ESTABLISHING AN INTEGRATED MODEL FOR MEASURING THE SITE SAFETY PERFORMANCE OF CONSTRUCTION PROJECTS: LITERATURE REVIEW AND FUTURE RESEARCH AGENDA

Daniel W.M. Chan* and Tracy N.Y. Choi
Department of Building and Real Estate, The Hong Kong Polytechnic University,
Hung Hom, Kowloon, Hong Kong

ABSTRACT

Safety issues have always been a major problem besetting the construction industry in many countries because of the hazardous nature and complexity of the work. Previous government statistics have manifested that the highest number of accidents and fatalities are found in the construction industry when compared with other major industry sectors throughout the world. In Hong Kong, the construction industry is also regarded as high-risk. There are different construction site safety assessment methods proposed by some researchers. However, there is a lack of holistic assessment model for site safety performance of construction projects. In this study, the essential factors needed for safety assessment and their associated sub-factors are those which affect the level of safety performance. This paper aims to put forward a research framework for developing a holistic site safety assessment model for new construction projects in Hong Kong using the Delphi survey technique. It will be a multi-factor model where the core factors are expressed both in broad terms and as finer, more detailed, sub-factors. Successful development of the site safety assessment model can then enable the setting up of a benchmarking tool for measuring and comparing the overall safety standards of the various construction projects within an organisation, between organisations and within the construction industry as a whole leading to an improved site safety culture.

Keywords: *Factors Affecting Site Safety; Hong Kong; Research Framework; Safety Performance; Site Safety Assessment Model.*

1. INTRODUCTION

Safety on construction sites in Hong Kong remains a prime concern even though significant improvements have been made in 2003-2012 (Labour Department, 2013). The high-risk construction industry still records the highest accident rate and number of fatalities amongst the various major industry sectors. As compared with 2011, the number of construction accidents recorded in 2012 increased from 3,112 to 3,160 by 1.5% (Labour Department, 2013). The implementation of a structured, holistic site safety assessment is thus regarded as good construction safety management practice for accident prevention and mitigation.

Despite the fact that different construction safety evaluation methods have been proposed worldwide, a more holistic site safety assessment model which takes into account all the essential factors and their associated sub-factors pertinent to safety performance has yet to be realised (Sawacha *et al*., 1999). There exist no comprehensive standard assessment tools which take account of all the essential factors and their underlying sub-factors which can be applied to measure an overall safety standard of a construction site. A site with a higher safety standard is more likely to achieve better safety performance. Therefore, a strong urgent need exists to formulate a holistic site safety assessment model now with a view to uplifting current construction safety performance as a whole in Hong Kong.

An effective safety assessment protocol can substantially improve site safety because it can not only identify in advance some under-performing areas and major hazards for remedial action at an early stage but also help management to devise ways of making operations safer and creating a safer working environment (Anton, 1989; Abdelhamid and Everett, 2000; Rowlinson, 2003). Systematic research is

*Corresponding Author: E-mail - daniel.w.m.chan@polyu.edu.hk

also needed in order to understand how to build a model which will provide a single overall measure of safety assessment for any particular project, a useful tool as part of a site safety assessment system. Therefore, an integrated site safety assessment model is an essential tool for measuring, evaluating, monitoring and raising the current safety performance of construction projects. With the purpose of developing such an assessment model, a basket of consolidated key factors and their corresponding sub-factors contributing to safety performance as a whole are required which, however, are at present lacking within the construction industry.

2. RESEARCH AIM AND OBJECTIVES

This paper purports to illustrate a research paradigm for establishing a holistic, objective and reliable site safety assessment model for construction projects in Hong Kong. And two specific research objectives were set out as follows.

Objective 1: To identify a list of essential factors and their associated sub-factors which affect the safety performance of a construction project.

Objective 2: To determine a series of weightings for these factors and sub-factors in assessing an overall site safety standard.

3. ESSENTIAL FACTORS AFFECTING CONSTRUCTION SAFETY PERFORMANCE

Several research studies have led to the identification of those essential factors affecting the safety performance of construction projects. For instance, Jannadi (1996) explored the major factors affecting construction safety in the United Kingdom, i.e. safe working conditions, safety training, good safety habits, effective control of subcontractors, and close supervision on site workers. Jaselskis *et al*. (1996) provided excellent strategies for improving construction safety performance in the United States, including the number of safety inspections, dollars spent on safety programmes and percentage of time devoted to safety issues. Mohamed (1999) undertook a detailed empirical investigation into the relationship between the intensity of safety management commitment and the overall safety performance in the Australian construction industry.

