competitive tendering as low price is the primary consideration	0.756	3.105	62.853
Factor 10: Absence of safety provisions in contractual clauses			
No standardized clauses for allocating a budget for safety in most contracts	0.809	2.810	65.663
Factor 11: Communication problems with a multicultural work force			
Diversified cultures and languages	0.746	2.622	68.268
Factor 12: Problem of fragmentation within the industry			
Difficulty in maintaining consistency in safety practices and systems due to industry fragmentation and existence of a large number of small-sized firms	0.739	2.340	70.626
Factor 13: Tight schedule			
Schedule is tight as developers/clients allocate little time for construction due to economic reasons; safety is often neglected	0.798	2.266	72.892

Factor 2: Role of the government in designing a sound S&H legislative framework

This factor shows that good S&H management cannot be wholly successful without an appropriate S&H infrastructure in place. The survey results indicate that the government has a major role to play. They should not wait for the contractors to improve on their own, but should apply external pressure in the form of tighter and harsher legislation. Government authorities should also dedicate more to promote good S&H practices in the industry. A larger number of trained and experienced government officers are needed to carry out inspection and audits at the construction sites.

Factor 3: Poor chain of command and management within contractor's organization

Companies in Singapore often set up S&H management policies but do not really monitor their implementation. S&H management policies should be formalized within the company. The safety management system, after being developed at the corporate level, should be communicated to the project managers, supervisors and workers level. Measures should be taken to raise the awareness of workers and motivate them to take responsibilities of their own safety. Both penalty and incentive mechanisms should be deployed to ensure that every worker becomes more safety conscious.

Factor 4: Problems with workers and insurance policies

In Singapore, most foreign workers do not know their rights to claim and they are also not represented by any union. When accidents occur, claims are often denied by the management, some of which may act irresponsibly by trying to cover up the incidents. Insurance premiums are usually calculated according to project type, size, location, expected hazards and difficulties. Past safety records of the contractor are not given much weight. Furthermore, insurance companies typically do not conduct site visits to check on the contractor's safety procedure. All these factors only encourage the management of some construction firms to act irresponsibly.

Factor 5: Problems with contractors' fraudulent acts or negligence

Some companies in Singapore treat S&H management as just a "paper exercise" to fulfil the legislation. Although S&H measures are in place and documented properly, some firms do not follow them strictly and regularly. Safety equipment, protective tools and gears and safety training are generally viewed as expense items. Some firms are not willing to replenish equipment that has worn out, or they

provide little training to their workers. They are willing to take such risks in an attempt to increase their profit margins due to the misconception that the chances of accident are rather slim. In reality, especially when new building techniques, equipment and machineries are involved, the chances of accidents will increase if workers and even supervisors are not trained for their jobs. Continual training and education are therefore indispensable to keep their knowledge updated on the relevant S&H issues.

Factor 6: Pressure on workers and non-governmental safety personnel

Many construction workers in Singapore work overtime everyday in order to increase their take home pay. In addition, there are weekend working and late night working during the peak of the project schedule. Project management typically involves a trade-off among cost, time and quality. In this environment, chances of role conflict are likely to be high. Safety officers are usually caught in a dilemma to balance cost reduction, high productivity and S&H concerns of their workers.

CONCLUSIONS

S&H remains a key aspect of construction. In the case of Singapore, many would have thought that the S&H standards have improved over the years in view of the decline in number of injuries and fatalities. However, these statistics should be viewed in the light of a larger percentage drop in contract volume and the number of workers hired. The survey implemented in this study confirms that the industry stakeholders largely remain neutral about any improvement in construction S&H standards, therefore a more intense and congruent effort should be sought to truly raise the S&H standards to a higher level.

There is a high degree of consensus on the three most important parties in assuming safety responsibilities: (i) workers who execute the physical works, (ii) contractors who employ the workers, and (iii) government who set up the legislative framework that governs S&H policies and practices. There is however a wider disparity of views on the safety responsibilities that should be shouldered by developers, non-government safety personnel and consultants. Recent literature suggested that consultants have an indirect and significant influence on safe structures by making better decisions during the design stage. The strongest evidence comes from the 2007 revision of the *Construction (Design and Management) Regulations* in the UK to improve the safety performance of the consultants.

