THE ROLE OF STATE DOTS IN HIGHWAY WORK ZONE SAFETY MANAGEMENT

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ABSTRACT

The highway construction sector in the United States accounts for an injury rate that is approximately one and a half times greater than the industry-wide average and nearly ten times greater than the all-industry average. According to literature, this exceptionally high injury rate is due to the prevalence of night time work, high speed traffic near work zones, highly repetitive work tasks, and poor safety management. In their role as funding agencies and employers, State Departments of Transportation (DOTs) are in a unique position to promote and enforce safe work practices for highway construction and maintenance. The study from which this paper is written aimed: (i) to identify safety management strategies implemented by DOTs; (ii) to distinguish between the strategies implemented to manage DOT employees and those designed to manage private firms; (iii) and to identify potential areas of improvement. These objectives were achieved by conducting an online survey of members of the American Association of State Highway and Transportation Officials (AASHTO) Subcommittees on Construction and Safety Management, both with at least one representative from each DOT. While the results indicate that most state DOTs have a well-established safety management program for their own employees, few strategies are implemented to promote and enforce safe work practices on sites managed by private construction firms. State DOTs could help to improve worksite safety by including contract provisions that require private contractors to implement specific safety program elements, pre-qualifying contractors with superior safety records, and actively participating in contractor's safety management activities.

Keywords: State Departments of Transport, Highway construction, Safety management requirements, Contractor management

INTRODUCTION

It is no secret that the construction industry accounts for a disproportionate injury rate. Within the construction industry, the highway construction sector is particularly dangerous. According to the National Safety Council (2008), the US highway construction sector accounts for an injury rate that is approximately one and a half times greater than the industry-wide average and nearly ten times greater than the all-industry average. The Federal Highway Administration (FHWA 2004) estimates that a work zone fatality occurs once every ten hours and a work zone injury occurs every thirteen minutes. Furthermore, the estimated direct cost of highway construction zone accidents was $6.2 billion per year between 1995 and 1997 with an average cost of $3687 per accident (Mohan and Gautam 2002).

Highway work zone safety has been a high-priority issue among both traffic engineering professionals and government officials over the past decade. In 1998, congress provided over $200 billion dollars for transportation-related programs by passing the Transportation Equity Act for the 21st Century (TEA-21). This Act and associated funding focused on increasing the volume of highway improvement projects and improving worker and passenger safety. Also in 1998, the National Work Zone Safety Information Clearinghouse was created to improve safety in highway work zones. Despite these efforts, the frequency of work zone injuries and fatalities has steadily increased between 1992 and 2000 while the volume of construction work remained relatively

constant (BLS 2007). This fact illustrates the importance of management strategies that improve work conditions on highway projects.
State Departments of Transportation (DOTs) play an important role in affecting work zone safety. First, states tend to self-perform the majority of highway maintenance work employing thousands of workers and maintenance managers. While small in physical size, maintenance worksites involve a high risk of injury for workers with incident rates as high as 10.60 recordable injuries per 200,000 worker-hours. Second, state DOTs serve as Owner agencies that fund billions of dollars of transportation projects each year. In this role, DOTs are in a position to require private construction firms to implement a comprehensive safety program on publically-funded highway projects.

This paper presents a study of US State DOTs' safety practices. Using a survey of state DOTs, this study aimed to identify safety management strategies implemented by DOTs; to identify any relationships between specific safety program elements and DOT safety performance; and to suggest potential areas for improvement.

BACKGROUND

A Bureau of Labor Statistics (2007) survey of fatal injuries occurring within American highway work zones found that, among 492 work zone fatalities, the leading occupations affected were construction laborers (42%), truck drivers (9%), construction trades supervisors (8%), and operating engineers (8%). In addition to risks associated with specific professions and work tasks, there are characteristics associated with work zones that contribute to the highway sector's disproportionate injury rate such as night-time work, use of heavy mobile equipment, and incursions. The following is a review of literature that discusses the impact of these characteristics on work zone safety and the management techniques recommended for mitigating the safety risks.

Night-time work

As state DOTs continue to repair America's progressively failing transportation infrastructure, roadways must be renewed quickly with minimum disruption to the community. Such work requires the use of specific strategies such as night time work, continuous work, extended shifts, to compress schedules. Night-time highway construction and maintenance is significantly more hazardous for workers because of decreased visibility, an increase in drivers impaired by drugs and alcohol, fatigue, and age-related vision impairments (Arditi et al. 2005). According to this study, the factors that most contribute the night-time fatalities on highway construction and maintenance sites include poor lighting conditions (43%), unfavorable weather conditions (8%), poor performance of safety garments (7%), workers not wearing safety garments (14%), conditions of vehicle operator (64%), and other causes (32%).

Heavy mobile equipment

The majority of fatal injuries on road construction sites have been attributed to vehicle- and mobile heavy equipment-related incidents. An analysis of 240 incidents involving serious injuries to workers on highway and bridge construction projects in New York State confirms that highway workers are at risk of severe nonfatal injuries from being struck by construction equipment (Bryden and Andrew 1999).

Incursions

Incursions, defined as the entries of a private passenger vehicle into an active work sites, are becoming a much larger problem as more highway construction work is performed on active roadways. The Indiana Department of Transportation (2008) found that the U.S. has over 40,000 work zone crash injuries each year. According to Harb et al. (2008), between 1999 and 2008, work zone related crashes have increased 334%.

Mitigating safety risk

To respond to the highway construction and maintenance safety risks, several studies have been performed that focus on identifying strategies that mitigate work zone safety risk. For example, the National Institute for Occupational Safety and Health (NIOSH) conducted a study that involved a three-day workshop that brought together sixty stakeholders from government agencies, labor unions, and private employers to discuss measures to reduce the rate of injuries in highway workzones. The resulting document includes preventative measures to help protect highway workers from hazards posed by construction and traffic vehicles and is considered the most definitive guide to highway work zone safety (NIOSH 2001).

NIOSH (2001) suggests that road builders and maintainers adopt the following strategies to prevent work zone accidents:

- Assign a traffic control supervisor who is knowledgeable in traffic control principles and who will assume overall responsibility for the safety of the work zone setup;
- Set up temporary traffic control devices, such as signage, warning devices, paddles, and concrete barriers in a consistent manner throughout the work zone to provide passing motorists with advanced warning of upcoming work zones;
- Educate flaggers in topics such as traffic flow, work zone setup, and proper placement of channelizing devices; and
- Require all workers on foot to wear high-visibility safety apparel

The above strategies are suggested to be performed in addition to a comprehensive safety management program. Safety studies of the general construction industry have identified the most effective safety program elements for mitigating safety risk (Jaselskis et al.,1996; Hinze, 2006; Hallowell 2008; Molenaar 2009). These studies agree that the safety program elements identified and described in Table 1 constitute an effective safety program. While these elements vary in their effectiveness, each is essential to the development of a synergistic safety program. The descriptions provided in Table 1 are based upon the large body of literature on the topic of construction injury prevention.

STUDY OBJECTIVES

This study departs from the established body of knowledge by describing the results of a study that aimed to benchmark the current level of safety management efforts implemented by state DOTs and to statistically evaluate the effectiveness of these efforts. This knowledge is expected to provide context for researchers who aim to improve safety management for highway maintenance and construction. Based on the relatively high injury rate and previous literature, the writers expected that state DOTs lag behind private industry in their level of safety management despite their unique position to improve safety and health for their employees and contractors.

Table 1 – Essential construction safety program elements

1	**Upper Management Support**	Demonstrated commitment of upper managers to worker safety including participation in regular safety meetings, serving on committees, and providing funding for safety
2	**Subcontractor Selection & Mgt**	Consideration of safety and health performance during the selection of subcontractors
3	**Employee Involvement and Evaluation**	A means of including all employees in the formulation and execution of other program elements
4	**Job Hazard Analyses & Hazard Communication**	A process of reviewing the activities associated with a construction process and identifying potential hazardous exposures that may lead to an injury
5	**Training & Regular Safety Meetings**	The establishment and communication of project-specific safety goals, plans, and policies before the construction phase begins
6	**Frequent Worksite Inspections**	Inspections performed internally by a contractor's safety manager, safety committee, representative of the contractor's insurance provider, or by an OSHA or private consultant
7	**Safety Manager on Site**	Employment of a full-time safety and health professional with the sole responsibility of promoting construction safety and health within the firm
8	**Substance Abuse Programs**	A formally established program that targets the identification and prevention of substance abuse within the workforce through regular for all new hires, after occupational injuries, and periodic random tests

9	**Safety and Health Committees**	A formal group composed of supervisors, laborers, representatives of key subcontractors, owner representatives, OSHA consultants, etc. formed with the sole purpose of addressing safety and health on the worksite
10	**Safety and Health Orientation**	Orientation and training of all new hires (including skilled and experienced workers) by informing them of company safety goals, policies, programs and resources
11	**Written Safety Plan**	The documentation of project-specific safety and health objectives, goals, and methods for achieving safety success.
12	**Record Keeping and Accident Analysis**	The documentation and reporting the specifics of all accidents including information such as time, location, work-site conditions, and cause
13	**Emergency Response Planning**	The creation of a plan in the case of a serious incident such as a fatality or an incident involving multiple serious injuries.

RESEARCH METHODS

Following the typical framework of any postpositivism knowledge claim, the principal strategy of inquiry was a survey. The survey data were supplemented with information obtained through interviews when necessary and appropriate. The specific structure of the survey and purpose for supplementary research methods are discussed below.

Survey design

A survey was selected as the primary research method because it was the most feasible means of gathering vast quantities of information in a limited timeframe and because it is the suggested research method for studies that aim to identify specific organizational characteristics or practices (Yin 2001). The purpose of this survey was to determine the state of practice among state DOTs regarding internal safety management of construction and maintenance employees. The survey included twenty-nine questions that focused on the demographics of the respondent, demographics of the state DOT that they represented, and the degree of implementation of the thirteen safety management strategies in Table 1.

This survey was directed towards the complete population of state DOTs to ensure optimal external validity. Fortunately, highway construction and maintenance experts are conveniently assembled as the American Association of Highway and Transportation Officials' (AASHTO) Subcommittee on Safety Management. This committee includes at least one representative from every state DOT who is knowledgeable about safety management activities for their state. To expedite the distribution and collection, the survey was posted online and circulated via hyperlink in an email sent to each member of the Committee.

The first section of the survey focused on defining the demographics of the respondents and the state DOT that they represented. Questions inquired about the respondent's experience in the highway construction industry, job title, and role with respect to safety. Respondents were also asked to answer questions related to their DOT's construction and maintenance budget, worker injury/illness rates, and percentage of construction and maintenance work self-performed.

The second section aimed to benchmark the current level of safety management implemented by DOTs to reduce the rate of injuries of their employees. Specifically, questions were designed to assess level of implementation of the thirteen safety program elements in Table 1. For each safety program element, the respondent was asked to indicate which of the following categories best describes the level of implementation: (1) implemented consistently on all projects (agency-wide); (2) specifically designed for and implemented on some sites; (3) specifically designed and implemented on most sites; (4) specifically designed for and implemented on all sites; or (5) rarely or not implemented. To maintain consistency and to ensure that all respondents understood the definition of the safety program elements, a link to a webpage that included the descriptions was provided. Finally, the third section included an open-ended question that inquired about specific safety-related contractual requirements for private contractors set forth by the DOT.

Because some respondents were unable to answer all survey questions, supplementary interviews were conducted. Since respondents had the most difficulty quantifying the injury rate and budget information for their state, personnel with senior management positions or individuals charged with the responsibility for maintaining statistical databases were contacted. Contact information was provided by the survey respondents.

RESULTS

The response to the survey was very strong and the respondents were well qualified. In total, a complete response was obtained by representatives from 32 of the 50 state DOTs (response rate = 64%). The respondents were surprisingly well qualified averaging over 18 years of experience in the highway construction industry. In addition, all respondents were either safety specialists or construction engineers with extensive safety training. Figure 1 presents the distribution of experience of the respondents.

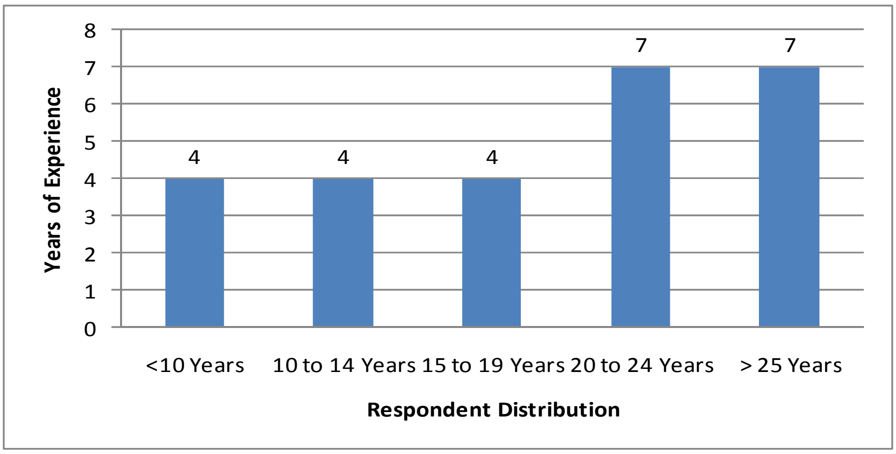

Figure 1: Histogram of Respondents' Experience in the Highway Construction Industry

The demographics of the 32 state DOTs varied greatly. For example, incident rates ranged from a low of 3.1 recordable injuries per 200,000 worker-hours in Florida to over 10 recordable injuries per 200,000 worker-hours in Oregon and Colorado. It was surprising that the range was so great given the the fact that the OSHA definition of a recordable injury has been adopted by each state. Not suprisiingly, however, the operating budget for the DOTs varied greatly as well ranging from under $100 million to over $2 billion. However, while the total budget for the DOTs varied greatly, almost all DOTs allocated approximately 25 percent of the budget for maintenance and 75 percent for new construction. Figure 2 illustrates the distribution of construction and maintenance budgets for the 32 responding state DOTs.

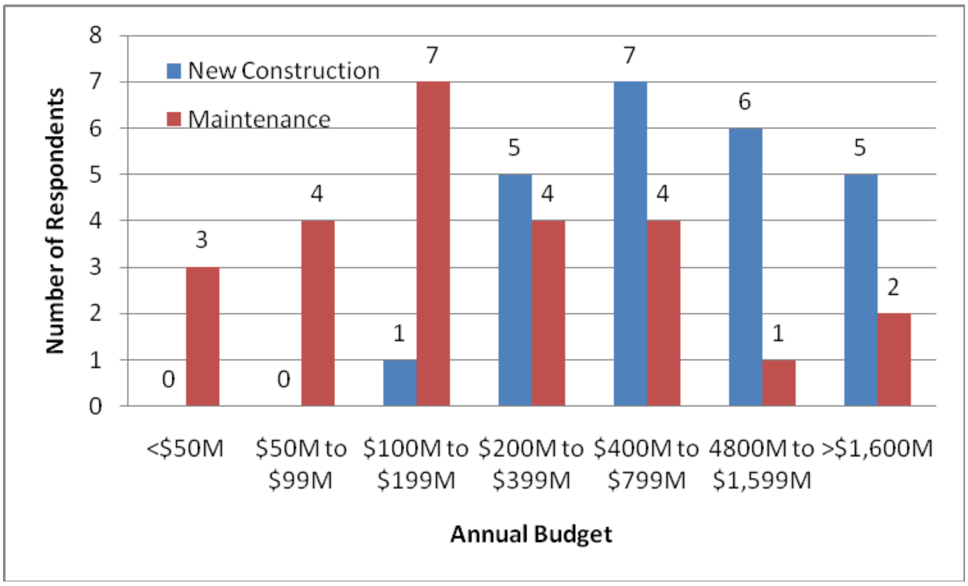

Figure 2: Histogram of 2007 DOT New Construction and Maintenance Budgets

Table 2 presents the salient results of the survey. This table includes a summary of the responses to the closed-ended questions about safety program element implementation. For easy comparison, the incident rate for each DOT is provided along with their safety program information in this table. One will note that five states could not report their incident rate (AK, DE, NY, PA, and VT) but provided complete information about their safety program. These states are included in this presentation of results but were not included in the subsequent analysis. The element numbers in Table 2 correspond to the numbers associated with each element in Table 1.

As one can see from the summary, implementation is equivocal among DOTs. This reflects the lack of integration, knowledge sharing, or consistency among the 32 state DOTs surveyed. While the data appear to be scattered, a comparison of the top 25th percentile of incident rates and 75th percentile reveal several trends. First, the majority of high-performing states implement the majority of their elements agency-wide with a standardized procedure throughout the state while DOTs with a poor safety record tend to have more project-specific elements and elements that are not implemented. Further analysis of the results is provided in the subsequent section of this paper.

The final section of the survey fcoused on determining what, if any, safety requirements of private firms are included in DOT contracts. The response was surprising in that 26 of the 32 responding states indicated that they do not require specific safety efforts as a part of their contracts. For the six states that did include safety requirments, respondents indicated that the requirement of a written safety plan (4), an emergency response plan (3), and a safety manager (2) were most commonly-included in contracts. One should note that the respondents did indicate that for some large contracts some additional safety requirements may be included. However, these requirments are not standard and are largely project-specific.

Table 2: Safety Element Implementation

State	Incident Rate	Safety Program Element												
		#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13
AK	--	AW	AW	AW	AW	AW	AW	AW	AW	AW	AW	PS-M	VR	AW
DE	--	PS-M	PS-M	PS-M	PS-M	PS-M	PS-M	PS-M	PS-M	PS-M	PS-M	PS-M	PS-M	PS-M
NY	--	AW	AW	AW	AW	PS-M	AW	AW	AW	AW	PS-S	PS-S	PS-S	AW
PA	--	PS-M	PS-M	PS-A	PS-M	PS-A	PS-S	PS-M	PS-A	AW	AW	PS-S	PS-A	AW
VT	--	AW	AW	PS-M	VR	AW	AW	AW	PS-S	VR	VR	AW	AW	PS-S
OR	10.6	AW	AW	AW	AW	AW	AW	AW	PS-A	AW	AW	AW	VR	AW
CO	10.0	AW	AW	PS-M	AW	PS-S	PS-S	AW	AW	AW	AW	AW	AW	AW
AK	8.2	PS-S	PS-S	VR	VR	PS-S	PS-S	PS-M	AW	VR	VR	VR	VR	PS-S
MN	8.0	AW	AW	PS-S	AW	PS-S	AW	AW	PS-S	AW	VR	PS-S	VR	VR
NC	7.1	AW	AW	AW	AW	PS-S	AW	AW	AW	AW	AW	PS-S	PS-M	AW
WI	6.9	AW	AW	AW	AW	PS-S	AW	AW	AW	AW	AW	PS-S	AW	AW
IL	6.7	AW	AW	PS-S	AW	PS-S	AW	AW	PS-S	VR	AW	VR	AW	AW
KT	6.6	PS-M	PS-M	PS-S	PS-S	VR	PS-S	AW	PS-S	PS-S	VR	PS-S	PS-S	PS-S
HI	6.5	AW	AW	AW	PS-M	AW	AW	AW	AW	AW	AW	PS-S	PS-S	AW
WY	6.4	AW	AW	AW	AW	PS-S	AW	AW	AW	AW	VR	VR	VR	AW
MI	6.2	AW	AW	AW	AW	PS-S	AW	AW	PS-S	AW	AW	PS-S	VR	PS-S
KS	6.1	AW	AW	AW	AW	PS-S	AW	AW	PS-S	AW	AW	VR	VR	PS-S
ID	6.0	AW	AW	AW	PS-M	AW	AW	AW	PS-A	AW	AW	AW	VR	AW
AZ	5.9	PS-M	AW	AW	AW	AW	AW	AW	AW	AW	AW	PS-S	VR	AW
MT	5.9	AW	AW	PS-S	AW	AW	AW	AW	AW	AW	PS-A	PS-S	PS-A	AW
VA	5.9	PS-S	AW	VR	AW	AW	PS-A	PS-A	AW	AW	AW	PS-S	PS-S	PS-A
GA	5.6	PS-S	PS-M	PS-S	PS-S	PS-S	VR	PS-S	PS-M	PS-S	VR	PS-S	VR	VR
ME	5.5	PS-A	AW	AW	AW	AW	AW	AW	AW	AW	AW	AW	PS-A	AW
WV	5.4	AW	AW	PS-S	PS-S	PS-S	AW	PS-A	PS-A	AW	AW	AW	AW	AW
NM	5.3	PS-M	AW	PS-M	AW	AW	AW	AW	AW	AW	PS-M	PS-M	VR	AW
CA	5.0	AW	AW	AW	AW	PS-S	AW	AW	AW	AW	AW	VR	PS-M	PS-M
MD	4.6	AW	AW	AW	AW	AW	AW	PS-M	AW	AW	AW	AW	VR	AW
ND	4.4	AW	AW	AW	AW	AW	PS-M	AW	AW	AW	AW	VR	PS-S	AW
NJ	4.3	AW	AW	AW	AW	AW	AW	AW	VR	AW	AW	VR	VR	AW
TX	4.1	AW	AW	AW	AW	AW	AW	AW	AW	AW	AW	AW	VR	AW
UT	3.9	AW	AW	PS-M	AW	PS-M	AW	AW	PS-M	AW	AW	PS-M	AW	AW
FL	3.1	AW	PS-A	AW	AW	PS-A	AW	AW	PS-A	AW	VR	PS-M	VR	AW

Legend

VR	Very Rare
PS-S	Project-Specific (Some)
PS-M	Project-Specific (Most)
PS-A	Project-Specific (All)
AW	Agency-Wide (Standard)

ANALYSIS

The data obtained from the survey was used along with risk mitigation ratings assigned to each safety program element by Hallowell (2008). The objective of this analysis was to draw statistical conclusions regarding the impact of specific safety program elements on incident rates and correlations between the nature of the safety program and safety performance. The Analysis of Variance (ANOVA) test and multiple linear regression analysis were used to analyze these data using the Statistical Package for the Social Sciences (SPSS). The use of ANOVA and linear regression was appropriate for this data set because the independence, equal variance, and normal distribution requirements were met. The samples were deemed to be independent as the incident rates had no possible impact on one another or on the level of implementation of safety program elements. Secondly, Levene's test for equal variance was used to detect and statistically significant differences among sample variance. All of the significance values for Levene's Test far exceeded 0.05 except for that of element #11 (Safety Manager on Site), which yielded a value of 0.04. Finally, histograms of each variable were created and a roughly normal distribution was observed with no outliers.

The second set of tests was performed to assess the potential impact of maintenance budget on safety performance. While a linear regression analysis did not return statistically significant results, a two-sample t-test for a difference between incident rates between the states with the ten highest incident rates and those with the ten lowest incident rates showed that, on average, states with a low incident rate had a maintenance budget that was $181 million (56%) higher than those with a high incident rate (p=0.03).

The final analysis for this study involved using linear regression to determine if a relationship exists between implementation of elements and incident rates using risk mitigation ratings published by Hallowell (2008). These risk mitigation ratings represent the best known distinction of effectiveness among construction safety program elements. For this analysis, the writers chose to include the risk mitigation rating for an element in the overall 'safety implementation effort' score if the element was implemented in any of the categories in Table 2 except 'very rare'. The scores were not included if the respondents indicated that the element was very rarely implemented. Unfortunately, there was no statistical correlation of significance (R-squared = 0.20).

It should be noted that there are some obvious discrepancies in Table 2. For example, Oregon, the worst performing state DOT, implements the vast majority of their safety program elements state wide. This is also true for other states with a poor safety record such as Colorado, Wisconsin, and North Carolina. This is counterintuitive because most literature supports the assertion that company-wide policies promote the standardization of safe work practices (Hinze 2006). It should also be noted that there are few discernable trends in Table 2 and that there is no consistency within or among state DOTs in their safety management practices. In fact, the only observable trend in Table 2 is that poor performing state DOTs implement project-specific elements only on some projects.