Sawacha *et al*. (1999) studied seven groups of factors that can have an influence on the safety performance of construction sites in the United Kingdom, including historical, economical, psychological, technical, procedural, organisational, and environmental factors. Fang *et al*. (2004) identified the significant factors that affect safety management and then developed a safety assessment method for measuring the safety management performance of construction sites in Mainland China using factor analysis.

Tam *et al*. (2004) examined the status of safety management in the Mainland Chinese construction industry and determined the essential factors influencing site safety, i.e. poor safety awareness of leaders and managers, lack of safety training and resources, low labour skills level, insufficient enforcement of safety rules and safety equipment. Ng *et al*. (2005) established a comprehensive framework which takes into account the main factors and sub-factors pertinent to an organisation and its project for evaluating the safety management standards of the various construction contractors in Hong Kong.

Teo and Ling (2006) developed a model that safety auditors may use to assess the effectiveness of safety management systems implemented by construction firms in Singapore. Imriyas (2009) established an expert system for strategic control of accidents and insurers' risks for building projects in Singapore, and selected some key factors to be adopted in estimating a Project Safety Index (PSI).

Despite the above research studies, those identified key factors have not been linked together to provide an integrated single safety management indicator with the objective of comparing different site safety standards.

4. RESEARCH METHODOLOGY

The research process will comprise the following key stages: (1) literature review; (2) face-to-face structured interviews; (3) Delphi questionnaire survey; (4) data collection; (5) data analysis; (6)

development of a site safety assessment model; and (7) validation of the developed model. Figure 1 indicates the overall research framework for the proposed study for perusal.

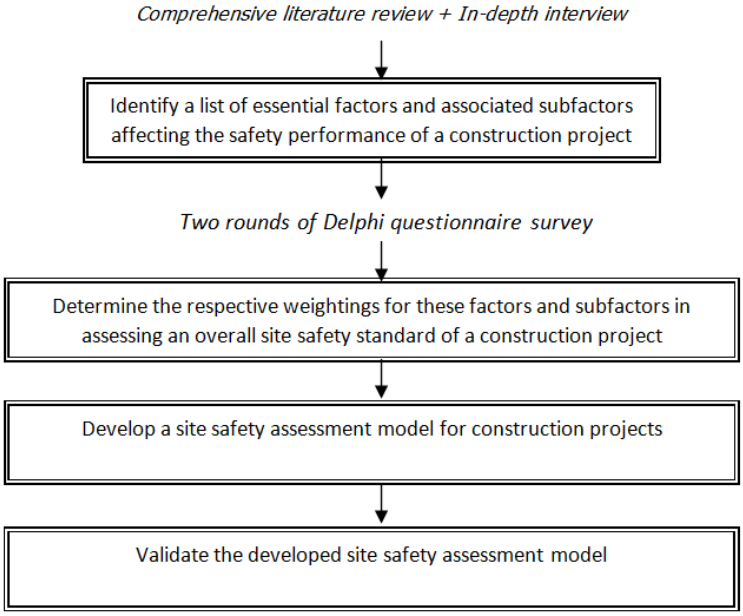

Figure 1: Flow of the Overall Research Framework

Objective 1: To identify a list of essential factors and their associated sub-factors which affect the safety performance of a construction project.

The study will begin with an extensive review of the literature on the essential factors contributing to safety performance and other site safety assessment systems and models for construction projects from all available sources. All previous relevant studies will be summarised so as to condense existing knowledge and experience on prevailing safety practices, safety regulations and safety management systems, safety performance assessment, and the principal causes of site accidents. The review will help develop the overall research framework, and help prepare appropriate templates for the in-depth structured interviews, and the Delphi questionnaire survey.

Typical core factors affecting the level of site safety performance may include: (1) complexity of project; (2) degree of safety supervision; (3) rate of labour turnover; (4) frequency of safety inspection; (5) control and management of subcontractors by main contractor; (6) frequency of legal conviction in safety; (7) experience of construction workers; (8) efforts on safety promotion; (9) frequency of safety audits or reviews; (10) frequency of reported accidents; (11) contribution of top management to safety; (12) extent of safety training and personal protection; (13) frequency of safety meeting; and (14) implementation of preventive and corrective safety measures (Chiu, 2009). Each of these 14 core factors will be further subdivided into underlying sub-factors to obtain more detailed understanding.

Through the literature review, an initial checklist of these essential safety factors and their associated sub-factors for a construction project will be placed within a systematic hierarchy of three levels: (1) the overall safety standard (at first level); (2) the core safety factors (at second level); and (3) the safety sub-factors (at third level) as indicated in Figure 2. Then a series of face-to-face in-depth interviews with relevant senior industrial practitioners (e.g. government officers, project managers, safety managers, safety officers, safety engineers, building engineers, building services engineers, safety consultants, safety academics, etc.) will be conducted to solicit their opinions and feedback on these core safety factors and sub-factors based on their abundant hands-on experience with site safety. Finally, a full list of the core factors and their associated sub-factors contributing to safety performance will be produced.