A total of 45 variables affecting S&H standards were originally identified through literature review and interviews. These were reduced to 13 principal factors using factor analysis, as listed in Table 5. The results reaffirm the significance of contractors' initiatives in S&H and an appropriate S&H legislation infrastructure. Early involvement of developers and consultants is also found to be important, so that the relevant parties can cooperate with one another starting from the early design stage to foresee and identify potential S&H hazards. By planning ahead, measures can be introduced more effectively to prevent or mitigate such risks. As a whole, the results are suggestive of a holistic approach that integrates collective efforts from all the project stakeholders, instead of placing the burden solely on the contractors.

The Singapore construction industry still relies on government intervention and regulations to facilitate S&H management. As mentioned, collective involvement from the developers, the contractors and the consultants are vital. However, this is still in the preliminary stage as many industrial practitioners are yet to change their mindsets. Although self-regulation may seem to be too ideal for the Singapore construction industry at this point in time, it should be targeted as the ultimate strategy in S&H management. To facilitate the principles of self-regulation, the government had proposed several measures with the new Workplace Safety and Health Act introduced in March 2006. The introduction of this performance-based safety legislation shows that the onus has moved away from the enforcement of prescriptive regulations to the setting up of an infrastructure within companies to manage S&H issues in the spirit of self-regulation.

LIMITATIONS AND RECOMMENDATIONS FOR FUTURE WORK

Both principal component analysis and factor analysis are data reduction techniques. This study used the latter technique. Ideally, factor analysis requires a sample size that is five times larger than the number of variables. This condition was not met in the study, and therefore, the results of Table 5 may not be "statistically stable". On the other hand, the results of reliability analysis, KMO and Bartlett tests all proved to be adequate. Therefore, the descriptions of the factors in Table 5 are still meaningful since the interpretation of numerical results was made in conjunction with the theoretical and industrial knowledge of S&H issues in Singapore. Obviously, it will be useful to increase the sample size in the future to further verify the significance of these factors. A second study is particularly useful after some time, when the effects of the new Workplace Safety and Health Act have fully taken place. A comparative study (against the current results) would then help to assess the differences caused by the implementation of this new act.

REFERENCES

Bryman, A. (2005). *Quantitative Data Analysis with SPSS 12 and 13: A Guide for Social Scientists*. London: Routledge.

Gambatese, J.A. (1998). Liability in designing for construction worker safety. *ASCE Journal of Architectural Engineering*, 4(3): 107–112.

_____. (2000). Safety in designer's hands. *Civil Engineering*, 70(6): 56–59.

Gambatese, J.A., Hinze, J. and Haas, C.T. (1997). Tool to design for construction worker safety. *ASCE Journal of Architectural Engineering*, 3(1): 32–41.

Hinze, J. and Wiegand, F. (1992). Role of designers in construction worker safety. *ASCE Journal of Construction Engineering Management*, 118(4): 677–684.

Jannadi, O.A. and Bu-Khamsin, M.S. (2002). Safety factors considered by industrial contractors in Saudi Arabia. *Building and Environment*, 37(5): 539–547.

Kartam, N.A., Flood, I. and Kuoshki, P. (2000). Construction safety in Kuwait: Issues, procedures, problems and recommendations. *Safety Science*, 36(3): 163–184.

Latham, M. (1994). *Construction the Team*. London, UK: HMSO Books.

Sawacha, E., Naoum, S. and Fong, D. (1999). Factors affecting safety performance on construction sites. *International Journal of Project Management*, 17(5): 309–315.

Straits Times. (2004a). MRT Worksite Collapse Wrecks Nicoll Highway. April 21.

_____.(2004b). Basement Disaster. April 30.

The Construction (Design and Management) Regulations 1994. UK Statutory Instrument 1994 No. 3140. www.opsi.gov.uk/SI /si1994/Uksi_19943140_en_1.htm (Accessed 25 June 2007).

The Construction (Design and Management) Regulations 2007 [online]. UK Statutory Instrument 2007 No. 320. www.opsi.gov.uk/SI/si2007/20070320.htm (Accessed 25 June 2007).

Zeng, S.X., Tam, C.M. and Deng, Z.M. (2004). Identifying elements of poor construction safety management in China. *Safety Science*, 42(7): 569–586.