LIMITATIONS

There are several limitations of this study that should be noted. First, the survey methodology utilized self-reported data. While each state utilizes similar benchmarking and metrics, self-reporting may have involves substantial bias. This study has relatively poor internal validity, as the effect of the chosen independent variables cannot be completely isolated from other plausible factors. Confounding factors may help explain the lack of statistically significant differences and correlations. Finally, the study does not distinguish the relative impact of the various implementation schemes shown in the legend in Table 2.

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this paper was to determine the state of practice for state departments of transportation with regards to construction safety. Surveys were collected from safety and construction professionals from 32 of the 50 state DOTs. Demographic information was acquired from the surveys for these DOTs, including data for annual budgets, safety department sizes, injury/illness rates, performance types of construction and maintenance work, and personal credentials for the respondents. Upon examining the survey results, it was found that most safety program elements were implemented at a company-wide level, accounting for 61% of all responses. The few exceptions of elements were worksite inspections and substance abuse programs, which were more commonly implemented on a project-specific level, and subcontractor selection and management, which were most often not implemented at all. This trend was steady across all states except Alaska, Delaware, Georgia, Kentucky, and Pennsylvania, that implemented a majority of their programs at a project-specific level. Furthermore, there is no consistency within or among state DOTs in their safety management practices. The authors recommend that state DOTs attempt to open lines of communication with regard to safety through formal forums such as the AASHTO Subcommittee on Safety, the American Society of Safety Engineers' Construction Practice Specialty, or the American Society of Civil Engineers' Site Safety Committee.

In an attempt to establish statistical relationships between incident rates and demographic or elements implementation data, two types of analysis were performed. These analyses included ANOVA tests for impact of safety program elements on incident rate and multiple linear regression to determine the impact and interrelationships among elements. No statistically significant results were achieved through any of these tests.

Qualitative data obtained through the survey proved to be most useful. For example, the benchmarking of current levels of implementation will aid researchers with continuing investigations of DOT safety management strategies as it provides the first baseline assessment of current practices. Secondly, the feedback from respondents that DOTs do not include safety-related requirements in their contracts indicates that there is great potential for DOTs to serve as model Owner agencies and take an active role in reducing the extraordinarily high injury rate on highway work zones. The authors suggest that DOTs utilize the findings presented by Huang and Hinze (2006). This study outlines the various ways that Owners can have a positive impact on site safety.

The writers suggest future research in this area that takes an in-depth look at the safety practices of DOTs with low incident rates. The writers believe that the lack of knowledge sharing among DOTs with respect to safety may be counteracted by strong case study research and dissemination of results.

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THE COORDINATION OF HEALTH AND SAFETY (H&S) AND THE INTEGRATION OF H&S INTO PROJECTS AND THE CONSTRUCTION PROCESS

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ABSTRACT
Historically, cost, quality, and time have constituted the traditional project parameters, and health and safety (H&S) has been perceived as the contractor's responsibility. However, enabling environment H&S legislation promulgated in South Africa has realised client and designer responsibility for H&S, and to a lesser extent, responsibility on the part of project managers and quantity surveyors.

There are two key issues, namely the extent to which H&S is integrated into projects, and, secondly, into the construction process. The former requires multi-stakeholder contributions, and the latter is site focused.

A survey was conducted among a group of 'better practice H&S' general contractors (GCs), the objectives being to determine: (i) the importance of the various project parameters to the South African construction industry; (ii) the performance of the South African construction industry in terms of various aspects / issues at project level and during the construction process, and (iii) the perceptions of respondents relative to various aspects / issues at project level and during the construction process.

Selected findings are: (i) cost, quality, and time are more important than H&S; (ii) design and construction are not integrated in terms of H&S; (iii) client appointed H&S agents are perceived to lack the requisite generic and H&S competencies; (iv) non-contracting stakeholders are perceived to lack the requisite H&S competencies; (v) stakeholders are not pre-qualified in terms of H&S, and (vi) H&S is integrated into site management, the construction process, and activities.

The paper concludes that the coordination of H&S and the integration of H&S into projects and the construction process are not effective. Recommendations include the inclusion of a project H&S coordinator to be responsible for the coordination and integration of H&S at project level and during the construction process in legislation.

Keywords: Health and safety, Coordination, Integration, Construction

INTRODUCTION

Lingard and Rowlinson (2005) contend that the way the construction industry is organised does not promote the development or implementation of ways to eliminate hazards or reduce risks to the H&S of workers to an acceptably low level. Design and construction are separated in general, but also in terms of H&S. Furthermore, design is executed by a range of designers, and subcontracting is pervasive, resulting in a range of contributors. Construction H&S competencies are also necessary to enable the various stakeholders to contribute to construction H&S.

Given the aforementioned, a pilot study was conducted, the two broad objectives being to determine the extent to which H&S is integrated into projects, and secondly into the construction process.

REVIEW OF THE LITERATURE

Project parameters

Hinze (2006) states that whenever a contract is entered into, cost, quality, and time are invariably included, or for that specifically, in that the project must be completed within a stated time, to the requisite quality standards, and for a specific sum of money.

A study conducted by Smallwood and Haupt (2006) required respondents to indicate the importance of five project parameters on a scale of 1 (not) to 5 (very), which enabled the computation of a mean score ranging between 1 and 5. The sample stratum consisted of member practices of the Association of Construction Project Managers (ACPM), Association of South African Quantity Surveyors (ASAQS), South African Association of Consulting Engineers (SAACE), and the South African Institute of Architects (SAIA), and a group of 'better practice H&S' general contractors (GCs) who had achieved a first, second or third place in the Building Industries Federation South Africa (BIFSA) national Health and Safety (H&S) competition during the years 1995 to 2004 inclusive. Based upon 300 responses, Table 1 indicates that in terms of the mean and each of the respective organisations, the traditional project parameters of cost, quality, and time were ranked within the top three.

Table 1: Degree of importance of various parameters to respondents' organizations (Smallwood and Haupt, 2006)

Parameter	ACPM		ASAQS		SAACE		SAIA		Contractors		Mean	
	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank
Project cost	4.63	2	4.74	1	4.42	2	4.39	2	4.89	1=	4.61	1
Project quality	4.37	3	4.15	3	4.64	1	4.64	1	4.78	3	4.52	2
Project time	4.68	1	4.41	2	4.29	3	4.25	3	4.89	1=	4.50	3
Project H&S	3.95	4	3.65	4	3.97	4	3.43	5	4.33	4	3.87	4
Environment	3.42	5	3.32	5	3.76	5	4.01	4	3.56	5	3.61	5

Interventions and competencies

In terms of the South African Construction Regulations, clients are required to undertake a range of actions, inter alia, appoint a principal contractor (PC) that is competent and has the resources. However, clients may appoint an agent in terms of the responsibilities, but the agent must be competent and have the resources (Republic of South Africa, 2003).

In terms of the Construction Regulations the definition of designers includes architects, engineers, and quantity surveyors, the rationale for the inclusion of the latter being that they specify inter alia, materials. The Construction Regulations require designers to: make available all relevant information about the design such as the soil investigation report; design loadings of the structure, and methods and sequence of construction; inform principal contractors of any known or anticipated dangers or hazards or special measures required for the safe execution of the works, and modify the design or make use of substitute materials where the design necessitates the use of dangerous structural or other procedures or materials hazardous to H&S.

These requirements in turn require that designers inter alia, conduct hazard identification and risk assessments (HIRAs). However, a pre-requisite is that they possess construction H&S competencies. Furthermore, the requirements imply that the client must ensure that the designers and contractors they appoint have the requisite competencies and resources.

In terms of the Construction Regulations (Republic of South Africa, 2003) principal contractors are required to: conduct risk assessments.

Pre-qualification

Levitt and Samelson (1993) advocate that H&S be included as a criterion for contractors and subcontractors to pre-qualify to bid on projects. They state that experience indicates that pre-qualifying and / or selecting contractors and subcontractors, in part, or on their expected H&S performance will help to decrease accidents.

Commitment / Integration

Levitt and Samelson (1993) state that in order for projects to achieve excellent H&S records the site managers must be committed and include H&S as an important goal by their own presence and example. They have to demonstrate how important H&S is to them such that their staff and workers take H&S seriously and integrate it into their everyday activities. They further state that the integration of H&S into all job activities is one of the fundamental tenets of healthy and safe, productive, quality project performance.

Site H&S personnel

According to Hinze (2006, citing Eich 1996), a study conducted among the 400 largest contractors in the USA determined that the contractors with the better H&S records had a standard practice of employing at least one full-time H&S representative on their sites. The South African Construction Regulations require the appointment of a part-time or full-time H&S Officer to assist in the control of all H&S aspects on a site. The South African Occupational Health and Safety Act requires that where there are twenty or more employees in a work place an H&S Representative must be appointed, and thereafter one for every additional fifty employees. Given that such a Representative must be a full-time employee elected from the workforce, the requirement has the intended effect of integrating H&S into the work place.

Coordination

Hinze (2006) emphasises the importance of coordination on site due to the number of subcontractors (SCs) involved. However, during research conducted on 24 high-rise projects in Canada (Hinze, 2006 citing Raboud, 1986) determined that the general contractors (GCs) with the better rated ability to coordinate construction activities had the better H&S records. A further study conducted on 57 large commercial and industrial projects in the United States of America (USA) determined that SCs working on the projects of GCs that were rated excellent in terms of coordination ability had better H&S performance than SCs working on the projects of GCs that were rated average in terms of coordination ability (Hinze, 2006 citing Hinze and Talley, 1988).

The Construction (Design and Management) Regulations 2007 (Health & Safety Commission, 2007) require the appointment of a CDM Coordinator. This requirement supercedes the appointment of a Planning Supervisor as previously required. The role of the CDM Coordinator is to provide the client with key project advice in respect of construction H&S matters. The CDM Coordinator should: assist the client in terms of appointing competent designers and contractors and the adequacy of management arrangements; ensure proper coordination of the H&S aspects of the design process; identify and collect the necessary pre-construction information and provide same to the designers and contractors; facilitate sound communication and cooperation between the project team members; manage the flow of H&S information between the client, designers, and contractors; advise the client regarding the suitability of the initial construction phase plan, and prepare the H&S file. The South African Construction Regulations do not require similar actions of Client Appointed H&S Agents, in particular, the coordination of the H&S aspects of the design process, and managing the flow of H&S information between the client, designers, and contractors.

Barriers to improvement of H&S

Lingard and Rowlinson (2005) contend that the traditional separation of design and construction functions can seriously limit the identification of innovative solutions to H&S problems at the design stage of a project. The reason being, that decisions made during the design stages of a project impact on the H&S of workers that have to execute the design. Furthermore, it is widely accepted that eliminating a hazard at source or reducing risks to an acceptable level through engineering or design solutions, are the most effective. Therefore, the integration of design and construction is a critical aspect in terms of achieving optimum H&S.

Competitive tendering constitutes a further barrier as it results in pressure on tenderers to keep their bids low, to increase the likelihood of being awarded the work. Such pressure can discourage tenderers from making an optimum allowance for H&S (Lingard & Rowlinson, 2005).

Subcontracting has also been cited as a factor contributing to the poor H&S performance of the industry (Lingard & Rowlinson, 2005). Subcontractor (SC) employees may not be familiar with H&S rules and healthy and safe systems of work. Furthermore, one SC's work might give rise to risks to another SC. Research conducted in the USA determined that the H&S performance of SCs is directly influenced by the number of SCs employed on the projects, the less SCs working on a project, the lower their relative reportable injury rate (Hinze, 2006 citing Hinze and Talley, 1988).

Emphasis on contractual relationships is a further factor identified by Lingard and Rowlinson (2005), the issue being that such emphasis detracts from communication. They cite Glenda and McKenna (1995) who contend that restricted communication is often associated with coordination problems.

RESEARCH

Methodology and sample stratum

Given the objectives of the study it was necessary to select a sample stratum consisting of contractors, which could be presumed to be committed to and which address H&S, and related issues, and therefore best able to rate the construction industry relative to H&S. The sample stratum consisted of 26 GCs, who had achieved first, second, or third positions in the Building Industries Federation South Africa (BIFSA) / Master Builders South Africa (MBSA) national H&S competition and, or BIFSA / MBSA 4 or 5-Star H&S gradings on one or more of their projects during the period 1995 to 2003 inclusive. 10 Responses were received and included in the analysis of the data, which equates to a response rate of 38.5%.

Findings

Table 2 indicates the importance of five parameters to the South African construction industry according to respondents in terms of percentage responses to a scale of 1 (not important) to 5 (very important), and a mean score (MS) ranging between 1.00 and 5.00. It is notable that all the MSs are above the midpoint score of 3.00, which indicates that in general the respondents can be deemed to perceive the parameters as important to the South African construction industry. However, a review of the MSs in terms of ranges provides a more detailed perspective:

- MSs > 4.20 ≤ 5.00: between more than important to very important / very important – project cost and project time;
- MSs > 3.40 ≤ 4.20: between important to more than important / more than important – project H&S and project quality, and
- MSs > 2.60 ≤ 3.40: between less than important to important / important – environment.

It is notable that two of the three traditional project parameters are ranked first and second, and that the third, namely quality, is ranked fourth after project H&S.

Table 2: Importance of project parameters to the South African construction industry

Parameter	Unsure	Not …………………………………… Very					Mean score	Rank
		1	2	3	4	5		
Project cost	0.0	0.0	0.0	0.0	20.0	80.0	4.80	1
Project time	0.0	0.0	10.0	0.0	30.0	60.0	4.40	2
Project H&S	0.0	0.0	0.0	20.0	50.0	30.0	4.10	3
Project quality	0.0	0.0	0.0	30.0	50.0	20.0	3.90	4
Environment	0.0	0.0	20.0	50.0	0.0	30.0	3.40	5

Table 3 presents the respondents' rating of various H&S aspects / issues relative to the South African construction industry in terms of percentage responses to a scale of 1 (very poor) to 5 (very good), and a mean score (MS) ranging between 1.00 and 5.00. It is notable that seventeen of the thirty (56.7%) MSs are all above the midpoint score of 3.00, which indicates that in general the respondents can be deemed to rate the South African construction industry more good as opposed poor.

However, a review of the MSs in terms of ranges provides a more detailed perspective. Firstly, no aspects / issues fall within the range > 4.20 ≤ 5.00: between good to very good / very good.

Secondly, the first six aspects / issues fall within the range > 3.40 ≤ 4.20: between average to good / good. It is notable that 'coordination of projects at site (construction team) level' is ranked first as coordination of the construction process facilitates and complements H&S, due to work being executed in an integrated manner. The MS of second ranked 'construction H&S competencies of Client Appointed H&S Agents' is an indication that the agents that fulfil the function are perceived to be competent to a degree. Third ranked 'integration of H&S into the construction process by H&S Officers' is notable as the achievement thereof is ideal, as opposed to H&S Officers merely reminding participants of the H&S requirements. 'Coordination of projects at project (client and design team included) level' also facilitates and complements H&S as the realisation thereof averts changes, which in turn may result in out of sequence work on site. The MS of fifth ranked 'construction hazard identification and risk assessments' is a requirement of the OH&S Act and the Construction Regulations. The MS of 'project management competencies of Client Appointed H&S Agents' is a further indication that the agents that fulfil the function are perceived to be competent to a degree.

Thirdly, the MSs of the aspects / issues ranked seventh to twenty-seventh fall within the range > 2.60 ≤ 3.40: between poor to average / average.

It is notable that 'the contribution of the Construction Regulations to the integration of H&S into projects at site (construction team) level', ranked seventh, falls within this range as the promulgation of the Construction Regulations was intended to promote such integration. However, the MS of 3.33 is at the upper end of the range. H&S management is an integral aspect of site and construction management, and therefore the MS of 3.33 relative to the 'integration of H&S into site management' is a cause for concern. Ninth ranked 'status afforded to H&S at site (construction team) level' is also a cause for concern as inadequate H&S primarily impacts on site and the activities thereon. Given that H&S is an integral aspect of construction, the MS of 3.30 relative to 'integration of H&S into construction activities' is also a cause for concern. 'Pre-qualification of contractors on H&S competencies' is ranked eleventh with a MS of 3.22. In terms of the Construction Regulations competent contractors must be appointed. 'Integration of design and construction' ranked twelfth with a MS of 3.22 is important in terms of H&S as the provision of inter alia, design and construction method statements as required in terms of the Construction Regulations, facilitate H&S. The MS of 3.20 thirteenth ranked 'construction H&S competencies of project managers' is notable as project managers coordinate design, integrate design and construction, and oversee construction, which all contribute to H&S. However, it is important that they possess construction H&S competencies. Fourteenth ranked 'design competencies of Client Appointed H&S Agents', is an indication that the agents that fulfil the function are perceived to be not competent to a degree. Fourteenth ranked 'design competencies of Client Appointed H&S Agents' are important as the Construction Regulations require a range of actions by designers, and clients or their agents in turn, are required to take a range of interventions, many requiring an interface with designers. Similarly, 'construction management competencies of Client Appointed H&S Agents', ranked fifteenth, are important as H&S is an integral part of construction management and such competencies are necessary to manage and to fulfil the function of agent. Sixteenth ranked 'integration of H&S into the construction process' is ranked lower than tenth ranked 'integration of H&S into construction activities'. Ideally, the former would have been ranked higher; however, the ranking of the latter is probably attributable to there being more focus on H&S relative to activities. The MS of seventeenth ranked 'construction H&S competencies of general contractors' is notable as GCs undertake projects and integrate the activities of SCs and are responsible for H&S on such projects. A similar argument applies to eighteenth ranked 'H&S competencies of site management'.

Equally notable is the 2.90 MS of nineteenth ranked 'site management commitment to H&S' as management commitment is critical and is one of the two pillars of construction H&S. 'Status afforded to H&S at project (client and design team included) level' is ranked twentieth with a MS of 2.90. H&S needs to be afforded the highest status for it to be addressed in an appropriate manner, particularly by clients and the design team. The MS of 2.89 of twenty-first ranked 'the contribution of the Construction Regulations to the integration of H&S into projects at project (client and design team included) level' indicates that the Construction Regulations have not been effective. 'Pre-qualification of project managers on H&S competencies', ranked twenty-second, indicates that project managers are effectively not pre-qualified on H&S competencies. This does not complement H&S as project managers are in a unique position to contribute to H&S as they coordinate design, integrate design and construction, and oversee construction, which all contribute to H&S. The 2.80 MS of twenty-third ranked 'construction management competencies of H&S Officers' is notable as they should possess such competencies as they fulfil an integral role relative to the construction process and its activities.

'Construction H&S competencies of engineers', ranked twenty-fourth with a MS of 2.78, is an indication that one of the primary design team members is effectively not competent. Twenty-fifth ranked 'design hazard identification and risk assessments (HIRAs)', with a MS of 2.75, is notable as designers are required to substitute hazardous materials and processes. This can only be achieved if HIRAs are conducted. 'Pre-qualification of designers on H&S competencies', ranked twenty-sixth, indicates that designers are effectively not pre-qualified on H&S competencies. This finding underscores the findings relative to 'construction H&S competencies of engineers', 'design hazard identification and risk assessments', and 'construction H&S competencies of architects'. 'Integration of design and construction in terms of H&S', ranked twenty-seventh with a MS of 2.70, is notable in that the integration of design and construction complements H&S.

Fourthly, the MSs ranked twenty-seventh to thirtieth fall within the range > 1.80 ≤ 2.60: very poor to poor / poor.

'Construction H&S competencies of architects' ranked twenty-eighth with a MS of 2.44 is an indication that a further primary member of the design team is effectively not competent. The twenty-ninth ranking of 'construction H&S competencies of subcontractors' with a MS of 2.30 is notable as subcontractors undertake a major percentage of all construction work. 'Construction H&S competencies of quantity surveyors', ranked thirtieth with a MS of 2.10, is yet an indication that yet a further primary member of the design team is effectively not competent.

Table 3: Rating of the South African construction industry in terms of various aspects / issues.

Aspect / Issue	Unsure	Very poor…………….Very good					Mean Score	Rank
		1	2	3	4	5		
Coordination of projects at site (construction team) level	0.0	0.0	0.0	20.0	80.0	0.0	3.80	1
Construction H&S competencies of Client Appointed H&S Agents	10.0	0.0	0.0	30.0	50.0	10.0	3.78	2
Integration of H&S into the construction process by H&S Officers	0.0	0.0	0.0	30.0	70.0	0.0	3.70	3
Coordination of projects at project (client and design team included) level	10.0	0.0	0.0	40.0	40.0	10.0	3.67	4
Construction hazard identification and risk assessments	0.0	0.0	0.0	40.0	60.0	0.0	3.60	5
Project management competencies of Client Appointed H&S Agents	10.0	0.0	10.0	40.0	30.0	10.0	3.44	6
The contribution of the Construction Regulations to the integration of H&S into projects at site (construction team) level	10.0	0.0	0.0	60.0	30.0	0.0	3.33	7
Integration of H&S into site management	0.0	0.0	22.2	22.2	55.6	0.0	3.33	8
Status afforded to H&S at site (construction team) level	0.0	0.0	0.0	70.0	30.0	0.0	3.30	9
Integration of H&S into construction activities	0.0	0.0	20.0	30.0	50.0	0.0	3.30	10
Pre-qualification of contractors on H&S competencies	10.0	0.0	10.0	50.0	30.0	0.0	3.22	11
Integration of design and construction	10.0	10.0	0.0	40.0	40.0	0.0	3.22	12
Construction H&S competencies of Project managers	0.0	0.0	20.0	40.0	40.0	0.0	3.20	13
Design competencies of Client Appointed H&S Agents	20.0	0.0	20.0	30.0	30.0	0.0	3.13	14
Construction management competencies of Client Appointed H&S Agents	10.0	0.0	10.0	60.0	20.0	0.0	3.11	15
Integration of H&S into the construction process	0.0	0.0	30.0	30.0	40.0	0.0	3.10	16
Construction H&S competencies of general contractors	0.0	10.0	20.0	20.0	50.0	0.0	3.10	17
H&S competencies of site management	0.0	0.0	22.2	55.6	22.2	0.0	3.00	18
Site management commitment to H&S	0.0	0.0	20.0	70.0	10.0	0.0	2.90	19
Status afforded to H&S at project (client and design team included) level	0.0	10.0	30.0	30.0	20.0	10.0	2.90	20
The contribution of the Construction Regulations to the integration of H&S into projects at project (client and design team included) level	10.0	0.0	30.0	40.0	20.0	0.0	2.89	21
Pre-qualification of project managers on H&S competencies	20.0	0.0	30.0	30.0	20.0	0.0	2.88	22
Construction management competencies of H&S Officers	0.0	10.0	20.0	50.0	20.0	0.0	2.80	23
Construction H&S competencies of engineers	10.0	10.0	20.0	40.0	20.0	0.0	2.78	24
Design hazard identification and risk assessments	20.0	10.0	20.0	30.0	20.0	0.0	2.75	25
Pre-qualification of designers on H&S competencies	30.0	10.0	10.0	40.0	10.0	0.0	2.71	26
Integration of design and construction in terms of H&S	0.0	10.0	30.0	40.0	20.0	0.0	2.70	27
Construction H&S competencies of architects	10.0	10.0	30.0	50.0	0.0	0.0	2.44	28
Construction H&S competencies of subcontractors	0.0	10.0	60.0	20.0	10.0	0.0	2.30	29
Construction H&S competencies of quantity surveyors	0.0	30.0	40.0	20.0	10.0	0.0	2.10	30

Table 4 indicates the respondents' degree of concurrence relative to twenty-two statements pertaining to various H&S aspects / issues relative to the South African construction industry in terms of percentage responses to a scale of 1 (strongly disagree) to 5 (strongly agree), and a mean score (MS) ranging between 1.00 and 5.00. It is notable that seventeen of the twenty-two (%) MSs are above the midpoint score of 3.00, which indicates that in general the respondents can be deemed to agree with the said statements, as opposed to disagree. Given that some of the aspects / issues addressed in Tables 3 and are common, it should be noted that Table 3 presents ratings, whereas Table 4 presents the degree of concurrence.