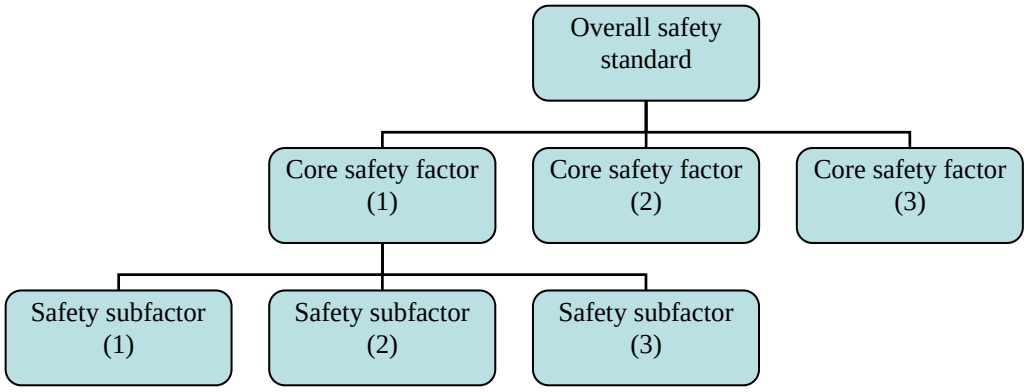

Figure 2: A Systematic Hierarchy of Essential Safety Factors and their Associated Sub-factors for a Construction Project

Objective 2: To determine a series of weightings for these factors and sub-factors in assessing an overall site safety standard.

After the literature review and interviews, two rounds of Delphi questionnaire survey will be launched as adapted by Lo (1999) and Yeung *et al*. (2007) in order to evaluate the relative importance (weightings) of the respective factors and sub-factors affecting project safety performance. The Delphi survey technique will be the primary analysis tool applied at this stage because a consensus needs to be reached. The Delphi survey method is a highly formalised method of communication designed to extract the maximum amount of unbiased information from a panel of experts (Chan *et al*., 2001; Yeung *et al*., 2007; Chan and Chan, 2012). It is generally conducted in several rounds interspersed with group opinions and information feedback in the form of relevant statistical data. Generally, the number of rounds ranges from 2 to 7 and the number of participants varies between 3 and 15 (Rowe and Wright, 1999; Adnan and Morledge, 2003). The desired outcome, by using an iterative forecasting procedure, is that on reaching the final round, the experts will have achieved unanimity on the issues put before them (Manoliadis *et al*., 2006). Therefore, the Delphi survey method is appropriate for identifying the set of the most important factors and sub-factors to be used in assessing site safety standards.

The selected panel of Delphi experts will include industrial practitioners equipped with extensive hands-on working experience in site safety assessment and prominent academics with demonstrated research experience in site safety. The Delphi experts will include government officers, project managers, safety managers, safety officers, safety engineers, building engineers, building services engineers, safety consultants, safety academics, and other allied construction professionals.

The first round of the Delphi questionnaire survey will be based on the identified list of core factors and sub-factors influencing safety performance in Stage 1. The target respondents will be invited to provide "importance" ratings to each of the identified safety factors and sub-factors based on a five-point Likert scale, ranging from 1 = least important; 2 = slightly important; 3 = important; 4 = very important and 5 = most important. A Likert scale will be adopted because the dimensions for measuring the importance of each safety factor or sub-factors should be unipolar, i.e. there are different degrees of the same attribute (Schwarz, 1996). When analysing the data, the focus must be on the opinions of the group rather than those of individuals. Therefore, the Kendall's concordance test measuring the consistency of the experts' responses over successive rounds of the Delphi questionnaire will be required. A statistical analysis will be performed on all survey questionnaires received in which the mean ratings for all the safety factors and sub-factors will be computed. Hence, a series of safety factors and sub-factors with their respective weightings will be derived based on the mean ratings advocated by the Delphi group of panel experts. The weighting for each safety factor and sub-factors will be calculated as their individual mean ratings divided by the total mean ratings of all the factors or sub-factors under consideration as computed using the following equation (Chow, 2005; Ng *et al*., 2005; Yeung *et al*., 2007; Eom and Paek, 2009; Chan *et al*., 2011; Chan and Chan, 2012):

$$W_{SF_a / SS_a} = \frac{M_{SF_a / SS_a}}{\sum_k M_{SF_k / SS_k}} \qquad \text{for a = 1} \qquad \text{(Eq: 01)}$$