MSs that fall within the range > 4.20 ≤ 5.00 indicate that the degree of concurrence is between agree to strongly agree / strongly agree – three statements. The concurrence relative to 'H&S is an integral function of site management' and 'H&S is an integral aspect of the construction process' is notable. Consequently, construction management and more specifically, site management, should be committed to H&S and possess the requisite H&S competencies, which is not the case according to the findings presented in Table 3 above. The concurrence relative to the 'Construction Regulations should require a project close out / final report that includes H&S indicates a need for a project management approach to H&S'.

MSs that fall within the range > 3.40 ≤ 4.20 indicate that the degree of concurrence is between neutral to agree / agree – nine statements. ‘An overall H&S Coordinator should integrate and coordinate design and construction in terms of H&S at project (client and design team included) level’ with a MS of 4.20 falls on the upper limit of the range. This is a requirement of the revised Construction (Design and Management) Regulations (Health & Safety Commission, 2007). The concurrence relative to H&S is as important as cost, quality, and time at site (construction team) level and H&S is as important as cost, quality, and time at project (client and design team included) level indicate an understanding and appreciation of the role and importance of H&S. However, the findings relative to status in Table 3 do not align with the ideal status.

The concurrence relative to ‘Client Appointed H&S Agents lack built environment competencies’ and ‘site management lacks H&S competencies’ underscores the related findings presented in Table 3 above. Given the status afforded H&S Officers in terms of the Construction Regulations, the concurrence relative to ‘H&S Officers have the organisational authority to integrate H&S into the construction process’, is notable. The reason being, they effectively fulfil a staff, as opposed to a line function. The consensus relative to ‘generally projects are coordinated by a project manager’ is notable in that project management of a project should engender H&S as project managers coordinate design, integrate design and construction, and oversee construction. The consensus relative to ‘Client Appointed H&S Agents lack construction management competencies’ underscores the rating of ‘Construction management competencies of Client Appointed H&S Agents’ presented in Table 3 above. The integration of design and construction complements H&S. However, ideally it should be in terms of H&S, and hence the consensus relative to ‘project managers integrate design and construction in terms of H&S’ is notable.

MSs that fall within the range > 2.60 ≤ 3.40 indicate that the degree of consensus is between disagree to neutral / neutral – eight statements.

The consensus relative to ‘H&S Officers lack construction management competencies’ underscores the related rating presented in Table 3 above.

‘Project managers integrate design and construction’ achieved lower consensus than ‘project managers integrate design and construction in terms of H&S’.

The fact that the Construction Regulations do not refer to the phases of projects is reflected in the consensus relative to ‘the Construction Regulations do not highlight the H&S requirements for projects in terms of the project phases’. The consensus relative to ‘the Construction Regulations promote fragmented contributions to H&S at project (client and design team included) level’ and ‘the Construction Regulations promote fragmented contributions to H&S at site (construction team) level’ indicates that they have not been effective in terms of promoting integration. The consensus (3.00) relative to ‘project managers possess the requisite construction H&S competencies to manage projects in terms of H&S’, to a degree, underscores the rating of 3.20 in Table 3 above. However, the consensus (2.90) relative to ‘engineers possess the requisite construction H&S competencies to manage projects in terms of H&S’, underscores the rating of 2.78 in Table 3 above. The rating (2.90) relative to site management is committed to H&S underscores the consensus relative thereto namely 2.80.

MSs that fall within the range > 1.80 ≤ 2.60 indicate that the degree of concurrence is between strongly disagree to disagree / disagree – two statements.

The consensus relative to ‘architects possess the requisite construction H&S competencies to manage projects in terms of H&S’ (2.50) and ‘quantity surveyors possess the requisite construction H&S competencies to manage projects in terms of H&S’ (2.00) also reflects the ratings in Table 3 above.

Table 4: Degree of concurrence with various statements pertaining to various aspects / issues

Statement	Unsure	(Strongly disagree……..Strongly agree)					Mean Score
		1	2	3	4	5	
H&S is an integral function of site management	0.0	0.0	0.0	11.1	33.3	55.6	4.44
H&S is an integral aspect of the construction process	0.0	0.0	0.0	11.1	44.4	44.4	4.33
The Construction Regulations should require a project close out / final report that includes H&S	0.0	0.0	0.0	20.0	30.0	50.0	4.30
An overall H&S Coordinator should integrate and coordinate design and construction in terms of H&S at project (client and design team included) level	0.0	0.0	10.0	0.0	50.0	40.0	4.20
H&S is as important as cost, quality, and time at site (construction team) level	0.0	0.0	10.0	10.0	50.0	30.0	4.00
H&S is as important as cost, quality, and time at project (client and design team included) level	0.0	0.0	20.0	10.0	30.0	40.0	3.90
Client Appointed H&S Agents lack built environment competencies	0.0	0.0	10.0	10.0	70.0	10.0	3.80
Site management lacks H&S competencies	0.0	0.0	10.0	20.0	50.0	20.0	3.80
H&S Officers have the organisational authority to integrate H&S into the construction process	0.0	0.0	0.0	50.0	20.0	30.0	3.80
Generally projects are coordinated by a project manager	10.0	0.0	20.0	10.0	30.0	30.0	3.78
Client Appointed H&S Agents lack construction management competencies	0.0	0.0	10.0	10.0	80.0	0.0	3.70
Project managers integrate design and construction in terms of H&S	30.0	0.0	10.0	30.0	20.0	10.0	3.43
H&S Officers lack construction management competencies	0.0	10.0	10.0	30.0	40.0	10.0	3.30
Project managers integrate design and construction	20.0	0.0	30.0	20.0	10.0	20.0	3.25
The Construction Regulations do not highlight the H&S requirements for projects in terms of the project phases	10.0	10.0	10.0	20.0	50.0	0.0	3.22
The Construction Regulations promote fragmented contributions to H&S at project (client and design team included) level	0.0	10.0	20.0	30.0	30.0	10.0	3.10
The Construction Regulations promote fragmented contributions to H&S at site (construction team) level	0.0	10.0	10.0	40.0	40.0	0.0	3.10
Project managers possess the requisite construction H&S competencies to manage projects in terms of H&S	10.0	0.0	30.0	40.0	10.0	10.0	3.00
Engineers possess the requisite construction H&S competencies to manage projects in terms of H&S	0.0	0.0	40.0	40.0	10.0	10.0	2.90
Site management is committed to H&S	0.0	10.0	20.0	50.0	20.0	0.0	2.80
Architects possess the requisite construction H&S competencies to manage projects in terms of H&S	0.0	10.0	50.0	30.0	0.0	10.0	2.50
Quantity surveyors possess the requisite construction H&S competencies to manage projects in terms of H&S	0.0	10.0	80.0	10.0	0.0	0.0	2.00

CONCLUSIONS

The traditional project parameters of cost and time are perceived to be more important than H&S. However, given that H&S is perceived to be more important than quality, and that traditionally cost, quality, and time are more important than H&S, it can be concluded that the Construction Regulations have probably contributed to the increased importance afforded to H&S. Previous research conducted in South Africa determined that the promulgation of the Construction Regulations had contributed to increased awareness relative to H&S (Smallwood & Haupt, 2006).

The coordination of projects at site and project level is rated between average to good / good, therefore it can be concluded that coordination does occur, but that it can be enhanced. H&S is deemed to be integrated into site management, construction activities and into the construction process, but given that the ratings are between poor to average / average, it can be concluded H&S is not afforded optimum status and therefore not an integral aspect of construction.

Client Appointed H&S Agents are generally rated poor to average / average in terms of perceived competencies. Therefore, it can be concluded that in all likelihood they are not appropriately educated and trained, and that clients do not ensure that such agents are competent.

Furthermore, it is known that assessment criteria do not exist. In terms of perceived construction H&S competencies, most stakeholders are rated poor to average / average, and architects, subcontractors, and quantity surveyors as very poor to poor / poor.

Therefore, it can be concluded that in all likelihood the tertiary education programs of built environment practitioners are inadequate in terms of construction H&S.

The low ratings afforded design HIRAs, and the integration of design and construction in terms of H&S, indicate that designers are not contributing sufficiently to construction H&S. This indicates a need for a project H&S coordinator to be responsible for the coordination and integration of H&S at project level and during the construction process.

Finally, it is necessary to note that the findings emanate from a pilot study, which entailed the survey of a small sample stratum, and therefore, the findings cannot be generalised. However, the sample stratum did consist of so called 'better practice H&S' GCs , who can be deemed to be knowledgeable in terms of H&S.

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AN INVESTIGATION OF THE CURRENT APPLICATION AND FUTURE DEVELOPMENT OF THE PAY FOR SAFETY SCHEME (PFSS) IN HONG KONG

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ABSTRACT

To improve the prevailing safety performance of the Hong Kong construction industry, the Pay for Safety Scheme (PFSS) which is a public sector initiative was launched in the public sector in 1996 to encourage the safety awareness by taking the contractor's pricing for safety items out from the area of competitive bidding. The research aims to investigate the current application and future development of PFSS in the Hong Kong construction industry. It will focus on how the PFSS can be effectively implemented in the public sector, extending its application in the private sector as well as the feasibility of implementing PFSS for subcontractors. The research findings are expected to provide a critical review of applying PFSS in both the public sector and private sector regarding its motives, features, benefits, difficulties, success factors, limitations and possible recommendations for successful implementation. By consolidating the opinions from different key project stakeholders, the research results would provide some valuable insights into the future development of PFSS, encourage a wider application of PFSS in the private sector and facilitate the implementation of PFSS for subcontractors in near future. It is also expected to allow decision makers to have a clearer insight into setting aside the optimal budget of contract sum allocated for the payable safety items in tender pricing by both main contractor and subcontractor organizations at an early stage of project development, and to investigate how the site accidents can be mitigated via PFSS.

Keywords: Pay for safety scheme, Construction Safety, Research framework, Hong Kong.

INTRODUCTION

In Hong Kong, the construction industry is regarded as a high-risk industry. It is evident that the construction industry has recorded the highest number of accident rate and fatalities among various industry sectors around the world (Koehn et al. 1995; Sawacha et al. 1999; Ahmed et al. 2000; Wong and So 2004; Choudhry et al. 2008). Some previous research pointed out that site accidents are mainly raised from competitive tendering, extensive use of subcontractors, poor accident record keeping and reporting system, the low priority given to safety, inadequate safety training provided to contractors management and workers, etc (Poon 1998; Tam et al. 1998). In 1996, the Hong Kong Government launched different safety measures to improve the safety performance of the construction industry. The Pay for Safety Scheme (PFSS) is one of the effective safety incentives launched by the government. It is obvious that both the accident rate and fatality rate have been decreased noticeably over the past decade.

PFSS has been introduced to the Hong Kong construction industry for more than 10 years since 1996. Thus, it is important to evaluate the current state of application and investigate the future development of PFSS in Hong Kong. As there is a lack of research on PFSS, it would be valuable to examine how PFSS can be effectively applied in the public sector, whether the scope of application can be extended to the private sector, as well as the feasibility of implementing PFSS for subcontractors.

SAFETY PERFORMANCE OF CONSTRUCTION INDUSTRY

The safety performance of the Hong Kong construction industry has been greatly improved over the past decade. The government has introduced a plethora of different safety initiatives that increased the safety awareness of construction workers and also reduced the accident rate. As shown in Figure 1, the accident rate of the construction industry in Hong Kong has been declining in recent years from 1998 to 2007 (Labour Department 2008). It is encouraging to note that the number of industrial accidents in the construction industry of Hong Kong decreased from 3,400 in 2006 to 3,042 in 2007, down by 10.5%, while the accident rate per 1,000 workers decreased from 64.3 to 60.6, down by 5.8% as compared with the 2006 statistical figures. When compared with 1998, the construction accidents in 2007 fell heftily by 84.5% and the accident rate per 1,000 workers also dropped by 75.6% as well.

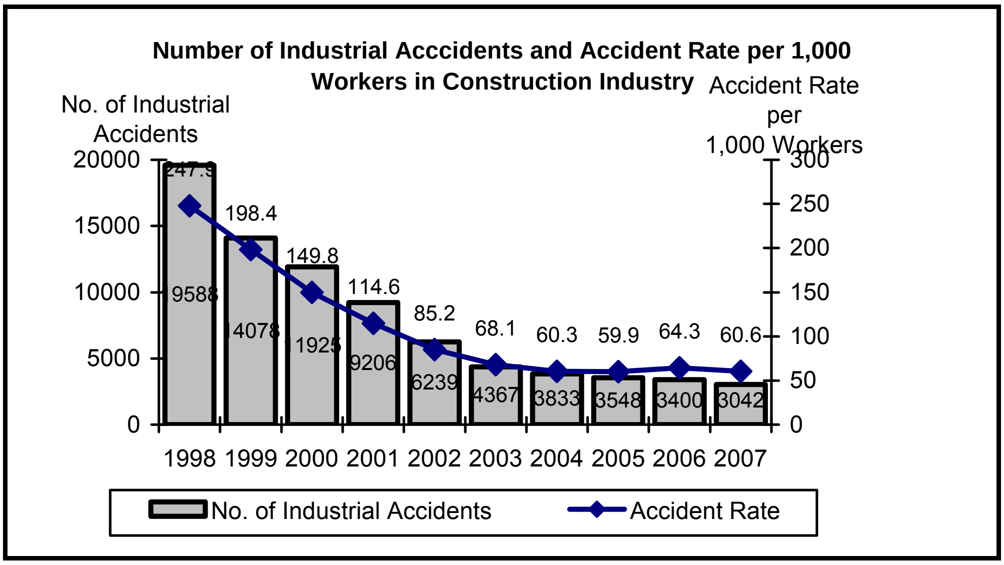

Figure 1. Number of industrial accidents and accident rate per 1,000 workers in construction industry from 1998 to 2007 (Labour Department 2008)

The fatality rate was also reduced between 1998 and 2007. In 2007, the number of industrial fatalities in the construction industry was 19, higher than 16 in 2006 by 18.8%, but lower than 56 in 1998 by 66.1% and the average of the past five years (20.4) by 6.9%. The industrial fatality rate of the construction industry in 2007 was 0.379, higher than 0.303 in 2006 by 25.1% and the average of the past five years (0.352) by 7.5%, but lower than 0.709 in 1998 by 46.6% (Figure 2).

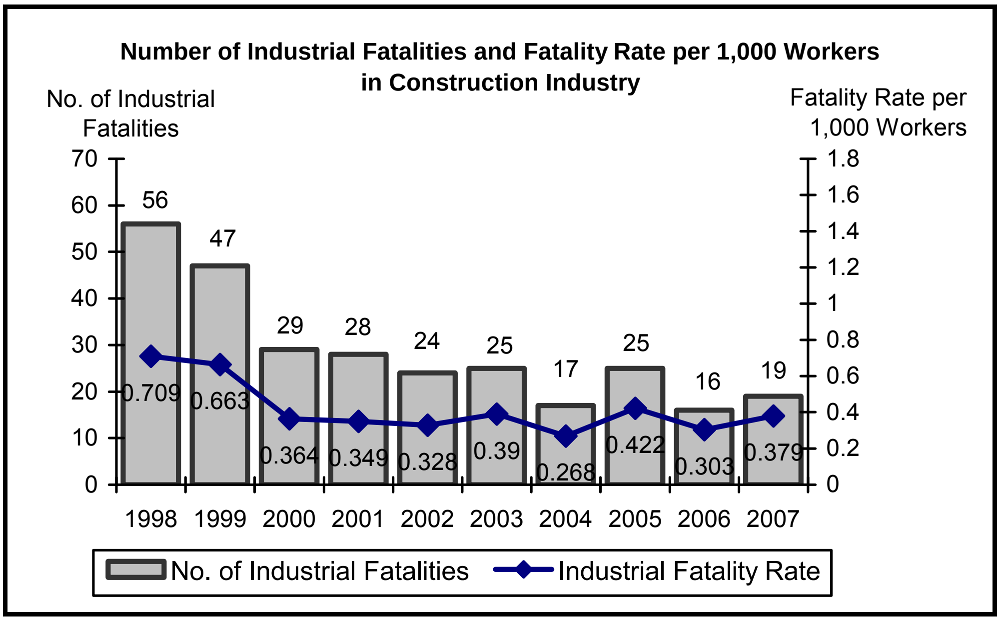

Figure 2. Number of industrial fatalities and fatality rate per 1,000 workers in construction industry from 1998 to 2007 (Labour Department 2008)

AIMS OF PAY FOR SAFETY SCHEME (PFSS)

The Report of the Construction Industry Review Committee (CIRC) published by the Hong Kong Special Administrative Region in January 2001 advocated that the safety performance of the construction industry has been improved significantly over the past decade in Hong Kong but the site accident rate still remains at an unacceptable level (CIRC 2001). The government launched PFSS to encourage the safety awareness by taking the contractor's pricing for site safety items out from the realm of competitive bidding (ETWB 2000; REDA/HKCA 2005).

As the contractors may try to bid contracts at the lowest price, it causes the sum payable for the safety-related items not to be measured and identified in the tender rates and prices. Therefore, contractors are likely to cut the budgets under the safety items to put in other necessary items (ETWB 2000). Under PFSS, all the items related to safety management that the contractor should carry out are included in the separate bill of quantities and a fixed sum is provided. When the contractor fulfills the stipulated safety requirements, payment is then made to the contractor. Therefore, it can enhance the safety awareness and ensure the safety measures to be carried out by the contractor from tender stage until project completion. PFSS has in fact secured intense support from the construction industry as a whole.

DEVELOPMENT OF PFSS IN PUBLIC SECTOR

The Works Bureau (now the Works Branch under the Development Bureau of the Hong Kong Special Administrative Region (SAR)Government) has first introduced a couple of major safety schemes, i.e. the Pay for Safety Scheme (PFSS) and the Independent Safety Audit Scheme (ISAS), towards the government construction contracts since 1996. A similar PFSS was later launched by the Hong Kong Housing Authority (HKHA) in 2000 to set aside a contract sum within the contract provision to encourage contractors to achieve good safety performance. The HKHA also required all the public housing projects to be undertaken under PFSS. There have been more than 800 public works projects which had implemented PFSS between 1996 and 2003 (Ng 2007). Hands-on experience derived from the public sector has demonstrated the effectiveness of PFSS in improving the overall site safety performance. It is indicated that there has been significant improvement in both the number of fatal accidents and the number of non-fatal accidents since the introduction of PFSS (HKHA, 1999 and Labour Department, 2008).

Under PFSS, the "Site Safety" section under the bill of quantities covered all the payable safety items. There are about 2% of contract sum for the contractors to carry out the safety items. However, the fixed sum may be adjusted depending on the size of the project. When contractors comply with each of these stipulated safety items and have been certified with satisfactory safety performance, payment is to be made on a monthly basis (ETWB 2000).

DEVELOPMENT OF PFSS IN THE PRIVATE SECTOR

The Real Estate Developers Association of Hong Kong (REDA) and the Hong Kong Construction Association (HKCA) have jointly established the Pay for Safety Scheme (PFSS) via their Safety Partnering Programme launched in June 2005, building upon the success of a similar one implemented by the former Works Bureau in 1996. The HKCA has started promoting the application of PFSS in the private sector on a voluntary basis since October 2005. The operation of PFSS in the private sector is more or less the same as the public sector. Three items, i.e. appointment of safety supervisors, provision of welfare facilities and provision of safe working cycle, are also added to the payable safety items list when PFSS is adopted by the private sector (REDA/HKCA 2005). First, the developer should express his intention to establish a higher standard of site safety performance during tender stage. Then the developer should demonstrate his commitment to pay for safety-related expenditure in the schedule of rates for site safety, and set the financial incentive to support the contractor's efforts on site safety between 0.5% and 2% of the contract sum (Figure 3). A total of 54 construction sites have participated in the Safety Partnering Programme since October 2005 with 21 active sites up to the end of February 2009 (REDA/HKCA 2009).

Encouraged by the success story of this major initiative, the HKCA took the initiative further down the supply chain by signing a "Safety Partnering Programme" agreement with the Hong Kong Subcontracting Association (HKSA) to encourage its members to support the safety charter, deploy resources for safety devices and equipment, develop and implement various safety management systems (Green Cross 2007). Since its introduction in March 2007, over 50 members of HKCA have joined this programme. It is timely for the proposed study to undertake some basic research necessary to develop a practical PFSS to help reinforce this initiative.

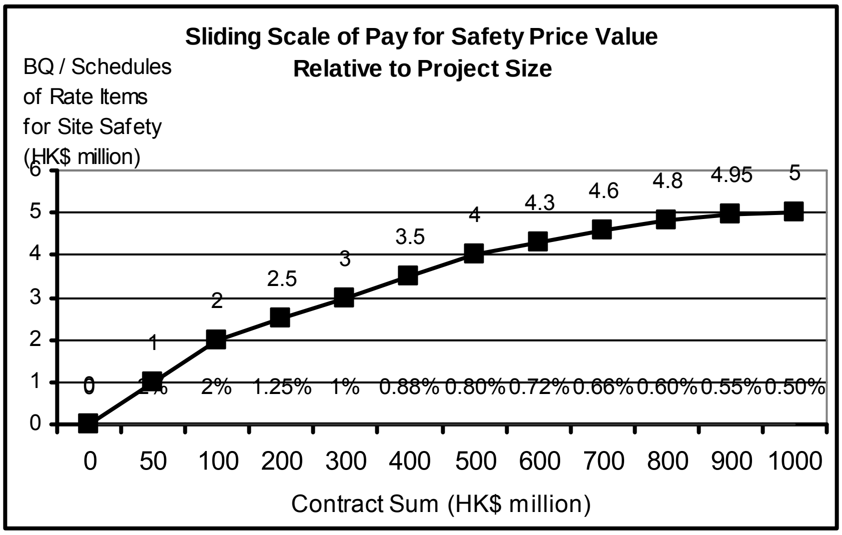

Figure 3. Sliding scale of pay for safety price value relative to project size (REDA/HKCA 2005)

As there are too few projects which have implemented PFSS in town, the accident rates remain very high in the private sector. Therefore, more urgent efforts should be placed on site safety management in the private sector to remedy this situation. It is recognized that unlike the former Works Bureau and HKHA, the private sector employers, being members of REDA, are made up of private property developers of different sizes. The corporate structure and management approach to conducting their businesses are essentially different from the public sector. Furthermore, unlike their public sector counterparts that have dedicated resources to monitor and guide the contractor's site safety performance, including enforcing the contractual provisions under PFSS and providing a focal point for the parallel Independent Safety Audit Scheme (ISAS) operated by the Occupational Safety and Health Council, many private property developers may not develop a proper monitoring mechanism to check and counter-check the contractor's site safety performance. There is also the issue of the additional administrative cost on the part of a participating employer if the scheme involves very complicated processes of certifying and cross-checking the safety-related payments, or requiring considerable professional inputs in ascertaining the safety audit results.

EFFECTIVENESS OF PFSS BETWEEN THE PUBLIC AND PRIVATE SECTORS

Figure 4 indicates the profiles of the accident rates between the public and private sector works in Hong Kong from 1999 to 2005. Despite their respective downward trends, it is evident to see that there is significant difference in the annual accident rates between the two sectors. The annual accident rate in the public sector is always significantly lower than that in the private sector. It is logical to accept that a wider application of PFSS in the public sector is one of the essential factors contributing to such significant difference. PFSS reimburses the expenditure on safety-related activities to main contractor, provided that the specified activities are satisfactorily performed. Although it is difficult to determine the sole impact of PFSS on site safety performance, it has coincided with a significant deterioration in accident rates. To further enhance the current safety performance of the whole Hong Kong construction industry, Cheung (2005) stated that it would be possible if the private sector could apply the best practices used in the public sector such as the Pay for Safety Scheme.

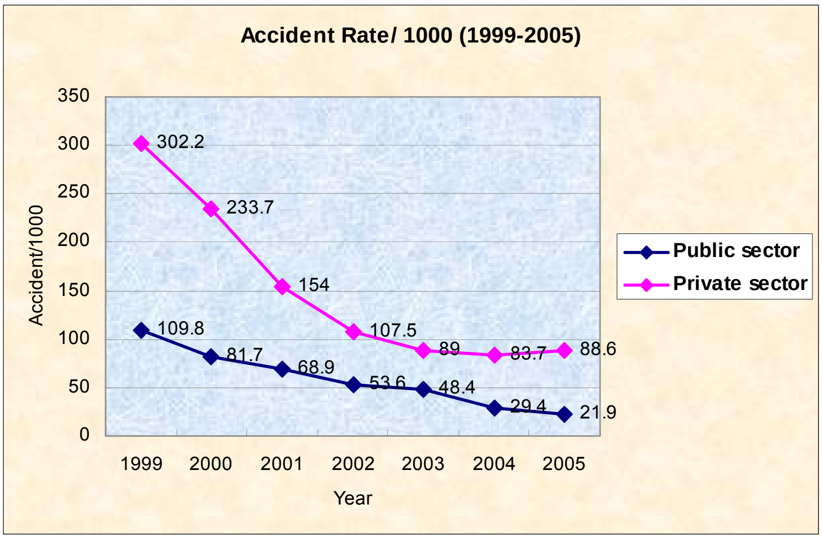

Figure 4. Accident rate per 1,000 workers in construction industry between public and private sectors from 1999 to 2005 (REDA/HKCA 2005)

FUTURE DEVELOPMENT OF PFSS

The Hong Kong construction industry is heavily dependent upon the practice of subcontracting work. Earlier studies indicate that subcontractors and their workers have a less positive attitude towards safety than their direct main contractor counterparts (OSHC 2003; Chan et al. 2005). Thus, PFSS should be down-streamed to cover "subcontracts". Better motivation of subcontractors is believed to be instrumental in making further construction safety performance improvement because subcontracting represents over 80% of the total project cost for most construction projects in Hong Kong.

However, there exist some potential problems associated with effective site safety control for subcontractors. A prime concern over managing the project delivery process is the effectiveness of control over the large number of subcontractors on construction sites due to the diversification of site activities. This responsibility becomes significantly more difficult to discharge if there is multi-layered subcontracting. Furthermore, main contractors may shift all the safety responsibilities to subcontractors and they are not willing to ensure that the subcontractors are capable of providing a safe working environment (Wilson and Kohen 2000).

Another safety-related problem arising from excessive layering of subcontract work is that as work is passed down through the supply chain, each layer shaves off a profit margin. The individuals on-site who end up doing the work have little or no resources available for safety expenditure even if they have the awareness and interest to invest in safety. Therefore, it is important to investigate the feasibility and develop a practical effective approach to implementing the proposed PFSS downstream to the level of subcontractors.

RESEARCH FRAMEWORK

In this research, different research tools, i.e. literature review, in-depth interview, case study and questionnaire survey will be adopted to collect appropriate and sufficient information and data of construction projects using PFSS based in Hong Kong.

A. Research Aim and Objectives

The research project purports to review the current application and explore the future development of PFSS within the Hong Kong construction industry, with the following six objectives:

(1) To provide a critical review of current application of PFSS in the Hong Kong construction industry.
(2) To examine the features, benefits, difficulties, success factors and limitations of implementing PFSS and analyze their importance.
(3) To examine the causal relationship between safety performance and project performance, i.e. whether better safety performance contributes to higher profit level.
(4) To investigate whether and how PFSS for subcontractors (P_fSS_fS) can motivate subcontractors for better safety performance.
(5) To identify the optimum safety incentive level of P_fSS_fS between the main contractor and major trade subcontractors across different types of projects.
(6) To suggest possible recommendations to facilitate the successful implementation of PFSS and future development of P_fSS_fS in Hong Kong.

B. Literature Review

A comprehensive literature review from related safety textbooks, professional journals, conference proceedings, academic journals, research monographs, previous dissertations, workshop or seminar notes, magazines, newsletters and internet materials, will be conducted to provide an abundant knowledge base on construction safety management and the implementation of similar PFSS across different countries, e.g. UK, USA, Australia, Japan and Hong Kong. Past and current implementation practices on PFSS including locally and overseas will be retrieved and documented for reference. It also helps develop an overall research framework and to prepare an appropriate template for the structured interview, questionnaire survey and case study.

C. In-depth Interview

In-depth face-to-face interviews with different senior industrial practitioners with abundant direct hands-on experience with PFSS projects are important in identifying the prevailing practices, current application and future development of PFSS in the construction sector. The purpose of face-to-face interviews is to solicit the collective ideas and valuable opinions on the motives, features, benefits, difficulties, success factors, limitations, safety performance, together with recommendations for improvement to this scheme from those target interviewees. This method helps collect their opinions and feedback in compiling the contents of the empirical survey questionnaire, and developing corresponding conclusions and recommendations. Potential interviewees include the key project team members of main contractors and related government departments. The content analysis technique will be used to document, analyze and compare the interview dialogues and also capture similarities and differences of the various attributes of PFSS under study for cross-comparison.

D. Case Study

Relevant data and information will be gleaned through face-to-face interviews and retrieval from collaborating firms. In-depth investigations on some representative real-life case study projects can enhance the real understanding of the implementation practices of PFSS and are also vital to validate the research findings. All the cases will be analyzed on both an individual basis and collectively in order to draw valid, representative conclusions.

E. Questionnaire Survey

The questions set on the empirical survey questionnaire aim to collect the perceptions of various contracting parties on implementing PFSS in terms of the motives, features, benefits, difficulties, success factors, limitations, safety performance, together with any desirable supplementary schemes suggested by the survey respondents and recommendations for further improvement to PFSS.

Self-administered survey questionnaires will be distributed to the key participants in those PFSS projects. The target respondents include Project Managers, Safety Managers, Architects, Engineers, Quantity Surveyors and other related professionals of main contractors and relevant government departments such as the Housing Department, Architectural Services Department, Highways Department, Drainage Services Department, etc which have gained sufficient sound experience in applying PFSS in Hong Kong. The main contractor companies are those on the Approved Contractors List for public works projects as provided by the Works Branch under the Development Bureau and HKHA Counterpart Lists. Leading private property developers and their projects' main contractors will also be considered for inclusion in the list of potential respondents. The data collected will also be used to compare the opinions between client organizations and main contractors on each of the above attributes towards PFSS.

Regarding the method of data analysis, the mean score ranking technique will first be used to analyze the data collected from the questionnaire survey. The mean score of each feature, benefit, difficulty, limitation and recommendation on PFSS will be calculated and used to determine the relative ranking by comparing each individual mean score. Then the relative rankings of those PFSS attributes in ascending order of importance can be found out for further analysis and discussion. These rankings were also essential in cross-comparing the relative importance of the PFSS attributes between any two groups of respondents, e.g. clients and contractors or public and private. After that, the Kendall's Coefficient of Concordance (W) Test will be adopted to measure the agreement on the ranking exercise amongst different respondents within the same survey group. It can ascertain whether the survey respondents within a particular group respond in a consistent manner. Then the Spearman's Rank Correlation Coefficient (r_s) Test will be used to measure the level of agreement on their rankings between any two respondent groups. All the quantitative data collected will be entered and manipulated via the Statistical Package for Social Sciences (SPSS) to facilitate further analysis of the responses derived from the empirical survey.

F. Regression Analysis

The causal relationship between safety performance and profit level can be explored based on historical data and information about some completed construction projects which will be obtained from the relevant major contractors in Hong Kong. Safety performance will be measured inversely by a performance indicator (PI) in aggregate sum of cumulative incidence rate (CIR), number of convictions (C) and number of fatal accidents (FA) throughout the whole contract period of a construction project, while the profit level will be measured in terms of profit percentage (gross profit divided by turnover).

It is necessary to infer a causal relationship through the collection of experimental data and their analysis. The Regression Analysis (RA) will subsequently be applied to establish the relationship between safety performance and project profit based on the relevant statistical data and information. In statistical terms, RA examines the relationship between a dependent variable (response variable) and specified independent variables (explanatory variables). The mathematical model of their relationship is the regression model equation. The dependent variable is modelled as a random variable because of uncertainty as to its value, given values of the independent variables. A regression equation contains estimates of one or more unknown regression parameters ("constants"), which quantitatively link the dependent and independent variables. The parameters are estimated from given realizations of the dependent and independent variables. Uses of regression include prediction (including forecasting of time-series data), modelling of causal relationships, and testing scientific hypotheses about relationships between variables (Hair et al. 2006).

G. Pairwise Comparison

As the Pay for Safety Scheme for Subcontractors (P_fSS_fS) has not yet been widely implemented now within the construction industry, the effect of PFSS as a proxy to P_fSS_fS on safety performance will be investigated. It is hypothesized that financial incentive is an important motivator to achieve better safety performance.

The mean value of the safety performance of projects which have implemented PFSS will be compared statistically with those without by an analysis of paired data to test whether there is any significant difference between the sample means. Pairwise comparison generally refers to any process of comparing entities in pairs to judge which of each pair is preferred, or has a greater amount of some quantitative properties. The method of pairwise comparison is used in the scientific study of preferences, attitudes, voting systems, social choice, and public choice. Under the psychology literature, it is often referred to as paired comparison (Hair et al. 2006).

H. Linear Programming and Sensitivity Analysis

The incentive level given under P_fSS_fS should be adequate to generate subcontractor impetus, but should not be so excessive that sacrifices the main contractor's own profit. Based on the statistical data and information obtained from the relevant major contractors, the optimum level of incentives with minimum payment to subcontractor in return of maximum profit to main contractor for various types of projects will be determined using some operational research techniques such as Linear Programming (LP) and Sensitivity Analysis (SA). A linear programming usually involves the optimization of a linear objective function, subject to linear equality and inequality constraints. A modification to this is the formulation of a linear goal programming model, which involves the optimization of, instead of one objective, several objectives with priorities (Tang 1999).

In this research project, the objectives will be, amongst others, optimizing the main contractor's profit (priority one), optimizing subcontractor's profit (priority two), optimizing subcontractor's safety facilities (priority three), and so on. The decision variables of the goal programming model will be safety facilities (e.g. number of safety walks required, number of safety committee meetings held, number of items of different safety equipment, etc). The coefficients of the decision variables will be the unit costs of the safety facilities. After that, a number of objectives can be optimized subject to a number of constraints (or goals). Later on, sensitivity analysis can be carried out for the optimal solution of the linear programming model in order to know more about how the safety performance changes with other independent variables.

I. 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 questionnaire survey and case studies will be cross-referenced to the published literature as well as with each other. Appropriate workshop discussions with prominent industrial practitioners who have acquired extensive hands-on experience in undertaking construction projects with PFSS will be organized to generate relevant information and to supplement and/or confirm the outcomes of the analyses, and a set of proposed recommendations for improving the prevailing implementation of PFSS and future development of P_fSS_fS. Several meetings will be scheduled via discussions and moderations to validate the research findings and explanations with practitioners involved in the study.

SIGNIFICANCE OF THE RESEARCH

PFSS can be an effective initiative to improve the overall safety performance of contractors and reduce accident rate of the construction industry in Hong Kong. This research study will carry out a thorough investigation of the current application and future development of PFSS in Hong Kong. It will first offer an overview of applying PFSS in both the public sector and private sector in respect of its motives, features, benefits, difficulties, success factors, limitations and possible recommendations for successful implementation. After collating the opinions from various major project stakeholders, the research results would engender some useful pointers to the future development of PFSS and encourage a wider application of PFSS in the private sector (e.g. empirical survey findings on the perceived benefits of PFSS as reported by Chan et al. 2009).

The proposed research is also timely because PFSS has been introduced in the public sector of Hong Kong since 1996 and in the private sector since 2005. It is high time for us to review its effectiveness in upgrading the site safety performance and seek further improvement for future application. The research findings are also essential to decision makers in allocating the optimal budget of contract sum for the payable safety items during tender submission by both main contractor and subcontractor organizations at an infant stage of project development, and in exploring how the site accidents can be reduced through PFSS. It is important to set minimum investment on safety-related items in return of maximum profit of a construction project for improvement in prevailing site safety performance. After reviewing the current state of implementation of PFSS between client and main contractor in Hong Kong, the application of PFSS between main contractor and subcontractors in near future will also be studied by developing a practical P_fSS_fS for achieving better safety performance.

CONCLUSIONS

The implementation of PFSS is now being adopted in spate across the public sector whereas there are a scarcity of private sector projects which have launched PFSS so far. Thus, the accident rate for the private sector building projects remains at a higher level, and the Hong Kong SAR Government should increase promotion on implementing these safety measures within the construction industry. It would be important to encourage the private property developers and contractors and even subcontractors to apply more safety initiatives in their projects for ensuring a safe and healthy workplace. Safety and health is everyone's responsibility. To prevent any accidents from occurring, it relies heavily on implementing effective safety measures, enhancing safety culture and creating good working environment on-site (Cheung 2004).

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E-HEALTH & SAFETY: BUILDING A CASE FOR COLLABORATIVE WORKING

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ABSTRACT

Methods of working to a high standard of health and safety should be a natural way-of-working for everybody! The introduction of Information and Communication Technologies (ICTs) may provide a means of streamlining construction project processes. This paper seeks to summarise this research and outline how collaborative working software could be used to improve the health and safety of construction projects. There has also been much research into the use of collaborative working software. The areas of CAD (modelling and visualisation) and knowledge management technologies and ICT systems are areas where health and safety may learn from. This paper investigates how collaborative working software, e.g. the 4Projects collaborative working web-based extranet, could be used to improve the management of health and safety in construction projects. The use of both collaborative working procedures and software to improve the management of project information is a key concern for many in the industry. The use of collaborative working software to communicate information in the fields of project management, design collaboration, construction management, incident and causation and individual health and safety training records amongst other things is considered. The paper describes current literature as well as key issues for implementing collaborative working into construction organizations, the business process and people issues also needing consideration. The paper presents information and experiences from two different sides of the industry, one a large world leading construction company and the second, a small-to-medium sized enterprise (SME) from Nottingham (UK).

Keywords: Collaborative working software, Web-based systems, Information and Communication technology

INTRODUCTION

The new millennium has seen widespread recognition from research findings and the construction industry itself that the UK Construction industry must embrace new ways of working if it is to remain competitive and meet the needs of its ever demanding clients. Inherent within this agenda of new ways of working is a move towards collaborative working (Latham, 1994; Egan, 1998) and its associated fields: concurrent engineering and lean production (Anumba et al., 2004).

Collaborative working is essential if design and construction teams are to address the entire lifecycle of the construction product and take account of not only primary functionality but also productivity, buildability, serviceability and even recyclability (Kusiak & Wang, 1993).
Much of the recent work on collaborative working has focused on the delivery of technological solutions (Kvan, 2000; Woo et al., 2001; Faniran et al. 2001) with a focus on the web, i.e. extranets, (Weippert et al. 2003; Nitithamyong & Skibniewski, 2004; Sexton & Barrett, 2004; Wilkinson, 2005), CAD (modelling and visualisation Kunz, 1999; Schwegler, 1999; Hew et al. 2001; Fulton, 2002; Edenius & Borgerson, 2003; Smoliar, 2003; Waly & Thabet, 2002; Zhu & Issa, 2003; Donath et al. 2004; Hiremath & Skibniewski, 2004;), and knowledge management technologies and systems (Rezgui et al., 1996; Lueg, 2001; Stewart et al., 2002; Stewart & Mohamed, 2003;

Asprey, 2004; Egbu, 2004; Kundu, 2004). It can be seen from the literature shown above the Health and Safety has yet to be included in collaborative working.
Effective collaboration does not result from the implementation of information technology systems alone (Alvarez, 2001; Vakola & Wilson, 2002; Ferneley et al., 2003). Therefore approaches that are purely based on information technology are bound to be less than successful, unless the organisational and people issues are considered as part of these implementations. On the other hand, approaches that exclusively focus on organisational and cultural issues do not reap the benefits derived from the use of technology, especially in the context of distributed teams (Grudin, 1994; Koschmann et al., 1996; Loosemore, 1998; Winograd, 1988; Eseryel et al., 2002; Baldwin, 2004), a delicate balance needs to be reached.

Implementing ICT into a number of Architecture, Engineering and Construction (AEC) organisations crosses many cultural boundaries (Credé, 1997; Proctor & Brown, 1997; Cheng et al., 2001). Managers of ICT implementations have to consider the barriers within the workplace that affect such introductions with a more strategic approach (Norton, 1995; Boddy & Macbeth, 2000; Maguire, 2002). To make matters more difficult, many individuals are apprehensive when confronted with technological change through the introduction of new systems and technologies (Manthou et al., 2004; Erdogan et al., 2005), a need for a more strategically managed approach is sought, particularly for the construction sector.

The recognition of these issues led to research (Planning and Implementation of Effective Collaboration in Construction (PIECC)) being undertaken within the Civil and Building Engineering department at Loughborough University in the UK. The remainder of this paper describes the work leading towards the development of a prototype framework for the planning and implementation of effective collaboration in construction projects. The adoption of collaborative working on projects using such a framework could make Health and Safety management in projects a simpler process.

THE PIECC PROJECT

The PIECC project has a focus on supporting strategic decision-making by highlighting areas where collaborative working can be improved incorporating the organisational (business), project and end users' needs. When carefully planned, and if based on informed decisions, it is believed that policies and protocols will help organisations improve their collaborative working, achieve better benefits from it, and maximize the use of tools and techniques that are currently commercially available.

AIMS AND OBJECTIVES

The main aim of the PIECC research was to develop a strategic decision making framework that will guide organisations in the planning for effective collaborative working practices and the implementation of suitable tools and techniques. The associated objectives were to:
Review state of the art collaborative working with a focus on both practices and technologies – see Erdogan et al. (2005); Koseoglu et al. (2005); Shelbourn et al. (2007, 2007a);
Conduct a requirements capture survey for collaborative working in construction at the organisational and project user levels, and identify key areas for improvement in collaborative working – see Shelbourn et al. (2007, 2007a);
Develop a framework for the planning and implementation of effective collaborative working taking into account both the organisational business processes and the project lifecycle processes – the main focus of this paper; and
Test and validate the framework within the construction project context – the final stage of the project.

To realise these objectives the PIECC project followed a rigorous methodology incorporating many features of recognised requirements and software development lifecycles. The next section summarises the methodology used in the project.

PROJECT METHODOLOGY

In order to achieve the aims and objectives of the project, a number of different methods were adopted. These were:

- Use of published sources – through an extensive literature review to establish current 'state-of-the-art' practice on collaborative working – and associated areas of interest – both in construction and other industries;
- Field studies – these were conducted to establish current practice for collaborative working. The studies used a questionnaire, semi-structured interviews (with identified key personnel) and case study examples from the collaborating organisations, to elicit requirements for collaborative working, and key issues to be considered at the organisational and project user levels; and
- Use a 'develop-test-refine' strategy (action research) – to improve the prototype iterations. This was achieved by using a project steering group (industry focused) that commented on iterations of the framework and supporting material.

PIECC – CURRENT STATE OF THE ART

A comprehensive literature survey was conducted using desktop study techniques to determine the current state-of-the-art of collaborative working in the construction (and other relevant) sectors. Complimenting the collaborative working review, two other specific subjects: collaboration technologies (Koseoglu et al. 2005) – including GRID technologies; and the change management implications of implementing and using new technologies for construction organisations (Erdogan et al. 2005) were also included in the survey. Results showed that there are many definitions of collaborative working. Some incorporated the word "concurrent" in terms of the approach and activity, and "collaborative" in terms of ownership (Moore, 2000). The difficulty in determining a single definition led the research team to describe the different forms that collaboration may take. Anumba et al. (2002) described four modes of collaboration – 'Face-to-Face', 'Asynchronous', 'Synchronous Distributed', and 'Asynchronous Distributed', and typical forms of use in the four areas have been described by Attaran and Attaran (2002).
The PIECC project had a focus on supporting strategic decision-making by highlighting areas where collaborative working could be improved incorporating the organisational (business), project and end users' needs. When carefully planned, and if based on informed decisions, it was believed that policies and protocols could help organisations improve their collaborative working, achieve better benefits from it, and maximize the use of tools and techniques that are currently commercially available.

Results from the requirements capture survey were summarised into the following requirements:

- **MODEL** – "…*a recognizable model for collaborative working does not exist at this time – it needs developing to enable a move forward*…"
- **MODEL** – "…*must build upon work being done in other aspects of collaborative working – the AVANTI programme for example*…"
- **PROCESS** – "…*processes that enable participants to agree a common vision & priorities for the collaboration – a route map for how the project is going to proceed, and must include suitable time for review of progress against vision & priorities*…"
- **PROCESS** – "…*procedures to promote trust in the collaboration – a key person needs to be in charge, they provide leadership, leading (hopefully) to better performance of the team, to build trust within the team*…"
- **PROCESS** – "…*a set of communication procedures that all stakeholders should use in the collaboration*…"
- **STANDARDS** – "…*standards that facilitate interoperability between different software and systems – we are fed up with learning a new system for every new project!!*"
- **STANDARDS** – "…*suitable (and appropriate) help templates/screens for users to familiarize themselves with the software tools. They are removed when a level of competence is reached*…"

- **GOOD PRACTICE** – "…*examples of good practice/case study material that shows tangible business benefits of collaborative working*…"
- **GOOD PRACTICE** – "…*evidence of good practice of collaborative working to be published to alleviate frustration of the industry*…"
- **DESIGN** – "…*intuitive interface design of software to reduce the requirement for training of new members of a collaborative project/environment*…"
- **LEGAL ASPECTS** – "…*clarification of professional liability of information generated. Who is responsible for the information generated and its trustworthiness? A right balance between the technology and professional liability is the issue to building trust*…" (Shelbourn *et al*., 2007, 2007a).

PIECC – FRAMEWORK DEVELOPMENTS

Effective collaboration is only achievable through the innovative design and development of a more balanced 'collaboration strategy', that does not rely solely on ICTs. As yet there is little evidence (Shelbourn *et al*. 2007; 2007a) of such a 'strategy' existing that prescribes to project managers effective ways of implementing and managing collaborative projects. To develop a strategy the PIECC project produced a questionnaire and conducted a number of interviews with key industrial representatives. The next section summarizes the results of these questionnaires and interviews.

Using these requirements the research team set up a development group that consisted of industrial partners and senior researchers in the project. Over a twelve month period and numerous iterations a framework for effectively planning and implementing collaborative working was ready for testing – see figure 1.

The framework was built around the premise that there should be harmonization of three key strategies: business, people, and technology, split on a 40/40/20% basis. Six key areas must be represented in the three strategies. They are:

- **Vision** – all members of the collaboration agree on the aims and objectives;
- (Stakeholder) **Engagement** – managers need to ensure that all key participants are consulted as to the practices to be employed during the collaboration;
- **Trust** – time and resources are needed to enable stakeholders to build trusting relationships;
- **Communication** – a common means of communication is decided by all key participants in the collaboration;
- **Processes** – both business and project, that describe to all key participants how the collaboration is to work on a day-to-day basis;
- **Technologies** – an agreement on those to be used to ensure the collaboration is easily implemented and maintained.