Where, W_{SF_a / SS_a} represents the weighting of a particular safety factor (SF) / safety sub-factors (SS)

M_{SF_a / SS_a} represents the mean ratings of a particular SF / SS

$\sum_g M_{SF_k / SS_k}$ represents the summation of mean ratings of all the SF / SS

In Round 2 of the Delphi questionnaire survey, each participating Delphi expert will be given the consolidated results obtained from Round 1. The average ratings of the Delphi experts for all the safety factors and sub-factors, together with the Delphi expert's own ratings suggested in Round 1 will be provided. Each Delphi expert will then be requested to reconsider his/her own ratings to see if they would like to adjust their original judgements in the light of the mean scores of all the Delphi experts. By doing so, the most important weighted safety factors and sub-factors will be found out. It should be noted that the Delphi survey technique has been widely applied in many complex areas in which a consensus needs to be reached (e.g. Chan *et al*., 2001; Anatharajan and Anataraman, 1982; Saito and Sinha, 1991; Manoliadis *et al*., 2006; Yeung *et al*., 2007; Chan *et al*., 2011). Therefore, the application of the Delphi method is desirable because of the rather subjective nature of the opinions.

5. VALIDATION OF RESEARCH FINDINGS

Triangulation from multiple sources will be employed to reinforce the credibility of the findings obtained from the research data and subsequent analyses. Results derived from the in-depth interviews and the Delphi questionnaire survey will be cross-referenced to the published literature as well as with each other whenever appropriate. Appropriate workshop discussions with prominent industrial practitioners who have acquired extensive hands-on experience in dealing with various essential factors influencing the safety performance of new construction sites will be organised to generate relevant information and to supplement and/or confirm the outcomes of the analyses, and a set of possible recommendations for improving the developed site safety assessment model based in Hong Kong. A meeting will be scheduled via discussions and moderations to validate the research findings and explanations with practitioners involved in the study.

6. SIGNIFICANCE AND VALUE OF RESEARCH

According to the Occupational Safety and Health Statistics for 2012 published by the Labour Department (2013), 25.2% of the industrial accidents (3,160 out of 12,547) were in relation to the construction industry in Hong Kong. The safety record of the construction industry was poor and much worse than other major industries in Hong Kong (Wong *et al*., 2004). Although the Labour Department has promulgated several safety and health policies and regulations to avoid or mitigate the occurrence of accidents, the frequently reported cases of site accidents prove that their effectiveness is far from satisfactory, and the overall safety performance is still at a high level.

Site supervisory teams do not usually conduct a proper, holistic site safety assessment. Despite some research studies undertaken on safety management evaluation, those important individual factors identified have not been combined together to generate an integrated single measure of site safety for the objective comparison of different workplace safety standards. This undesirable situation may be attributed to the lack of an appropriate safety assessment mechanism that could be employed to evaluate the existing safety standards in town. To remedy this deficiency, this proposed study will investigate the subject and develop a holistic, objective and reliable site safety assessment model for use. Project managers, safety managers, safety officers, safety engineers, safety consultants and other related construction personnel will be assisted with such a model to objectively assess the overall safety standards of their individual projects, and to prioritise improvement measures for the under-performing areas.

A practical site safety assessment model can enable developing a benchmarking tool for measuring and comparing the overall safety standards of the different construction projects within an organisation, between organisations and within the construction industry. A composite overall site safety assessment score, which is representative of all the essential factors and their associated sub-factors, will be derived by the model to provide this single measure. The safety standards of different construction projects can then be evaluated and compared objectively on the same basis for benchmarking purposes. The overall safety assessment score can be monitored throughout the entire construction period for any one site and upon completion. The model will ultimately be developed as an online computerised system enabling industrial practitioners to easily and promptly measure and compare their overall safety standards in search of future safety excellence.

7. CONCLUSIONS

There exist many causes of accidents on construction sites, but key is the general lack of awareness of the nature of the various essential factors contributing to safety performance. Assessing safety performance simply by looking at the number of accidents or legal convictions alone has long been perceived as an inadequate measure or indicator for a particular construction site (Ng *et al*., 2005). However, there is no comprehensive and systematic empirical research into this issue which takes into consideration all the essential factors and their underlying sub-factors available that influence the safety performance of construction projects as a whole, especially in Hong Kong. To improve the situation of short of an appropriate safety assessment mechanism in town, this proposed research aims to develop a holistic, objective and reliable site safety assessment model. The site safety assessment model will be made computerised to facilitate easy application. Although the research study will primarily focus on the prevailing situation in Hong Kong, the research methodology will be applicable to many other parts of the world. Indeed, it could form the basis for international comparisons of the extent to which the essential factors contributing to safety performance are identified, evaluated and guarded against.

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