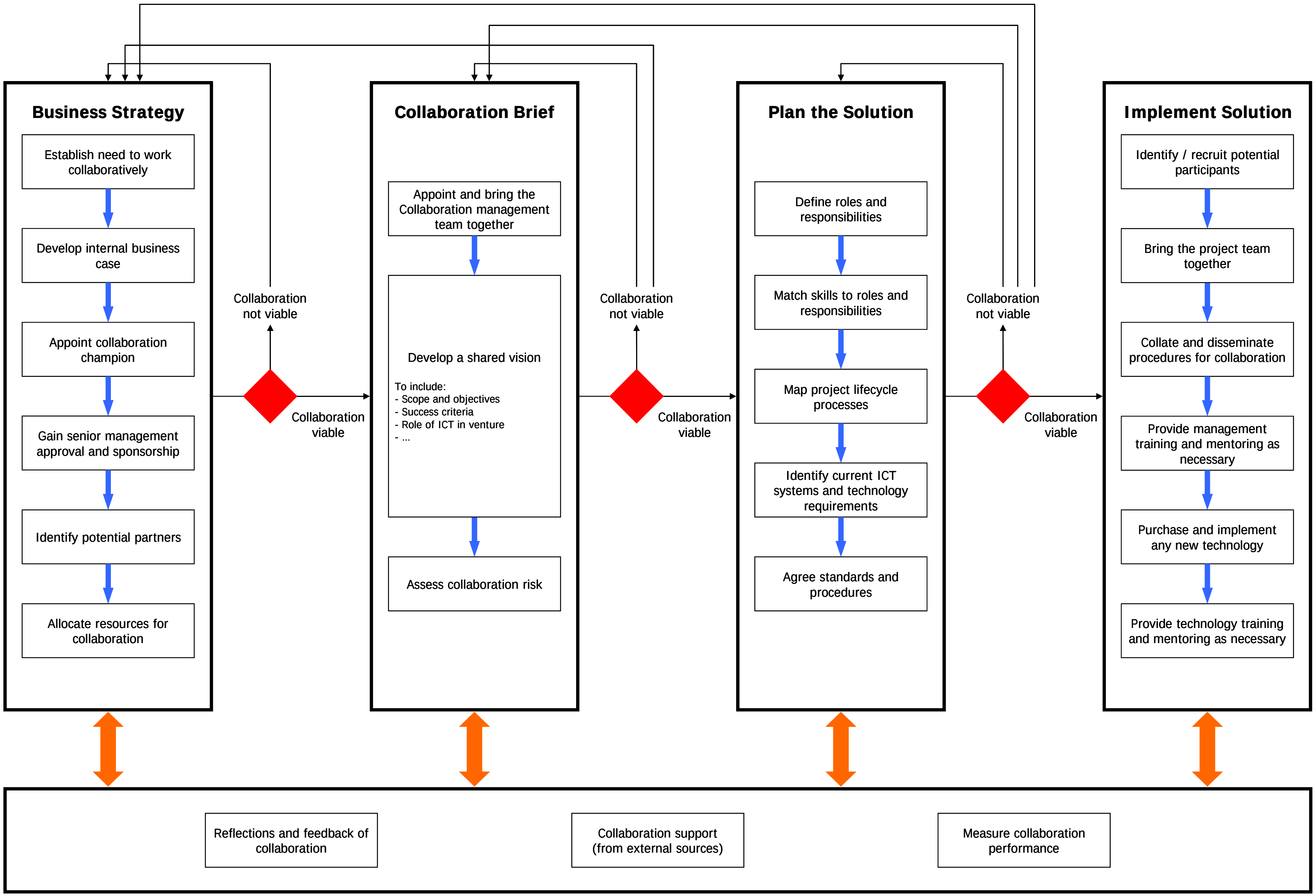

Figure 1: The PIECC decision making framework

HEALTH AND SAFETY AND COLLABORATIVE WORKING

The process of health and safety in the UK begins with a 'plan' at the tendering stage. Once the plan has been agreed with the contractor the plan is put into 'practice' during the project, with all the information collated and put together into a Health and Safety File at the conclusion. This process has in the past been paper based and costly at the SME level. Larger contractors have begun to develop a system of processes to make the process electronic. This kind of approach may be appropriate for a large client such as Sainsbury's and their larger contractor partners, but how does a UK contractor with a turnover of £3-4million undertake health and safety? and how can a collaborative working approach aid such a contractor?

An interview with such a small contractor in Nottingham in the UK revealed a number of key issues. The production of the Health and Safety File has traditionally been completed using a paper based model. This contractor recognised that approach was unsustainable in terms of sizes of folders and not having the most up-to-date information contained in these Files, however they did stress that many other contractors were still following such a paper based approach.

The question was asked as to whether ICT could improve the process? Such systems as those described by Wilkinson (2005) could be used but the real problem that smaller contractors face is weighing up the cost of implementation against the potential benefits that could accrue from implementing such ICT. However, before the implementation of ICT into the process there are other issues that need to be addressed.

A major problem with health and safety at the SME level is one of cost of undertaking the requirements for compliance. For an SME the costs are "*disproportionably expensive*" when compared to a larger contractor. A larger contractor may have a whole team dedicated to health and safety whereas for an SME the onus will often fall on the office staff or senior management. One potential solution to this could be the introduction of a health and safety section to a contract such as JCT. This would mean that all health and safety requirements, including roles and responsibilities of all stakeholders in the project, would be made explicit at an earlier stage. If this contract was then made available in an electronic format it could reduce the costs to the contractor significantly. The electronic format would also cut down the time of everybody sending the copies of documents through the post to sign. Standardisation not disorganization.

An electronic copy of the joint contract and health and safety plan should take away the requirement of not only satisfying the need for legal compliance, but it should also provide a process of allowing the contractor to actually spend more valuable time conducting the works under a safe working environment. Health and safety in action.

As with all ICT implementations that may improve more traditional processes they should not be introduced in isolation. The introduction of ICT into any health and safety process should also include appropriate training of those who will be gathering, manipulating and publicising the information for the project. This is often an area where many ICT implementations fail as highlighted by et al., (2003).

In the UK on any construction project, under the 1994 Construction (Design and Management) Regulations (CDM), the client and project team must produce a variety of health and safety documents during and after construction. One such requirement, the Health and Safety File, has traditionally been a substantial, comprehensive and expensive-to-produce library of documents. Collation requires extensive inputs from across the project team; often the File can fill over 20 thick ring-binders, and several copies of the whole File may be required and disseminated. Typically, the File is not completed until weeks, even months after the project handover. Once compiled, the File is passed to the client, who must then store it, maintain it and make it available to anyone needing information about the facility – whether for routine operation and maintenance or for long term use, for example: major alteration works. If the client sells all or part of the facility, the File, updated to reflect any further works, must be passed to the new owner. It is, therefore, a key part of a built asset's whole life documentation.

Many project extranet providers now provide a service as part of their ICT project collaboration platforms to streamline the process of putting together this Health and Safety File. A typical example has been provided by Wilkinson (2005) using the Building Information Warehouse (BIW) project extranet. He describes "…building on information already routinely exchanged using its collaboration platform, BIW and Sainsbury's developed a system capable of producing an electronic Health and Safety File which is CDM-compliant, faster, easier and cheaper to compile, maintain and update, and is more accessible to facilities management (FM) staff who need to manage post-construction operation and maintenance processes throughout each built asset's whole life…"

CONCLUSIONS

The work presented in this paper has shown research and development activities that aimed to assist organisations (or organisational units) to plan and implement collaborative working more effectively. The research has determined that there are sporadic examples of balanced approaches to collaboration being implemented in the construction sector. However, these rarely take into consideration the business process or human/organisational issues. A need was clearly identified through the questionnaire and interviews conducted in the PIECC project for a more balanced approach to planning and implementing collaborative working. Developments in the PIECC project now provide the industry with a framework to allow effective collaborative working to be planned and implemented in projects.

Using this framework and introducing collaborative working into projects does have its benefits. One area where there seems to be a lack of e-tools is health and safety. This paper has shown some of the issues associated with introducing such an approach into SMEs and larger contracting organisations. There is clearly a need for more work in this area – particularly at the SME level. As the SME contractor (who was interviewed) said "…*the SME should stop being a health and safety consultant and get back to what they do best – being a builder!!!*...".

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EVALUATION OF MODEL CLIENTS IN THE AUSTRALIAN CONSTRUCTION INDUSTRY

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ABSTRACT

The construction industry presents a number of unique and challenging problems areas that hinder safety performance. Construction projects are inherently dangerous, complex, highly fragmented and multi-organizational. The temporary nature of construction work, the changing work environment and high-degree of subcontracting result in unsafe work environments. Whilst these challenges are well recognised within the construction literature there is a lack of empirical evidence identifying how clients can affect the level of safety performance and safety culture of project environments.

The aim of this research is to examine the influence of Model Clients on safety performance within Australian construction projects. Specific objectives are: 1) To evaluate the effect of the Federal Safety Commissioner Model Client Framework on safety performance; and 2) To identify the effect of different procurement methods on the implementation of the Model Client Framework. The establishment of dedicated theory for Model Clients within the construction industry would improve understanding of the challenges and how to overcome them.

Despite a significant amount of research into the potential influence of various stakeholders (Clients, Designers, Engineers, etc.) on safety performance, there is limited empirical evidence that examines what impact clients can have on safety performance. Furthermore there is a need to examine the effect of the Model Client Framework on safety performance within the Australian Construction industry.

Keywords: Model client behaviour, Safety performance, Procurement

INTRODUCTION

The Australian construction industry performs relatively poorly in Occupational Health and Safety (OHS). Over the past 30 years, due to increased responsibility (legal/financial/social), improved technology, and a better understanding of OHS risks, the Australian construction industry has significantly improved safety performance. Despite this, the Australian construction industry continues to make the same mistakes, recording an unacceptable number of fatalities and compensated injuries each year. In 2006-07 the Australian construction industry recorded a fatality rate of 7.8 fatalities per 100,00 employees, three times the national average of 2.5 fatalities per 100,000 employees for all industries (ASCC 2008). These figures reveal an industry hampered by a number of unique and challenging problem areas. There is need for significant improvement in order for the Australian construction industry to demonstrate best practice.

In response to the poor safety record of the construction industry, this paper reports on a research project in its initial stages. The overall objective of the research project aims to empirically evaluate the impact of model clients on safety performance. More specifically the research aims to evaluate the impact of the Australian Federal Safety Commissioners (FSC) 'Model Client Framework' on safety performance of construction projects. In addition, the research will examine the effect of varying project delivery strategies (i.e. Traditional, Design and Build, Alliance) on the effectiveness of implementing the 'Model Client Framework'. This paper explores the roles of clients in accidents causation and their potential to engage in OHS. It is believed that Clients have great potential to influence safety performance within construction and drive the cultural change needed to further improve industry performance.

BACKGROUND

The construction industry plays a significant role in the development and growth of world economies. Employing hundreds of thousands, construction workers "build our roads, houses, and workplaces and repair and maintain our nation's physical infrastructure" (Behm, 2008). In Australia, the construction industry employs around 9% of the population and contributes significantly to the economy GDP. Whilst construction is instrumental to a nations economy, there are a number of unique and challenging problem areas that hinder safety performance and result in serious social and financial consequences. Within Australia, improvements in construction safety performance are estimated to generate $2.3 billion dollars annually, a 1% increase in GDP and a 1% decrease in the cost of living for all Australians (Department of Employment and Workplace Relations 2003; 2005). Although there are significant costs associated with workplace accidents, more important are the social consequences associated with workplace fatalities and injuries. The stress and emotional trauma related to workplace accidents can have devastating effects on families, friends and colleagues of injured employees.

Over the past decade the Australian construction industry has seen a plateau in safety performance. As a result, there is a need to adopt new approaches in managing safety in order to reduce the number of accidents and fatalities being recorded on construction sites. In order to achieve best practice in the Australian construction industry, it will require a 'whole of industry' approach to managing safety, whereby all stakeholders are invested in managing, controlling, and eliminating OHS risks throughout the lifecycle of construction projects. This will require all project stakeholders (Clients, Owners, Designers, Contractors, Sub-contractors and Suppliers) to work collaboratively towards achieving a common goal – zero injuries and fatalities.

ACCIDENT CAUSATION

In order to prevent accidents from occurring on construction sites, it is vital to have a clear understanding of the circumstances that lead to and cause accidents. Through developing models of accident causation, appropriate preventative measures can be developed. However, accident causation is a complex issue that requires thorough investigation of workplace accidents in order to determine both direct and root causes. Although there are a number of varying models of accident causation, Suraji et al. (2001) highlights that there are two vital questions that need to be answered in order to determine accident causation – How do accidents happen? and Why do accidents happen?

Original models of accident causation focussed largely on the individual and the environment as direct causes of accidents. Heinrich's (1931) influential 'Domino' theory proposed accidents were a result of either/or unsafe acts and unsafe conditions (Cooper 2001). Similar theories during the same period considered accidents a result of deficiencies in human behaviour preceded by social and environment factors. Heinrich's 'Domino' theory has formed the basis for many models of accident causation. For example Adams' (1976) accident causation model introduced upstream factors (i.e. management and organisational issues) as contributing causes of accidents (Cooper 2001). Bird's (1974) modified domino theory emphasised management and organisational aspects as fundamental underlying factors in accident causation. Bird's model acknowledges that if management control is not addressed, then accidents will continue to occur – regardless of worker traits (Cooper 2001).

In contrast to the 'domino' theory, 'Human Error' theories recognise the predisposition of humans to make mistakes in a number of situations and in different environments (Abdelhamid et al. 2000).

Reason (1990) acknowledges that humans will make mistakes, but by adopting a holistic organisational approach, an organisation should allow for human error and provide defences against the accident from occurring. Therefore, while actions of the worker may contribute to an accident, other organisational issues must be considered central to the consequence/outcomes.

Although there has been significant research into accident causation, research specifically relating to construction has not received the same attention (Haslam et al. 2005). Although previous studies have been able to analyse and interpret data collected from accident reporting schemes, these methods are troubled by poor data collection and classification (Haslam et al. 2005). Lingard et al. (2009) commented, “Contemporary models of accident causation recognise the importance of organisational issues and management actions in contributing to workplace accidents”. Through root cause analysis, studies have identified professional and managerial failures as common characteristics in accident causation. The HSE (2003) and Bomel (2001) refer to the planning and design stages as notable phases in which professional and managerial failures will occur.

Suraji et al. (2001) developed an accident causation model to describe the various contributing factors experienced by all parties throughout all stages of a construction project. Suraji et al. adopting a ‘human error’ approach recognised the inherent nature of humans to make mistakes at all levels of an organisation. They proposed a general model of accident causation in which undesired events or accidents were a direct result of ‘Proximal Factors’ (‘Situation or condition in event area’ and ‘Inappropriate operative actions or responses’) caused by ‘Distal Factors’ (Constraints and Responses). Suraji et al. stress that all participants involved in the construction process can influence safety performance.

While there are limited studies of accident causation within the construction industry, there is a relatively good understanding of the direct and root causes of accidents within construction (Haslam et al. 2005). Gibb et al. (2001) emphasise root causes of construction accidents occur well before construction activities begin which requires the risk assessment process to be initiated first by the owners (Clients) then by the designers.

ROLE OF THE CLIENT IN PROMOTING OHS

Within the temporary organisations formed to complete construction projects, clients are integral to the overall characteristics and operation of the project. Clients are key to establishing a project and will determine the delivery strategy, project finances, expected completion time, expected quality of the finished product and main contractor to build the project. The objectives and requirements, as set out by clients, have been identified as significant root causes of construction site accidents (Lingard et al. 2009). Depending on the project delivery method, the designers will be motivated to consider OHS and constructability in their design (Lingard et al. 2009). In this context, the client has significant influence over the construction project and possesses an opportunity to affect the outcomes of safety performance of the project (Bomel, 2001). Lingard et al. (2009) highlight clients have the largest potential to “drive cultural change needed to bring about further improvements in OHS in the construction industry”.

Each stakeholder involved in a construction project has a specific role to play in managing site safety and controlling risks associated with construction activities (Toole, 2002; Gambatese 1996; Huang and Hinze 2006). Although clients and designers do not have direct control over the construction site and employees, there is still significant room to influence site safety and performance. Designers can influences site safety by considering constructability of their designs, and promoting safe construction processes and procedures. Clients of construction projects can play a significant role in influencing site safety of construction projects through selecting safety contractors and completing site safety walks.

The following provide examples of Legislation, Guidelines, Standards and Industry tools that establish roles and responsibilities for clients in regard to OHS or provide a framework for clients to actively engage construction projects to promote and enhance site safety.

National OHS Strategy 2002 – 2012 (NOHSC – Australia)
In 2002, the National OHS Strategy was developed to provide the foundation for improving the health and safety of work environments in Australia. One of the five priorities of the National OHS Strategy aimed at strengthening the capacity of the Government to improve OHS and provide examples of good practice. The National OHS strategy recognised that Governments can greatly influence workplace health and safety in their role as major employers', policy makers, regulators, and purchasers of equipment and services (ASCC, 2006). A key focus of the National Strategy was industries that posed significant risks and challenges (e.g. Building and Construction, Transportation and Storage, Manufacturing and Health and community services). In response to the National OHS Strategy, Australian OHS authorities developed and reviewed national OHS standards, frameworks and tools that promote the vision of the National OHS Strategy.

National Standard for Construction Work (NOHSC – Australia)
In order to address the National OHS Strategy, the National Occupational Health and Safety Commission (NOHSC) developed the National Standard for Construction Work. The National Standard was developed to "protect persons from the hazards associated with construction work" (ASCC, 2005). This is achieved by assigning OHS responsibilities for individuals involved in the construction process. The standard was developed to apply to clients, designers, persons with control of construction project (i.e. Principal contractor, Main contractor, Builder, etc.), persons with control of construction work (i.e. Principal contractor, Main contractor, sub contractors, employers and self-employed), persons engaged to undertake construction work and construction sites. The standard stated that clients must consult with the designer and person with control of the construction project regarding OHS matters. The client is responsible for ensuring constructors can work in a safe manner and ensure no person on or near the construction site is put at risk as a result of the construction work.

Model Client Framework (Federal Safety Commissioner - Australia)
The Model Client Framework is a publication, developed by the Office of the Federal Safety Commissioner (FSC), aimed at providing practical and systematic approach to integrating OHS activities into the management of construction projects. Furthermore the Model Client Framework highlights 'best practice safety principles' and 'Key Management Actions' (KMA's) that promote a system of managing safety that recognises the importance of key stakeholders (i.e. clients, designers, contractors, subcontractors and suppliers) throughout the lifecycle of construction projects (from planning through to completion). It is no longer the case where the constructor is left with all responsibility for managing safety.

Construction (Design and Management) Regulations (HSE – United Kingdom)
Within Australia there are inconsistent OHS requirements in relation to clients. Although, within the UK, Clients have been required to consider OHS in construction under the Construction (Design and Management) Regulations 1994. The regulations have since been updated, now known as the Construction (Design and Management) Regulations 2007. The CDM Regulations specify OHS legal requirements for duty holders (e.g. Clients, CDM coordinators, Designers, Principal contractors, Contractors and Workers) involved in construction work. Under the CDM Regulations (2007) clients are required to:

- Check competence and resources of all appointees;
- Ensure there are suitable management arrangements for the project welfare facilities;
- Allow sufficient time and resources for all stages; and
- Provide pre-construction information to designers and contractors.

PROCUREMENT DELIVERY STRATEGY

As consumers of building and construction services, 'clients' initiate the building and construction process. As such, clients play a significant role in the selection and implementation of procurement delivery strategies. Therefore, the selected procurement delivery strategy has significant and direct implications for the performance of construction projects and the OHS culture of the project team (i.e. Client, Designer, Contractors, etc.). The procurement strategy establishes the contractual framework for any project and determines project relationships, authority and general responsibility for the various stakeholders (Rowlinson and McDermott 1999). Furthermore, the procurement strategy determines the level of influence project stakeholders can exert on project OHS. There are 3 broad categories in which procurement strategies can be classified (i.e. Collaborative, Hybrid and Traditional).

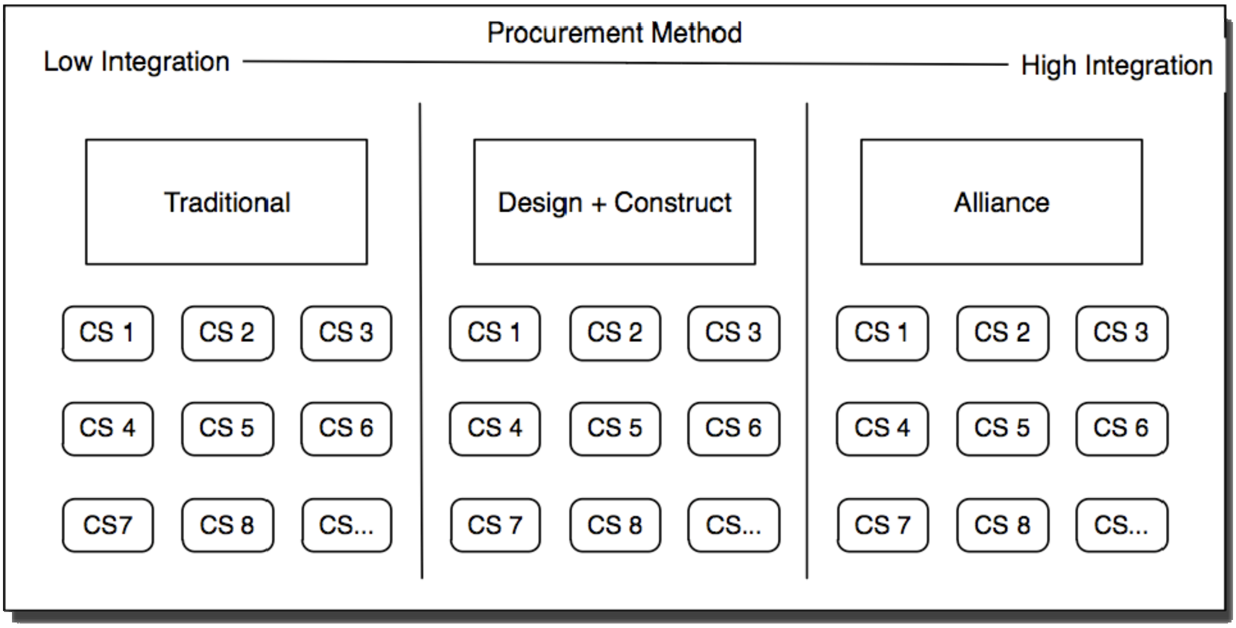
In a ‘Traditional’ competitive tendering process (e.g. design-bid-build), a principal contractor bids for and constructs the project in regards to a pre-determined design that has been prepared by the client’s designers. Lingard and Rowlinson (2005) suggest the transfer of OHS risk and information exchange within the design-bid-build process is least advantages for improving OHS performance. Due to the nature of the design-bid-build process, responsibility for OHS is transferred down the supply chain to rest mainly with the constructors.

In contrast to the ‘Traditional’ approach, ‘Collaborative’ arrangements attempt to involve all project stakeholders in the design and development stages of the project. In this situation the common understanding and expertise of project participants can be fully utilised. Project Alliances, Partnering and Joint Ventures are examples of collaborative approaches. As risk is usually distributed amongst project stakeholders, and requires all stakeholders to drive a strong OHS culture, there is greater potential for OHS to be strengthened within the project.

RESEARCH APPROACH AND DESIGN

There is a clear trend that owners are becoming increasingly aware of and responsible for the safety performance of construction projects. Although there are guidance material and tools available to clients, there is a lack of empirical evidence that highlights what impact model clients have on safety performance within the Australian construction industry. The significance of the project lies in the need for valid tools that guide clients on how to best engage and promote safety in construction projects. As part of a systematic literature review and analysis, this research project will take the form of a structured multiple-case study (Figure 1).

Figure 1: Model of Research Design



* CS = Case Study

- **Study Questions and Hypothesis**

The principal objective of this research is to explore the theory of Model Clients and empirically evaluate the 'Model Client Framework'. Specific study questions and proposed hypothesis include:
Study question 1: Is the Model Client Framework valid?

- Hypothesis 1: Implementation of the 'Model Client Framework' will positively impact the overall safety performance of construction projects.

Study question 2: How and why do different procurement methods affect the implementation of the Model Client Framework?

- Hypothesis 2: The procurement method will dictate the level and extent of improved safety performance.

It is expected that the selected procurement method will influence the implementation of the 'Model Client Framework' by affecting the level of integration and communication between stakeholders.

Study question 3: Identify correlations between organisational variables (Organisational size, structure, shape, etc.) and the effect of the Model Client Framework?

CONCLUSION

Although there have been efforts to increase OHS responsibilities of clients and designers, efforts to manage OHS still fall largely to the constructor. These efforts focus on implementing physical and procedural barriers that reduce worker's exposure to construction risks. Mitropoulos et al. (2005) highlights "this perspective has a narrow view of accident causality, as it ignores the work system factors and their interactions that generate the hazardous situations". In order to further improve safety performance of the construction industry, it is important to address causal issues before they occur at the construction level. Addressing safety at the construction site is contrary to modern models of accident causation that highlight the impact of professional or managerial actions during the planning and design stage (Bomel, 2001; HSE, 2003). Therefore it is important for safety issues to be addressed during the planning and design stages, where there is the greatest potential to impact job-site safety whilst keeping project costs at a minimum.

This research aims to empirically evaluate the 'Model Client Framework' and its effect on safety performance within Australian construction projects. As a result, empirical evidence gathered would provide information in regard to how clients can best influence project safety outcomes. More specifically, the research project would identify how Key Management Actions (KMA's) specified within the Model Client Framework affect safety performance of construction projects. It is envisaged that as a result of this research, a practical guide can be developed for the implementation of the Model Client Framework. Such guidance would maximise resources and efficiency of the implementation of the Model Client Framework.

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MOVING TOWARDS NATIONAL HARMONISATION IN AUSTRALIA: THE DESIGNERS' DUTY OF CARE FOR DESIGNING BUILDINGS AND STRUCTURES

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ABSTRACT
National and international research indicates that poor design and poor planning are contributing factors in a significant number of deaths and injuries in the building and construction industry. A major European study claims that two thirds of deaths in the industry can be attributed to poor design and poor planning.

In Australia, legislative frameworks continue to be developed both nationally and at the state and territory level to include design as an integral component of safety in the workplace.

The design profession's statutory duty for designing a building or structure varies under the current OHS frameworks across all Australian jurisdictions. One Australian association claims that the varying OHS frameworks reduce the capability and the competence of employers and consultants to understand their OHS obligations across the jurisdictions.

National harmonisation of occupational health and safety (OHS) has been on the national agenda for two decades in Australia. The business community in Australia has long been claiming that OHS reform is required to reduce the regulatory burden on employers and employees operating across all jurisdictions.

This article examines the economic and social costs of failing to eliminate hazards at the design phase of a construction project. It provides an overview of the design profession's statutory duty for designing a building and structure under the current OHS frameworks. Furthermore, this article examines and discusses whether national harmonisation of OHS will improve OHS performance and reduce the regulatory burden on stakeholders across all Australian jurisdictions.

Keywords: Construction, Designers, National harmonisation, Legislation

OHS LEGISLATIVE FRAMEWORK IN AUSTRALIA

Currently there are ten principal OHS statutes across Australia, six states, two territories and two Australian Government acts, one relating to Australian Government employees and the other relating to seafarers. There are also other state based industry specific safety laws such those covering mining in New South Wales and Queensland (The Australian Department of Employment and Workplace Relations 2005).

Historically the state and territory governments in Australia have taken a broadly similar approach to regulating OHS. This approach involves a principal OHS act codifying common law duties of care, supported by detailed regulations and codes of practice, and a system of education, inspection, advice, compliance activities and, where appropriate, prosecution (Australian Government 2008).

However, despite this commonality across jurisdictions, there remain differences as to the form, detail and substantive matters in relation to OHS legislation, particularly in regard to duty holders and duties, defence mechanisms and compliance regimes, including penalties (Australian Government 2008).

In Australia there is no consistent legal definition of 'duty of care' in the OHS legislation implemented across the various jurisdictions. This leads to confusion about legal obligations amongst stakeholders that operate across the jurisdictions. OHS duty of care obligations are not always based on what people reasonably and practically control in the workplace as required under international obligations (Business Council of Australia 2007, p. 4).

NATIONAL HARMONISATION

National harmonisation has been on the national agenda in Australia for two decades (Bellamy). Harmonisation refers to the notion that the differences in laws and policies between various jurisdictions be reduced by adopting and implementing similar laws and policies across the jurisdictions (Brown & Furneaux 2007).

The Australian Federal Government has committed to working cooperatively with state and territory governments to achieve the important reform of harmonised OHS legislation within five years and to develop and implement model OHS legislation as the most effective way to achieve harmonisation (Australian Government 2008).

The model legislation will consist of a model principal OHS act, supported by model regulations and model codes of practice that can be readily adopted in each jurisdiction (Australian Government 2008). The Federal Government and the business community claim that harmonising OHS laws in this way will cut red tape, boost business efficiency and provide greater certainty for all workplace parties (Association of Consulting Engineers Australia 2008, p. 4; Australian Government 2008).

All OHS statutes across Australia have common objectives based upon 'duty of care' principles to regulate for the prevention of workplace injury and illness (The Australian Department of Employment and Workplace Relations 2005). This approach is also internationally consistent with the International Labour Organization (ILO) Occupational Health and Safety Convention 155, to which Australia is a signatory nation (WorkCover New South Wales 2006).

SAFE DESIGN IN THE BUILDING AND CONSTRUCTION INDUSTRY

One of the fundamental principles in OHS is to eliminate hazards and risks, or where elimination is not reasonably practicable, to minimise them. The earlier the intervention, the more effective it is to eliminate or reduce the hazards and risks (Australian Government 2008, p. 67).

In 1995, the Industry Commission into Work, Health and Safety claimed that *"…the key to controlling injury and disease at work is to be found in the design and control of the workplace and the activities conducted within it."*

Research indicates that construction workers (nationally and internationally) are exposed to many risks that are in part dictated by the design of a particular project. These risks can be eliminated or reduced by taking OHS considerations into account during the design stage of a project (Durham, Culvenor & Rozen 2002, pp. 40 – 41).

WHY FOCUS ON SAFE DESIGN IN THE BUILDING AND CONSTRUCTION INDUSTRY?

In recent times safe design in the construction industry has become a major topic of OHS discussion in Australia. Australian and international research has identified design as a contributing factor in a significant number of deaths and injuries that occur in the construction industry (Trethewy 2003, pp. 189 – 199).

Research conducted by the National Occupational Health and Safety Commission (NOHSC) between July 1st 2000 and June 30th 2002 concluded that 18 fatalities in the construction industry were design related incidents. These fatalities represented 44% of all work related deaths in the construction industry (Australian Safety and Compensation Council 2005, p. 14).

In 1993 a major European study (conducted over a period of approximately 5 years and involving 12 member states) concluded that 63% of construction fatalities and 80% of structural damage or defects could be a result of design and planning decisions (Commission of European Communities 1993).

In the United Kingdom recent research indicates that approximately 64% of injuries and 36% of deaths in the building and construction industry could be traced back to a design factor and lack of planning in this key area of the project (Churcher & Alwani-Starr 1996; Sommerville 2003).

Two reports on the Irish construction industry over a 10-year period indicate that at least 25% of fatal accidents are directly attributable to the pre-construction stage of projects (Heffernan 2004, pp. 20 – 22).

Recent research from 16 case studies across 14 EU member states has concluded that better planning at the design phase could save 300 lives and prevent 500,000 accidents each year in the European construction sector (European Agency for Health and Safety at Work)

Trethewy argues that a greater focus on design and OHS in the Australian building and construction industry may result in an annual saving of between US$500m and US$1b to the economy (without taking into consideration indirect cost factors, including lost productivity and the cost of investigating accidents) (Trethewy 2003, pp. 189 – 199).

Design changes are more efficient and cheaper to implement at the planning phase and can prevent hazards from entering a workplace that may cause harm or injury (National Occupational Health and Safety Commission).

Figure 1 illustrates the cost-effectiveness of early intervention on safety problems in the building and construction industry. It is based on the original model by Wakeling and Knight-Jones, "Site Safety by Design" (Breslin 2007, pp. 89 – 99).

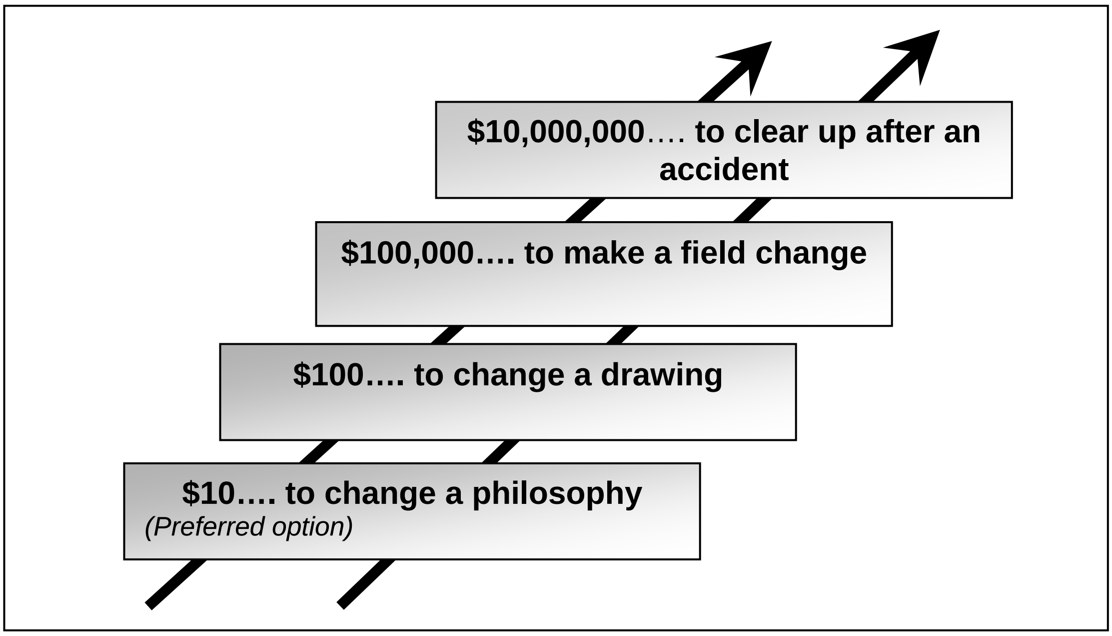

Figure 1: Site safety by design (after Wakeling & Knight-Jones 2000).

REGULATING SAFE DESIGN IN THE AUSTRALIAN CONSTRUCTION INDUSTRY

Traditionally, in Australia, the designers of plant had a duty of care (under the OHS Legislation in all jurisdictions) to design plant that was without risk as far as is reasonably practicable. This statutory duty did not apply to the designers of buildings and structures.

In recent times the OHS legislation in the Australian Capital Territory (ACT), the Northern Territory, Queensland, South Australia (SA), Tasmania, Victoria and Western Australia (WA), has been amended to ensure that designers of buildings and structures now have statutory obligations to design buildings and structures that are safe and without risks. However the designers' statutory obligations vary across the jurisdictions.

One of the key objects of the Victorian *Occupational Health and Safety Act* is to eliminate, at the source, risks to the health, safety or welfare of employees and other persons at work. However, designers only have a duty of care under Section 28(1) of the Victorian *Occupational Health and Safety Act 2004* to design a building or structure, or part thereof that is to be used as a workplace, without risks to the health and safety of those people using it (WorkSafe Victoria 2005, p. 1). The duty does not require designers to consider buildability and the safety of the construction workers.

It has been argued that Section 28 should be amended to achieve harmonisation with other jurisdictions that have designer duties covering 'buildability' (Stensholt 2007 pp. 32 – 33; Victorian Government 2008).

The Queensland *Workplace Health and Safety Act 1995*, Sections 30(a)(b)(c)(31), is similar to the United Kingdom legislative framework, the *Construction (Design and Management) Regulations*. The Queensland legislation requires the client to consult with the designer, the project manager and the principal contractor about how the construction work can be undertaken in a way that prevents or minimises all risks to health and safety (Department of Industrial Relations 2006).

In New South Wales there is no obligation for the designer of buildings and structures. A recent review of the OHS Act in New South Wales concluded that WorkCover does not recommend amending the OHS Act to address the issue of design safety as it would be introducing a new class of duty holder and would significantly extend the scope of the Act (WorkCover New South Wales 2006, p. 46).

This is one example of the inconsistent approach by the state and territory governments and the regulators. It can certainly be argued that the risks associated with the construction of a building or structure are the same in Queensland and New South Wales and that the legislation in New South Wales should have been amended to ensure that designers and other stakeholders have a duty of care to eliminate or minimise the risks to construction workers.

The Western Australia OHS legislation takes a holistic approach to safety in design. The Western Australia legislation places a statutory obligation on designers in relation to safety during construction, maintenance, repair and service of a building or structure, whereas the Victorian legislation places responsibilities on designers only if the completed building or structure is to be used as a workplace.

Western Australia is the only jurisdiction in Australia that has a three-tier approach to the designers' statutory duty. The duties for designers under Section 23(3a) of the Western Australia *Occupational Health and Safety Act 1984* are supported by the requirements under the *Occupational Health and Safety Regulations 1996* S3.140. The Western Australia *Code of Practice for Safe Design of Buildings and Structures* provides practical guidance on how designers can comply with the specific duties under the legislation. This model provides certainty and clarity to the designers in Western Australia.

On August 19th 2008 the Australian Capital Territory Government introduced the new *Work Safety Bill 2008* to replace the old OHS Act. The *Work Safety Bill* now expands the safety duties to all parties including building designers.

The statutory duty for the designers of buildings and structures is an ever evolving process. The governments and regulators in various Australian jurisdictions have different approaches to the issue of statutory obligations for the designers of buildings and structures under their OHS legislation.

There are also obligations for designers for safe design under:

- The National Construction Work Standard ;
- The Building Code of Australia (BCA) ; and
- Relevant Australian Standards.

THE NATIONAL STANDARD FOR CONSTRUCTION WORK

Designers also have an obligation under The National Construction Work Standard to consider the hazards and risks associated with the design of a building or structure and to consult with the client. This includes recording and providing information in a written report to the client. The Standard is not legally enforceable unless the state and territory governments adopt it under state and territory law. For example, the Northern Territory has adopted the Standard into their regulations under their principal OHS act.

The safe design provisions in the National Standard are based on a European directive that has been implemented in all European Union member states. The scope of the designer's responsibilities in the National Construction Work Standard is consistent with their general duties under the OHS acts (in the relevant jurisdictions where designers have a duty of care) but the National Standard provides more specific guidance as to their application in the construction environment (National Occupational Health and Safety Commission 2005, p. 11).

THE BUILDING CODE OF AUSTRALIA (BCA)

The Building Code of Australia was first released in 1996. The BCA is produced and maintained by the Australian Building Codes Board (ABCB) on behalf of the Australian Government and state and territory governments. The BCA has been given the status of building regulations by all states and territories (Department of Consumer and Employment Protection, 2008). The BCA is the principal document for regulating the design profession involved in the design of buildings and structures (Australian Safety and Compensation Council 2006, [b] p. 8).

Designers are required under the BCA to test for loads, capacities and speeds. Although the BCA is comprehensive in regulating some aspects of design such as choice of material and construction methods, its scope is considerably less than that of the OHS statutes and regulations.

One of the main aims of the BCA is to ensure that people (the end users), including emergency services, are protected from death, disease and injury during the life cycle of the building. However, the BCA is not concerned with the health and safety of people during the construction process (Bluff 2003, pp. 4 – 7).

The BCA provides a nationally consistent approach to building regulation in all jurisdictions. The National Occupational Health and Safety Commission claims that there is no reason to doubt that this approach could not be applied to consistent OHS regulation in the construction industry (National Occupational Health and Safety Commission 2005, p. 9).

DEFINITION OF A DESIGNER WITHIN THE CONSTRUCTION INDUSTRY

Currently there is no definition of a designer in the OHS Acts of Queensland, South Australia, Tasmania, Victoria and Western Australia. The Association of Consulting Engineers Australia (ACEA) claims that the inconsistency of key definitions in each jurisdiction causes uncertainty and misunderstanding for duty holders. Furthermore, the ACEA claim that it is vitally important that the definition of designer be contained within the National Model OHS Act, as certainty is a fundamental requirement in OHS legislation and regulation. Designers need to be in a position to adequately understand their obligations under the Model OHS Act (Association of Consulting Engineers Australia 2008, pp.10 – 11).

REGULATING SAFE DESIGN INTERNATIONALLY

In the United Kingdom, the Construction (Design and Management) (CDM) Regulations took effect in 1995 and were introduced as a response to the European Community's Temporary or Mobile Construction Sites Directive. The design and planning elements of the Construction Site Directive were adopted into the CDM Regulations. The CDM 1994 regulations are a prescriptive approach to regulating safe design in the construction industry (Cole 2003, pp. 54 – 57).

Evidence from the UK suggests that since the introduction of the CDM Regulations in 1995 there has been a downward trend in the number of fatalities in the construction industry despite some unexpected fluctuations. Since the introduction of the Construction Site Directive in 1992 few of the European States claim a reduction in incident frequency rates - except the Netherlands and Finland. Both of these countries report a decline in incidence frequency rates and fatalities. However, it is unclear if the reduction was due to factors in the construction industry, as manufacturing and transport experienced a similar reduction. The overall impact of the Construction Site Directive on the construction industry is ambiguous (Bluff 2003, p. 16).

A recent report released by the Health and Safety Executive in the United Kingdom has revealed that designers in the construction industry are becoming increasingly aware of their responsibilities to design out health and safety risks. Overall, 70% of designers were assessed as having an adequate or good knowledge of their legal duties under the CDM Regulations and other legislation compared to 33% in 2003 (Franklin 2005, p. 6).

NATIONAL HARMONISATION: THE DESIGNERS' DUTY OF CARE

Currently each jurisdiction in Australia tends to reap ideas off each other's efforts in revising and refining its OHS legislation, which probably means that overall, the country is progressing OHS standards at a very good rate towards national harmonisation.

An example of this approach is the adoption of the requirements (or principles) of the National Standard for Construction Work which was declared by NOHSC, in accordance with Section 38 of the *National Occupational Health and Safety Commission Act 1985* (Cth), on 27th April 2005 (National Occupational Health and Safety Commission 2005, p. 1).

Since the inception of the National Standard for Construction Work the OHS legislation in a number of jurisdictions has been amended to ensure that designers of buildings and structures now have statutory obligations to design buildings and structures that are safe and without risks to the occupants and workers.

The designers' duty of care for designing buildings and structures in Queensland, Northern Territory, South Australia and Western Australia is very similar, but in many respects the Western Australia legislation exceeds the legislative requirements in other jurisdictions.

New South Wales and Victoria have had the opportunities to have designer duties cover 'buildability' and also achieve harmonisation with other jurisdictions, but have failed to do so in both cases. This is one example of the inconsistent approach by the state and territory governments and the regulators.

The first report on the National Review into Model OHS Laws contains a number of recommendations that would provide consistency and clarity to stakeholders in relation to safe design across all jurisdictions. This includes recommendations 29 to 33 which outline specific duties of care for designers to ensure that the health and safety of those contributing to the use of, otherwise dealing with or affected by the use of the plant, structures or substances is not put at risk from the particular activity including building and construction. The duties of care that are recommended to cover the different life cycle phases are more extensive than in current legislation (Bluff 2009, p. 7).

Furthermore, the report recommends that the duties of care should apply to any reasonably foreseeable activity undertaken for the purpose for which the plant, structure or substance was intended to be used (e.g. construction, installation, use, maintenance or repair) (Australian Government 2008, pp. 70 – 75).

The Business Council of Australia claims that businesses need and want a practical, commonsense approach to fixing OHS problems (Business Council of Australia 2007, p. 23).

However, the case for national harmonisation of OHS legislation is perhaps not a black-and-white issue. The advantages of full and complete OHS harmonisation throughout Australia would include certainty and efficiency for those companies and suppliers operating nationally.

This would improve consistency and, in turn, the designers' (and all other industry stakeholders') knowledge and increase their confidence in dealing with safety in design issues as they move around the nation from project-to-project.

One of the greatest drawbacks to national harmonisation of OHS laws is that, once established, it may stagnate as change would require the agreement and cooperation of all states and territories. A consensus based approach to developing such legislation could create a lag between the legislation and the best practice, and model OHS legislation could rapidly become an inferior and/or obsolete standard of OHS. Either Commonwealth bureaucracy and/or a need for simultaneous consensus from eight separate state & territory regimes could also inevitably stifle responsiveness to innovation and change.

As a nation it is imperative that any economic benefits of the harmonisation process do not diminish the importance of OHS legislation and improve health and safety outcomes for all Australians (Business Council of Australia 2007, p. 7).

CONCLUSIONS

National and international research indicates that design is implicated as a causation factor in fatalities, diseases and injuries to construction workers, maintenance workers, end users and the public. The key to controlling injury and disease at work is to eliminate or minimise the risks or hazards during the design phase of a building or structure. The earlier intervention, the more effective it is to eliminate or reduce the hazards and risks.

The design profession's statutory duty for designing a building and structure varies under the current OHS frameworks across all Australian jurisdictions and one Australian association claims that the varying OHS frameworks reduce the capability and the competence of stakeholders to understand their OHS obligations across the jurisdictions.

Despite the commonality in the OHS legislation across jurisdictions, there remain differences as to the form, detail and substantive matters in relation to OHS legislation, particularly in regard to duty holders and statutory duties.

Currently there is no consistent legal definition of 'duty of care' in the OHS legislation implemented across the various jurisdictions. Most OHS Acts do not clarify what 'reasonably practicable' means in relation to ensuring OHS. Furthermore, there is no definition of a designer in the OHS Acts in Queensland, South Australia, Tasmania, Victoria and Western Australia.

The inconsistency of key definitions in each jurisdiction causes uncertainty and misunderstanding for duty holders that work across the different jurisdictions. The definition of 'duty of care', 'reasonably practicable' and 'a designer' should be contained within the National Model OHS Act to provide clarity and certainty to all stakeholders which is a fundamental requirement in OHS legislation and regulation. Designers need to be in a position to adequately understand and comply with their obligations under the Model OHS Act.

In the United Kingdom there is one national set of Construction Design Management (CDM) Regulations that provides consistency and clarity to those designers and organisations operating in various parts of the country. Research suggests that since the introduction of the CDM Regulations in 1995 there has been a downward trend in the number of fatalities in the construction industry despite some unexpected fluctuations.

Although national harmonisation may reduce bureaucracy, cut the amount of paperwork, provide consistency and clarity to designers and all other stakeholders in Australia, the main focus must be and should always be on improving OHS performance and reducing fatalities, injuries and diseases in the workplace.

DISCLAIMER

The opinions expressed in this paper are the author's own.

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INDUSTRY'S PERSPECTIVE OF DESIGN FOR SAFETY REGULATIONS

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ABSTRACT

Addressing safety and health hazards through the design of a product or system, often referred to as "designing for safety" or "prevention through design", is viewed by safety professionals as the most effective means for providing a safe work environment. Formal application of this intervention in the construction industry, however, can be difficult as a result of common construction industry characteristics and mindsets. In some countries regulations have been put in place to compel implementation of the intervention. One example of such regulations is the Construction (Design and Management) Regulations in the United Kingdom which place responsibilities on design professionals and others involved in projects to address the safety and health hazards on their projects. An on-going study of the prevention through design concept has investigated the perspectives of the UK construction industry regarding the CDM regulations. The study involved conducting focus group interviews of architects, design engineers, facility owners/developers, constructors, manufacturers/suppliers, and health and safety consultants in the UK. The interviews revealed perspectives of the CDM regulations that vary across the industry with regards to their acceptance and value. In addition, the extent to which the regulations are implemented in practice and knowledge of the regulations varies amongst different project team members. The findings from the focus group interviews indicate the value of formal regulations in promoting the design for safety concept and in overcoming obstacles faced when implementing the intervention in the construction industry.

Keywords: Design, Construction, Safety, Health, Regulations

INTRODUCTION

Maintaining a high level of occupational safety and health (OSH) is a common goal to protect and promote social and economic welfare. To ensure a minimum level of worker safety and health, many countries and governmental jurisdictions enact regulations that govern safety and health in the workplace. For example, in the United States, the "Occupational Safety and Health Standards for the Construction Industry" are developed and enforced by the Occupational Safety and Health Administration (OSHA) and disseminated as Title 29, Part 1926 of the Code of Federal Regulations (USDOL, 2002). These standards present the minimum requirements that an *employer* working in the construction industry must take to provide a safe and healthful work environment for its *employees*. Failure to comply with the standards may result in fines assessed against the employer or incarceration if willful negligence is present.

Regulations on the responsibilities of architects and design engineers in regards to construction site safety are not as common but present in some countries. When designing a building, bridge, roadway, or other type of facility, designers adhere to design codes adopted by the governmental jurisdictions in which their projects reside. In the US, the International Building Code (ICC, 2009) is an example of a design code commonly adhered to for the design of buildings. The code provides design guidance in structural, fire, and life safety provisions covering means of egress, interior finish requirements, comprehensive roof provisions, seismic engineering provisions, innovative construction technology, occupancy classifications, and material design. However, the design codes are commonly developed and written solely to ensure the safety and health of the occupants of the facility during its use after it is constructed. The design standards do not formally address or provide guidance for those who construct the buildings. In addition, adherence to the design codes is commonly a condition of standard practice and the design contract, and is not required under formal legislation.

Some countries and governmental jurisdictions have recently taken the additional step to develop and enforce regulations that govern a designer's involvement in construction site safety. The regulations are developed based on a perspective that all those who participate in the planning and design of a project can play a positive role within their scope of work to reduce construction site safety hazards. This perspective acknowledges and accepts that the form which a design takes influences the safety hazards to which the workers are exposed. The integration of construction worker safety and health considerations into the design of a facility provides opportunities to eliminate or control hazards before they exist on the jobsite. Some of the regulations also go further by establishing a responsibility to fulfill that role. The regulations appropriately match the responsibility of designing for safety with those who have the opportunity and position to design for safety. Failure to abide by the regulations may result in a variety of penalties depending on the nature of the negligence, including a fine, loss of professional licensure, and imprisonment.

The success of occupational safety and health regulations and of design codes, such as the OSHA standards for construction and the International Building Code, are widely evident. Worksite injury and fatality rates in the US construction industry has improved since the inception of the OSHA regulations (NSC, 1952-2008), and completed facilities continue to be designed that provide a high level of fire and life safety to their occupants. Where enacted, the success of design for safety regulations is not as clear due in some respect to the contemporary nature of the regulations and lack of historical data and to the difficulty in measuring their impact on safety performance. A research study is being conducted in the US and UK to understand the impact of design for safety regulations not specifically on safety performance, but on the role and perspectives of designers and on the nature and characteristics of design and construction practice. The regulations chosen for the study are the Construction (Design and Management) Regulations in Great Britain which place responsibilities on design professionals and others involved in projects to address the safety and health hazards on their projects. This paper presents preliminary results from a series of focus group interviews of design and construction industry professionals about the CDM regulations. The overall study, funded by the National Institute for Occupational Safety and Health (NIOSH) in the US, aims to understand the impacts of such legislation and provide guidance on expanding the prevention through design concept in the US. The goals of the study support NIOSH's National Initiative on Prevention through Design (PtD). Information about the initiative and PtD can be found at: http://www.cdc.gov/niosh/topics/PTD/.

DESIGN FOR SAFETY REGULATIONS

Examples of design for safety regulations that have been implemented by countries and governmental jurisdictions are described below. Similar regulations may be in force in other countries.

In 1992, the European Union passed EC Directive 92/57/EEC that requires all parties involved in EU projects, including designers, to address OSH hazards and risks on construction sites. As a result, EU member countries have enacted legislation in response to the directive. Great Britain's response was to enact the Construction (Design and Management) Regulations in 1994 (CDM, 1994). Following their initial implementation, concerns were raised that their undue complexity, coupled with the bureaucratic approach adopted by many duty holders, obscured the underlying objectives. These concerns led to the regulations being revised and updated in 2007.

The CDM regulations place a duty on designers to ensure that foreseeable hazards and risks to construction workers are avoided (MacKenzie et al. 2000). According to the Approved Code of Practice (ACOP) (HSC, 2007), the key aim of the regulations is to integrate health and safety into management of the project and to encourage project participants to work together to: (a) improve the planning and management of projects from the very start; (b) identify hazards early on so they can be eliminated or reduced at the design or planning stage and the remaining risks can be properly managed; (c) target effort where it can do the most good in terms of health and safety;

and (d) discourage unnecessary bureaucracy. The regulations are divided into five parts (HSC, 2007):

- Part 1 addresses matters of interpretation and application.
- Part 2 covers general management duties which apply to all construction projects, including those which are non-notifiable.

- Part 3 sets out additional management duties which apply to projects above the notification threshold (projects lasting more than 30 days, or involving more than 500 person days of construction work). These additional duties require specific appointments or documents that will assist with the management of health and safety from concept to completion of the project.
- Part 4 covers physical safeguards which need to be provided to prevent hazards on construction sites. Duties to achieve the standards are held by contractors who actually carry out the work, irrespective of whether they are employers or are self-employed. Duties are also held by those who do not perform construction work themselves, but control the way in which the work is done. This does not mean everyone involved with design, planning, or management of a project must ensure that all of the specific requirements are complied with. They only have such duties if, in practice, they exercise significant control over the actual working methods, safeguards, and site conditions.
- Part 5 covers issues of civil liability.

The Approved Code of Practice further describes what designers should do for all projects to fulfill their obligations under the regulations as follows:

> “Designers should:
> (a) make sure that they are competent and adequately resourced to address the health and safety issues likely to be involved in the design;
> (b) check that clients are aware of their duties;
> (c) when carrying out design work, avoid foreseeable risks to those involved in the construction and future use of the structure, and in doing so, they should eliminate hazards (so far as is reasonably practicable, taking account of other design considerations) and reduce risk associated with those hazards which remain;
> (d) provide adequate information about any significant risks associated with the design;
> (e) co-ordinate their work with that of others in order to improve the way in which risks are managed and controlled.
>
> In carrying out these duties, designers need to consider the hazards and risks to those who:
> (a) carry out construction work including demolition;
> (b) clean any window or transparent or translucent wall, ceiling or roof in or on a structure or maintain the permanent fixture and fittings;
> (c) use a structure designed as a place of work;
> (d) may be affected by such, for example customers or the general public.”

Other countries within the European Union have enacted similar regulations in response to the directive. The regulations in other countries vary to a great extent in their nature and requirements. The extent to which they are implemented and enforced varies as well.

Similar to the CDM legislation in the UK, in three jurisdictions within Australia (Western Australia, Queensland, and South Australia), occupational safety and health statutes establish obligations of designers of buildings and structures to address safety (Bluff, 2003). Additionally, the government of New South Wales requires safety through design aspects on public works projects worth more than $1 million and on certain high risk projects less than $1 million. This requirement is part of a comprehensive OSH management system required for governmental construction projects that includes 12 key management elements such as management responsibility, purchasing, and training. To assist with implementing this requirement, WorkCover NSW, a statutory authority within the portfolio of the Minister for Finance of New South Wales, developed the Construction Hazard Assessment Implication Review (CHAIR) process to facilitate addressing construction safety through design (WorkCover, 2001).

No design for safety regulations are currently in place in the United States. The nature of the design and construction industry in the US, coupled with a traditional aversion to more regulation, has kept such legislation from materializing. To date, integration of the design for safety concept has been voluntary and predominantly within larger and more progressive owner/client, designer, and construction management firms.

STUDY AIMS AND METHODS

The goal of the research study is to assess the effects of the CDM regulations on the construction industry in the UK. The research study includes gathering and analyzing experiences and perspectives through focus group interviews and an on-line survey. This paper provides preliminary results from the focus group interviews only; the on-line survey has not yet been completed. Focus group interviews of personnel involved in the UK construction industry were conducted to explore the following questions:

- How has the EU and CDM legislation affected the design, construction, and safety of a construction project?
- How has involvement in prevention through design (PtD) affected perceptions of safety, roles on the project, and organizational and professional culture?
- To what extent have innovative processes and products been developed in response to the directive to address safety in design?
- What is done differently now compared to practice prior to the CDM regulations?
- How has management of projects changed under the CDM regulations?

The targeted participants of the focus group interviews were representatives of six different professional "communities" within the UK construction industry: architects, design engineers, facility owners/developers, constructors (general contractors and trade contractors), manufacturers/suppliers, and health and safety consultants. These communities represent the primary participants involved in the development, implementation, and control of the planning, design, construction, and safety and health aspects of construction projects, and are the key implementers of the requirements set forth in the CDM regulations. Using a convenience sample from selected industry organizations and personal contacts of the researchers, a total of 13 focus group interviews were conducted. The sample of focus group participants includes individuals who are members of, or whose employers are members of, one or more of the following construction industry professional organizations in the UK: Chartered Institute of Building, Royal Institute of British Architects, Institution of Civil Engineers, British Safety Council, and Association for Project Safety. Potential focus group participants were selected from the members of the organizations listed above that are located in London and the surrounding area. A series of questions exploring the application of the CDM regulations and their impact were developed for use as a guide in the focus groups interviews. The focus group interview responses were recorded for later analysis (hand-written and tape-recorded). Data analysis consisted of basic descriptive statistics and text analysis to understand the participants' collective perspectives. Content analyses were used to extract key themes supported by the participants that are related to the research questions posed above.

RESULTS

A total of 61 participants participated in thirteen focus group interviews conducted for the study. One additional focus group interview of architects is planned in order to increase the number of responses from those with an architectural perspective. All of those who participated in the interviews had experience with implementing the CDM regulations (mean = 11.1 years, min. = 1 year, max. = 18 years). Most of those interviewed (46%) work in large firms (>1,000 employees). The industry sectors in which the participants' firms conduct work are approximately equally distributed between the commercial (36%), industrial (35%), infrastructure (29%), and residential (28%) sectors. The types of services provided by each firm are as follows, along with the percentage of firms that provide that service: health and safety consultation 26%, project management 22%, construction 20%, engineering 18%, and architecture 14%.

To get an understanding of the changes that have occurred in their respective roles and positions as a result of the introduction of the CDM regulations, the participants were asked to describe what is done differently in their work now compared to before the regulations. The following are common responses to this question:

- More safety notes and symbols are placed on the drawings to alert the constructors of potential hazards.
- More pre-fabrication is used to eliminate work on the jobsite.
- There is more consideration of construction earlier in the project and inclusion of safety into the discussions.
- There is more paperwork (required to meet the CDM regulations).
- Designers are more open to considering safety.
- There is more communication and collaboration as a team. According to one interview participant, “This is causing them to just do what they should do as professionals.” Another participant added that the CDM regulations were just the catalyst; more communication and collaboration was the real driver of improvements.

The participants were also asked to identify barriers to implementing the CDM regulations. The most common barriers cited were: a lack of designer education and training; difficulty in assessing risks; a lack of knowledge of the CDM regulations; the extensive amount of paperwork required; competing priorities (e.g., safety vs. cost/schedule); and the separation of the design and construction areas of expertise on the project team and in the project delivery process. With regards to assessing risks, it was also recognized that there are differences in risk thresholds between those who assess the risks, which can be a barrier. For example, an architect may interpret an aspect of the project as being relatively safe while a trade contractor who has more knowledge of the associated construction activities may feel that there is significant safety risk involved. In addition to barriers, the participants were asked to identify enablers. The most commonly cited factors that enable implementation of the CDM regulations were: a high level of construction experience amongst the architects and engineers; an integrated project delivery (IPD) approach on the project; a quality CDM Coordinator; and early involvement of the CDM Coordinator in the planning and design phases.

The participants voiced a variety of issues regarding practical implementation of the CDM regulations during the interviews. The following are commonly raised issues:

- Inconsistent implementation across the industry. The extent and quality of implementation tends to be better on larger projects and in the petro-chemical manufacturing and infrastructure sectors.
- On some projects, it feels more like “just doing the CDM paperwork” as opposed to worker safety and health being integrated into the project culture and practices. The extent to which this occurs depends on the quality and credibility of the CDM Coordinator.
- More guidance is needed regarding where the designer’s responsibility ends. It would be helpful if, along with the CDM regulations, there was guidance on best design practices. This includes descriptions of what hazards are best mitigated through the design and what should be left up to the constructor.
- The amount of paperwork is too extensive. Minimizing and/or streamlining the paperwork would facilitate the process and increase interest.
- The CDM Coordinator position should be elevated to a more “professional” level position, similar to that of the architect/engineer.

The decision to implement design for safety regulations stems in part on the impact that designing for safety can have on safety performance. Research has identified the design as an influence on safety hazards and that designing out hazards could have prevented construction site injuries

(Gibb et al., 2004; Haslam et al., 2003; Behm, 2005; Lorent, 1987, as cited in European Foundation 1991). Another means of identifying the success of design for safety efforts is to look at the need for downstream safety and health interventions. If a project is designed for safety, the need for safety and health interventions during construction would theoretically be less. The participants indicated that the need for downstream safety management has perhaps changed rather than lessened. While in some instances the need for traditional safety practices and measures is less (e.g., fewer temporary fall anchorages need to be added during construction because they are already designed into the structure), there is a greater need to document the hazards as required by the regulations and to manage the CDM documents.

The extent to which the design and construction industry needed the CDM regulations in order to incorporate the design for safety concept into its practices was explored as well. The interview participants were asked whether their design for safety roles and activities would have materialized without the CDM regulations. Some of the participants in the larger, more progressive, firms indicated that their firm was progressing toward designing for safety without the CDM regulations. However, most of the responses indicated that implementation of design for safety concepts and practices would not have occurred if the CDM regulations were not present.

CONCLUSIONS AND RECOMMENDATIONS

A review of the focus group interview responses provides the industry's perspective of the CDM regulations with regards to their impact, applicability, and utility. Overall, the participants expressed a positive view towards the regulations. Different examples of how they are implemented and have benefited projects were described. Design culture and practices have changed as a result of the regulations. In addition, new designers entering the industry carry with them the perspective that addressing safety in a design is just part of a designer's role. Similar to other types of safety regulations, however, negative aspects of the regulations were presented along with a variety of suggestions for improvement.

The CDM regulations in the UK provide one example of design for safety regulations. Other countries have implemented similar regulations or may be considering similar legislation. The preliminary results from this study provide some important issues to consider regarding the presence and structure of similar regulations. The following issues should be addressed when considering developing and implementing design for safety regulations:

- Will the regulations push safety and health interventions up the hierarchy of controls? Under the CDM regulations, there is a tendency to just document the risk and manage it as usual. Some participants felt that, while the CDM regulations led to more discussion and documentation of safety and health risks, this did not always translate into designing out the hazards (i.e., there was minimal effort to move safety and health management up the hierarchy of safety and health controls). In addition, where the designs were changed, their focus tended to be on maintenance and user safety, not construction safety. Construction safety and health hazards were documented and their mitigation sometimes left up to the constructor.
- What priority should be given to safety compared to other project goals such as cost and schedule? A decision that is "commercially practicable" is allowed by the CDM regulations. However, selecting design features and systems based on their commercial practicability may hinder the implementation of interventions that can significantly impact on safety and health.
- How will designing for safety be communicated rather than simply designing to meet the regulations? Discussion of the prevention through design concept in the focus groups tended to drift towards discussion of the CDM regulations. The prevention through design message was frequently lost amidst the need to meet the regulations.
- Is the design community ready for the regulations? Success in implementing the design for safety concept requires that designers know about and understand the concept and are trained on how to implement it in practice. Current university-level and continuing professional education may not be sufficient. Strategies for diffusing the design for safety

concept should be developed and implemented to ensure that the design community is able to respond.

- What other safety regulations and initiatives are being promoted and diffused? Implementing design for safety regulations may be overshadowed by other, more readily acceptable, efforts. The connection between other interventions to improvements in safety and health may be more evident, and therefore designing for safety may not receive the credit it deserves.

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DESIGNING FOR SAFETY: PERSPECTIVES FROM EUROPEAN UNION, UNITED KINGDOM, AUSTRALIA AND UNITED STATES PERTAINING TO SAFETY AND HEALTH IN CONSTRUCTION

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ABSTRACT

Occupational safety and health in construction is a global issue. Designing for safety in the features of a building or structure can facilitate the safety of people during construction and in the use of the facility as well. Almost all work on safety design to date has been undertaken in member countries of the European Union, Australia and the United States. This study sheds light on the history of 'design for safety' in these countries that can provide lessons learned and guidance for others to pursue and adopt. The study reviews relevant literature on 'design for safety' in general, with particular emphasis on construction. It is confirmed that designers should have responsibilities for addressing occupational health and safety for construction workers and building users and there is significant value for improved studies and practices on design for safety in the construction industry, although the concept and its application is still at its initial stage and there is a varying degree of successes in practice. Policy and practice implications to policy makers and project stakeholders are also identified respectively.

Keywords: Design, Safety, Construction safety, Designing for safety

INTRODUCTION

An increasingly popular approach to preventing and controlling injuries, illnesses, and fatalities in construction is to minimize hazards and risks early upstream in the design process. Designing for safety is recognized internationally as a feasible method to reduce construction workers' risk (HMSO 1994; WorkCover 2001). Generally, design errors are slipped through the check and review process. Kinnersley and Roelen (2007) reveal that for the accidents and incidents in the aircraft and nuclear industries, about 50% have a root cause in design. They found that the proportions for the aviation and nuclear industries are 51% and 46% respectively which are remarkably similar. Hale et al. (2007b) indicate that the influence of design on accidents and incidents vary across publications, but were typically in the range of 20-60% of accidents having at least one significant or root cause attributed to design. Hale et al. (2007b) conclude that 40% to 60% of accidents have at least some root causes in the design stage. This means that if such root causes would have been corrected in the design stage, the projects would have been completed more safely. Thus, the best route to operational safety is to 'get it right' from the start, during design. Lin (2008) states that designing for safety is a cross-cutting concept which can affect the practice of safety in all industries. Culvenor (2003) stated that safe design is about decisions which impact positively on safety downstream and has life-cycle effects. The authors postulate that designers need to be aware of how design affects workers, builders and users. However, what is known about the extent to which design issues contribute to work-related accidents, is limited. Manuele (2008) revealed that designing for safety was inadequately addressed in the popular safety literature. Further, design-safety know-how and knowledge were not accumulated in any organized manner, theories and principles that have been developed, are often not practiced. Almost all these limited efforts on 'design for safety' to date have been carried out in member countries of the European Union, United States and Australia. The objective of this study is to review perspectives and evolutions of designing for safety in these countries that would provide lessons learned and guidance for others to follow and adopt.

In order to better understand design-safety concept, a number of past studies have been examined. Most of the papers that have been covered in this review are listed in Table 1, which provides a summary of the most relevant designing-for-safety research. It is believed that the seventeen (17) studies selected for this review constitute a general view of the subject matter. A discussion based on the studies together with a streamlining of the history of the topic is given in this paper to reflect on the important issues of designing for safety.

Reference	Summary of Research
Gambatese (1998)	Focuses on the liability of design consultants in the project delivery system and addresses the design community to incorporate design safety knowledge for construction worker safety into the scope of work for the purposes of fewer worker injuries and fatalities, and ultimately a safer construction jobsite.
Gambatese and Hinze (1999)	Build on the previous study of Gambatese et al. (1997) which recognizes an existing knowledge gap between constructors and designers and their commitment to jobsite safety. The work requires a major education effort in the design community and offers design suggestions or best practices for implementation in design. The study recommended that owners must provide the initial impetus requiring through contract terms that designers consider construction worker safety in their designs.
Coble and Blatter Jr. (1999)	Report that because of the separation of design and construction concepts, the construction process has become an haven for litigation, with owners routinely shopping for the cheapest designer. The paper suggests that there exists a need to foster synergy among participants in the construction process.
Rechnitzer (2001)	A discussion paper which describes generally the role of designers as regard responsibility and accountability for safety for the full product life cycle.
Bluff (2003)	A discussion paper that examines the regulation of safe design and planning of construction works. Taking account of existing Australian law and approaches drawn from European experience, the paper outlines some directions for Australian OHS law for the benefit of workers engaged in construction.
Culvenor (2003)	A discussion paper that emphasized safe design is a driver of innovation. Safe design can yield safety benefits as well as production benefits, quality improvement, new products, cost savings, and so on. Safe design is about thinking about downstream or life-cycle effects.
Gambatese et al. (2005)	Present a pilot study conducted to investigate the practice of addressing construction worker safety when designing a project. Through 19 interviews of architects and design engineers, the study found that design professionals are interested and willing to implement the concept of designing for safety. The study describes the key changes needed for implementing of the concept in practice which include: a change in designer mindset towards safety; establishment of a motivational force to promote designing for safety; increase designer knowledge of the concept; incorporate construction safety knowledge in the design phase; utilize designers knowledgeable about design-for-safety modifications; make design for safety tools and guidelines available for use and references; and mitigate designer liability exposure.
Weinstein et al. (2005)	Describe the impact of a safety-in-design initiative during the design and construction of a semiconductor manufacturing facility in the United States. The analysis of the initiative provided that injury prevention efforts in the construction industry can begin upstream by involving designers, engineers, and trade contractors in preconstruction processes.

Reference	Summary of Research
Kjellen (2007)	The paper analyzes two different perspectives of the principles used in different phases of design by the Norwegian oil and gas companies. Human centered approach focused on the design of work places while 'energy barrier' perspective provided technical safety functions on the platform. The paper shows that the barrier perspective has been implemented in design to prevent fires and explosions.
Gambatese et al. (2008)	Provide evidence of design's influence on construction site safety. To confirm the findings of a previous study (Behm 2005), an expert panel was established to review a sample of the 224 fatality cases. The previous research results and expert panel responses were in agreement for 71% of the cases reviewed that design influenced on site safety.
Schulte et al. (2008)	Offer 'prevention through design' initiative 2007-2014 in terms of four overarching areas where action can be directed: practice, policy, research, and education. A seven year strategy is envisioned to design out hazards rather than dealing with them.
Manuele (2008)	Discusses in short the 'prevention through design' initiative in historical and prospective perspectives.
Creaser (2008)	Presents safe design activity in Australia in the context of providing an overview of the regulatory environment.
Driscoll et al. (2008)	Present the analysis of fatal work-related injuries in Australia. The Australian National Coroners' Information System (NCIS) was the data source and deaths resulting from workplace injuries on or between 01 July 2000 and 30 June 2002 were analyzed. Results indicate that 37% of 210 workplace fatalities had design-related issues involved; another 14%, circumstances were suggestive that design issues were involved.
Kovalchik et al. (2008)	Present the quiet-by-design approach of a noise control that reduced noise exposures of continuous mining machine operators by 3dB(A) using the four functional area of 'prevention through design', namely research, practice, policy, and education.
Behm (2008)	Presents suggestions of the workshop participants describing that there was much enthusiasm for 'prevention through design', nonetheless, numerous challenges exist and among those, the liability issue must be resolved at a national level. The study asks that a clearer definition of 'prevention through design' must be agreed upon.
Toole & Gambatese (2008)	Suggest that the application of Construction Hazards Prevention through Design (CHPtD) concept can evolve along four trajectories: increased prefabrication, increased used of less hazardous materials and systems, increased application of construction engineering, and increased spatial investigation and consideration.

Table 1: List and summary of prior designing for safety research.

COUNTRY STUDY

The European Union and United Kingdom

In 1992, a rigorous effort was initiated to improve OHS in the European construction industry. The directive 92/57/EEC "on the implementation of minimum safety and health requirements at temporary or mobile construction sites", commonly referred to as the *Construction Site Directive* (European Commission 1992) was issued. In response to this Directive, the United Kingdom passed into law the Construction (Design and Management) Regulations (CDM), which became effective in 1995 (Her Majesty's Stationary Office 1994). France passed regulations which mandate a holistic view of construction safety including the design (OPPBTP 2002) and other European countries have since followed with similar regulations (Gibb, 2004). The EU directive is now adopted in the law of all member states of the European Union. It represents the most far-reaching regulatory initiative to improve OHS in the design and planning of construction works.

In the UK, particularly, the design and planning elements of the *Construction Site Directive* were adopted with enhanced amendments, in the *Construction (Design and Management) Regulations 1994* (CDM regulations). The CDM regulations require that designers are to give adequate consideration to the safety of construction and maintenance workers. The client must appoint one or more persons to coordinate OHS matters during the design and planning, and construction phases. The CDM regulations also address designers' involvement in selecting the bidders and in procurement. The CDM Regulations place duties on several parties who can contribute to the OHS management of construction works. These parties include *client, designers*, the *planning supervisor* and the *principal contractor*. The *client* must appoint persons, who are competent and have allocated resources to carry out their role under the CDM regulations. The *client* must:

- Appoint the planning supervisor and provide information to him/her that is relevant to OHS;
- Appoint the principal contractor;
- Ensure that a designer, if engaged, is competent;
- Ensure that the health and safety plan is prepared; and
- Ensure that s/he receives the health and safety file at the end of the project.

Under the CDM regulation, the *designer* must ensure that the client is aware of his/her duties and that OHS matters are addressed in the design of the project. Designers have responsibilities for OHS in all designs that they prepare directly, as well as designs prepared by their employees or other persons under their control. The *planning supervisor* must ensure for the project that: OHS matters are addressed in the design; ensure cooperation between designers; give advices to the client and contractors to enable them to comply with the regulations; ensure that a health and safety plan is prepared. The *principal contractor* must coordinate OHS matters in the construction phase of the project, including the development of the construction phase health and safety plan. The CDM Regulations require the *planning supervisor* to ensure that notice of the project is given "as soon as practicable" after his/her appointment. The regulation warns that with late notification, there is little opportunity for the regulatory authorities to intervene or address weaknesses in the design and planning phase, except after the event.

The Health and Safety Executive (HSE 2002) suggests that designers take the following specific steps: "Identify the significant health and safety hazards likely to be associated with the design and how it may be constructed and maintained; consider the risk from the hazards which arise as a result of the design being incorporated into the project; if possible, alter the design to avoid the risk, or where this is not reasonably practical, reduce it." HSE (2002) further states that designers must ensure construction documents properly communicate the designer's suggestions for dealing with specific risks, such as ensuring "the design details of items to be lifted include attachment points for lifting."

Efforts on designing for safety in the academic and professional areas progressed side by side. For example, there is a special issue in January-February 2007 of the journal *Safety Science*, which is concerned with getting safety into design. Fourteen of its sixteen articles were the presentations made at a workshop on "Safety by Design" held by the NEW Technology and Work Network, a European entity. The purpose was to assist the designers to stand back from their work and see the processes that are operating and how safety fits into them, and then to reengage in that work with the help of the knowledge, tools, and approaches offered through the workshop to embrace the designing for safety concept (Hale et al. 2007a).

Australia

Safe design work in Australia commenced at a national level under the National Occupational Health and Safety Commission (NOHSC) in the late 1980s. In 1994, the National Standard for Plant (NOHSC 1994) was published, which described duties for designers, manufacturers, importers, and suppliers, to ensure that risk and hazards associated with the plant that they were designing, manufacturing, and supplying, were eliminated, or where this was not practicable, minimized. In 1998/1999, the Safe Design Project was initiated by the NOHSC and in 2000, two reports were prepared. The first was a review of safe design literature and of initiatives of OHS authorities, and other key players, relating to safe design (Cowley et al. 2000). This report identified areas of deficiency in the understanding of legal requirements and knowledge related to safe design, and was helpful in setting the direction of future work in this area. The second report was an analysis of 225 fatality studies, involving machinery and fixed plant in Australia, between 1989 and 1992 (NOHSC 2000; Driscoll et al. 2008). Of these fatalities, 117 were found to have at least one design factor contributing to the incident. Several other research papers (Caple and Associates 2000; Gunningham et al. 2000; National Research Centre for Occupational Health and Safety Regulation 2002) were produced under the Safe Design Project. These papers collectively elevated the issue of safe design as a key OHS policy and highlighted that improving design would reduce injury and fatality rates.

To “eliminate hazard at the design stage” is one of the priorities set out by the National Occupational Health and Safety Commission (2002). The National Occupational Health and Safety Strategy states that the ‘responsibility to eliminate hazards or control risk rests at its source. This principle applies to all sources of hazards. Responsibility falls on a wide range of parties, including those outside of the workplace such as designers, manufacturers, constructions or suppliers (NOHSC 2002: p. 9).

Another report (NOHSC 2004) disclosed that 37% of 210 workplace fatalities studied had design-related issues involved; another 14%, circumstances suggested design issues were involved and design issues appeared to contribute to at least 30% of injuries. A work-related serious injuries report by Driscoll et al. (2005) found that design problems were involved in many fatal incidents and design is an important contributor to fatal injury in many industries.

In May 2006, The Australian Government issued *Guidance on the Principles of Safe Design for Work*. The Australian Safety and Compensation Council (ASCC 2006a) published *Guidance on the Principles of Safe Design for Work* and launched an educational resource package *Safe Design for Engineering Students* (ASCC 2006b). The package was designed to enable educators to incorporate examples of safe design into the existing engineering curriculum. This safe design effort got strong support from Engineers Australia, the professional and registration body for engineers in Australia.

In a separate effort, the ASCC is currently revising the National Standard for Plant and is developing Essential Safety Outcomes (ESOs) as the minimum standards for plant design. In relation to Australia, Driscoll et al. (2008) found design problems associated with fatal incidents. The most common scenarios involved problems with rollover protective structures or associated seat belts; inadequate guarding; lack of residual current devices; inadequate fall protection; failed hydraulic lifting systems in vehicles and mobile equipment; and inadequate protection mechanisms on mobile plant and vehicles. According to Driscoll et al. (ibid), there is a considerable scope for preventing serious work-related injuries through improving design of plant, equipment, and vehicles used for work-related purposes.

Regarding construction design, several state regulations are in place in Australia that require designer to consider how the structures they design are going to be safely constructed (Bluff 2003). For example, New South Wales requires that a management strategy to be in place in the design process which includes consideration, evaluation, and control of occupational safety and health during construction (New South Wales Construction Policy Steering Committee 2000). Additionally, the Construction Hazard Assessment Implication Review (CHAIR), a design for construction safety implementation tool, was developed (WorkCover 2001). However, the effectiveness of these developments for *safety through design* is still to be determined.

The United States

In the early 1990s, several safety professionals recognized that designing for safety was inadequately addressed in the safety literature in United States. For example, Gambatese et al. (1997) stated that the designers were not directly involved in the safety efforts. In 1995, the National Safety Council of USA established “the *Institute for Safety through Design*” (Manuele 2008). An *advisory committee* for the *Institute* was formed with the mission: “to reduce the risk of injury, illness, and environmental damage by integrating decisions affecting safety, health, and the environment in all stages of the design process." The term '*safety through design'* was used which defines the integration of hazard analysis and risk assessment methods early in the design and engineering stages (Manuele ibid). This was done to take actions necessary to achieve that risks of injury or damage are kept to an acceptable level. The strategies adopted by the *Institute* included: (1) expand the knowledge and concept of *safety through design*; (2) develop engineering curricula course materials; and (3) establish liaisons with school, socities, industry, and labor to increase awareness. Much work has been done by the *Institute* in forms of seminars, workshops, and symposia.

In March 2007, the Occupational Safety and Health Administration Construction Alliance Roundtable Design for Construction Safety Group issued a 3 hour course entitled "Design for Construction Safety". In July 2007, the first Prevention through Design (PtD) Workshop was held in Washington DC to launch a National Initiative at the National Institute for Occupational Safety and Health (NIOSH) aimed at eliminating occupational hazards and controlling risks to workers "at source" or as early as possible in the life cycle of projects. As part of the initiative, NIOSH was entrusted to send letters to the chief executive officers of the 5,000 largest companies in the United States describing what the initiative intend to accomplish (Manuele 2008). CEOs of the companies were asked to write to the Deans of engineering schools, and science degree programs, highlighting the need of graduates to be knowledgeable about hazards, risks, and risk assessment techniques. The objective is 'to achieve a cultural change whereby management insists that engineers and safety science graduates have knowledge of designing for safety concept (Manuele 2008).' Additionally, a three-hour course in PtD was made available by NIOSH to schools and research grants were established to support safety educators and professionals to consolidate their best practices.

IMPLEMENTATION: STANDARDS/CODES, PROCESSES/TOOLS, AND REGULATIONS

Hale et al. (2007b) state that design standards provide designers with instructions and guidance on how and for what situations to design. Fadier and De la Garza (2007) revealed that designers place a great reliance on these standards and if something is not in the standards, then they claim not to consider it. Also, there is a danger of standards which are not complete or not updated with recent experiences. ISO (2000) aim to resolve these issues by adopting work processes to be used by the design organization. The Building Code of Australia 2008 (BCA) is concerned with safeguarding people from injury, illness or loss of amenity in the use of a building including authorized emergency activities such as rescue operations and fire fighting (ABCB 2008). When the BCA is comprehensive in its approach to regulating various aspects of design, choice of materials and methods of construction, its scope is considerably narrower than the OHS regulations. The BCA is concerned with minimizing risks arising in buildings once they are constructed – it is not concerned with OHS in the construction phase. In the USA, some standardized tools are available including the Design for Construction Safety Toolbox (CII 1996) which is utilized in practice. Nevertheless, designers also need to learn from accidents, incidents and errors.

The shift in legislation is altering that view and asking designers to consider systematically the case for increased attention to safety during design. In the EU, the standards of 'good design practice' for example the EN standard 292 (CEN 1991) provides a powerful incentive to make design explicit. They can be used in court cases as a benchmark for assessing design that whether each party had fulfilled its responsibility. Nevertheless, creating statutory occupational health and safety duties for designers do not automatically deliver reductions in construction safety risks. When statutory responsibilities for occupational health and safety in the construction stage of a project were imposed upon construction designers under the *CDM Regulation,* they created a new professional role by requiring the appointment of a *Planning Supervisor*, with the responsibility to co-ordinate the occupational health and safety activities on construction sites. The *CDM regulations* place a duty on the designers to ensure that any design prepared avoids foreseeable risk to construction workers. Nonetheless, the success of the CDM regulations in reducing construction fatalities was not established (Gibb 2004). Designer's lack of knowledge (Gibb 2004) and their disregard for the legislation (Cosman 2004) was always been a barrier to a successful legislative process.

IMPLEMENTATION: PERFORMANCE

Since the advent of the *Temporary and Mobile Construction Site Directive* of 1992 in Europe, legislative duties have been placed on designers (Anderson 2000). In the UK as mentioned before, the design and planning elements of the *Construction Site Directive* are adopted with enhanced amendments in the form of *Construction (Design and Management) Regulations 1994*. Nonetheless, a survey by HSE (2004) revealed that only 33% of designers had sufficient knowledge of their legal responsibilities to “design out” risk and only 8% had received any training on the subject. Thirty-seven percent (37%) of designers had little or no knowledge of the *CDM regulations* affecting contractors. Sixteen percent (16%) of designers abdicated their responsibilities in the design risk assessment process, resulting in principal contractors having to deal with risk that could have been addressed during the design process. Fifteen percent (15%) of designers included specified solutions to work-at-height by relying on safety harness systems, without necessarily having considered alternative design solutions. On the subject of work-at-height hazards, one third of designers had not considered “constructability” and “buildability” with regard to risk from working at height, nor had they considered risk from work at height associated with future maintenance. Of course, there were examples of good practices in this regard, but the actual practices exposed in this survey definitely fell below expectations (HSE 2004). Despite CDM regulations, UK designers frequently expressed the opinion that it was not their responsibility to know how the building was to be built, as that was a problem for the *principal contractor* (Gibb 2004). It appears that there are areas of weakness in the UK approach to regulating designing for safety in construction works.

Nevertheless, Gibb (2004) revealed that significant work had been done in the UK to provide practical design tools to improve construction site safety and health. For example, a renowned designer Ove Arup has produced “Work sector guidance for designers” for the Construction Industry Research and Information Association (CIRIA). The revised report provides advice for designers of various elements of building and civil engineering projects (CIRIA 1997/2003). Additionally, revised *CDM 2007 regulations* came into force on April 6, 2007 with the focus on effective planning and management of risk – ‘manage the risk not the paper work’ (HSE 2007a). The regulations of 2007 can ensure that construction projects are safe to build, safe to use, and safe to maintain and deliver good value (HSE 2007b). Nonetheless, CDM 2007 regulations require choosing a competent team and helping them to work safely and efficiently together.

SUMMARY AND CONCLUSION

Designers including architects, engineers and related technical experts, should give ‘designing for safety’ a high priority. Safety will improve if a design process is well managed in terms of construction safety mitigation. By addressing safety during the design process, hazards can be eliminated or reduced during construction, thus improving the safety performance of the constructor. Also, there is a need to create design documents that address worker safety throughout the design process. The success of design for safety depends upon the joint efforts among stakeholders including owners, designers, researchers, educators, practitioners, manufacturers, and policy-makers. By sharing and collaborating opportunities and challenges, progress on injury prevention can be made by adopting the safe design. Additionally, designers are urged to understand that their job is to design use of the facility, not just to design the facility.

Despite the implementation approaches that need to be improved and a mixed performance, the authors do not want to end the discussion with a negative note. The designers are urged to take a reasonable share of ownership of safety in their designed product and service. Designers are urged to agree to a safety policy for designers so that safe design practices would flow. It is stressed that designers should develop their own ‘safety culture’ for contributing towards a safer construction. Also, the authors would like to make a strong appeal for studies to be undertaken on designing for safety. The authors believe that there is an utmost need to develop modern design standards. Implementation and use of modern design standards and tools can foster change in the construction industry of respective countries. Use of safe design standards and tools can generate additional safety suggestions, which are to be incorporated into future versions of design software. Continuous use of safe design standards and tools can lead to further development of functions in the safe design programs to better meet the needs of designers.

It is believed that this study will help in developing awareness and understanding of designing for safety concept when there have been little progress in producing designs that are safer to construct. This study may be helpful to provide background information to regulatory agencies in policy making, and architects, design engineers, developers, project owners, and safety professionals in project level decision making about utilizing the design for construction safety concept and applying it in practice.

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DESIGNERS' HEALTH AND SAFETY RISK ASSESSMENT PRACTICE: A CASE STUDY OF A UK ARCHITECTURAL PRACTICE

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ABSTRACT
Recent changes in UK Regulations have impacted upon practice requirements regarding construction design risk management for health and safety. This research reviews these regulatory changes and undertakes to provide a case study investigation of design risk management within a UK architectural practice.

An insight into designers' knowledge, practices and attitudes regarding design risk management for health and safety is provided through a series of seven interviews. Access to the designers and their practice has been facilitated by the fact that the researcher is a design practice 'insider' – a 'practice-member-researcher'.

The architectural practice of this case study investigation proffers a view that the research provides for 'an audit of practice' which serves to facilitate enhanced understanding of current practice, and provides an agenda for the meaningful discussion and development of future practice.

Keywords: Design risk management, Design process

INTRODUCTION

The Construction (Design and Management) Regulations 1994 (CDM 1994) came into force in the UK in March 1995. These regulations placed health and safety-related design management responsibilities upon designers. The Construction (Design and Management) Regulations 2007 (CDM 2007) amended the requirements placed upon UK designers with regard to health and safety risk management. These changes informed the initiation of the research concept – the investigation of construction design practitioners' understanding and practices regarding UK health and safety risk assessment practice.

A series of interviews have been conducted within a case study architectural design practice in order to provide a qualitative insight into designers' understandings and approaches to H&S risk management within the design process. The investigation has not sought to test a hypothesis or develop theory, instead it has provided for an exploratory audit of design risk management practice within the case study context of one UK design practice. The primary objectives of the investigation were twofold:

1. To review the imposed CDM 2007 legal requirements relating to the process of design risk management and the assessment and recording of risk; and to
2. To explore post-CDM 2007 design risk management practice and the use of designers' risk assessments within the context of a UK architectural practice.

THE ARCHITECTURAL PRACTICE OF THIS CASE STUDY

The specific case study context of this investigation is that of a medium sized UK-based architectural practice. The practice is a RIBA Chartered Practice and currently employs 15 personnel - five architects, five technician/technologists, one trainee and four administration staff. At the time of the research investigation there were two further architects who declined to participate and have since retired. The practice was formed in the late 1980's and is now considered (by practice staff) to be a premier practice in a northern region of England in terms of project size, profile and turnover. The practice works on a diverse range of projects including private and social housing, leisure & hotels, industrial and commercial, with project values up to £20 million.

METHODOLOGY

A series of qualitative interviews were conducted in order to explore health and safety management in the design process within the case study architectural practice.

A record-based audit approach was not adopted as the investigation concerned exploring designers' understandings, perceptions and practices regarding design risk management. A series of pre-prepared questions provided a common framework for the interview sessions. The pre-prepared questions were:

- What is your understanding/knowledge of designers' responsibilities under the CDM 2007 Regulations?
- How are you made aware of key changes in CDM that affect you in practice?
- How did you practice design risk management (Health & Safety) under CDM 1994?
- What is your approach under CDM 2007 and how has your approach changed?
- What do you see as the major differences for designers between the 1994 and 2007 regulations?
- Is there anything other than the CDM regulations that would prompt you to record design decisions or produce risk assessments?
- How does the HSE's approach to design under CDM 2007 affect you in practice?

Access to the case study architectural practice and the interviewees (designers) was facilitated by the fact that the interviewer was himself a design practitioner within the case study organisation. As a design practitioner employed within the practice the researcher had ready access to and an established rapport with the interviewees. Of the 10 design staff within the practice, 2 architects were unwilling to participate and 1 year out placement student had only very little experience. As such, 7 of the 10 designers participated in this exploratory study - three technologists and four architects.

Interviews were digitally recorded and transcribed for analysis and inclusion in the appendices. Listening and transcribing the interview helped to form tentative ideas about categories and relationships as outlined in Maxwell (1996 p.78) 'Qualitative Research Design'. Issues raised were mapped and grouped into relevant themes using QSR XSight software for qualitative research. The write up of the research data summarises the themes that arose from the interviews. This research reveals a snapshot of design practice attitudes to both the current and previous CDM regulations through the eyes of the designers.

DEFINITION OF THE DESIGNER

A review of literature and regulations was initially carried out in order to clarify the definition of designer and the legal responsibilities of designers for design risk management.

In the 1996 publication 'Designing for Health and Safety in Construction' the HSC referred to the term designer as having *'a very broad meaning in the regulations'* (1996 p.11). The HSC recognised that under CDM 1994, the responsibility for design extended far beyond the Architectural and Engineering professions and accommodated the increasing role of other construction professionals within the design process.
Under the 1994 CDM regulations, the HSC makes reference to *'anyone with authority to specify, or alter the specification of design to be used for the structure'* (1996 p.11). The definition of designer introduces the concept that design is not solely the domain of the architect, involving many different professionals throughout the project.

CDM 2007 defines a designer as:

> "any person (including a client, contractor or other person referred to in the regulations) who in the course of furtherance of business – prepares or modifies a design: or arranges for or instructs any person under his control to do so".

The CDM 2007 regulations present a broadened definition of designer. This is reflected in Smith's (2007a, p. 67) interpretation of this regulatory definition of a designer as *'anyone who considers the way a structure is to be built'.*

Understanding of this definition was not entirely apparent in the case study practice. One architectural technician considered that he was not the designer:

> "Well yes, I mean, obviously I am not the designer, generally speaking I am a detailer if you like, in that the design is probably not carried out by me."

Further to this technician, the remainder of the 6 designers interviewed understood their classification as a designer, regardless of their job title or role in a project.

DESIGNER COMPETENCE AND CPD FOR HEALTH AND SAFETY

The Approved Code of Practice that accompanies CDM 2007 states that '*designers must not produce designs that cannot be constructed, maintained, used or demolished in reasonable safety'* (2007, p. 28).

CDM 2007 underpins this requirement with formalised requirements for competency relating to design activity and health and safety design risk management. Under CDM 2007, there is reliance on a company or an individual's skill in recognising and designing out risk as a major part of the strategy for managing health and safety in design.
Regulation 4 of the CDM2007 states:

> "no person on whom these regulations place a duty shall – appoint or engage a CDM Co-ordinator, designer, principal contractor or contractor unless he has taken reasonable steps to ensure that the person to be appointed or engaged is competent".

Regulation 8 of the 1994 regulations state, '*No person shall arrange for a designer to prepare a design unless he is reasonably satisfied that the designer has the competence to prepare that design'* (1994 p.7).

The 2007 regulations specifically use the word 'competent' as opposed to the phrase 'competence to prepare that design'; this places the emphasis on an individual's professional qualification as recognition of their ability to manage design risk. Summerhayes recognises that the competence of a designer is a main area of change under the 2007 regulations and states, *'designers must ensure they are competent and adequately resourced'* (2008, p. 51). In 'Design Risk Management', Smith (ed.) dedicates two chapters to the subject of competency, resources and commitment and the capability of other designers and states:

> It goes without saying that individuals must have appropriate qualifications and experience unless their work is being overseen by other competent persons, and the new Approved Code of Practice has established a series of thresholds relating specifically to Health and Safety and design risk management for Designers and companies to meet (2007, p.26).

The issue of competency is as much about the responsibility of the company as of any individual, as demonstrated by Smith's (ed.) statement. However the regulations apply to everyone; it is implied that each member of the design team should be aware of each other's competency and resources, both prior to and during the design process. In order to fully comply with the 2007 regulations, competency should be recorded if the designer or consultant is to discharge their regulations in full.

CPD is essential for maintaining competence when regulatory change impacts upon the requirements of the design process. Interestingly how case study interviewees developed knowledge and understanding of CDM 2007 highlights a potential lack of effective compulsory training and assessment and a lack of a robust attendance monitoring system.
Issues arose relating to how the respondents established knowledge relating to the CDM regulations and the recording of health and safety. Designers working at the company when CDM 2007 was implemented, cited in house CPDs run at the time as the primary source of information for the regulation changes. Details of these CPD events were vague, as highlighted by a technician with over twenty years' experience:

> "I think there may have been brief CPD events at that time, given by possibly X, but my recollection is hazy how I became aware of the latest changes."

Two respondents practiced elsewhere at the time of the changes, one of whom acknowledged missing all the seminars relating to CDM 2007. The other respondent was the only interviewee to have attended external seminars although that person's showed no significant difference in their knowledge of the CDM 2007 to other respondents. Both these practitioners considered that they had a requirement to improve their knowledge of CDM 2007, specifically with regard to changes from the CDM 1994 regulations.

A common view expressed by designers within the practice was that H&S-related CPD was limited. Also formal training in practice and was often limited to just two hours a year compulsory Health and Safety CPD as required by RIBA Chartered Practice regulations. Several designers indicated a reliance on CDMCs (in house and external) to inform and guide their understanding of necessary practice for compliance with regulatory requirements. The quality of this information is very dependent on the CDMC's experience, interpretation of the regulations and overall knowledge of the designers' responsibilities. It is debatable whether this is a reliable way of acquiring the knowledge required, as reflected by quotes such as:

> "CDM Co-ordinators who we do work with as well, you know, they often put a different slant on things because I think, like a lot of things, regulations are down to interpretation and one, CDMC might have a slightly different view to another CDMC."

The risks are that, although CDM Co-ordinators should be assessed as competent and have a good knowledge of the design process, this cannot be guaranteed without rigorous adherent to the recommendations and procedures. Once appointed by the client, a CDMC is unlikely to be checked for competence by the designer (although all the design team should be competent); because of this it would be unwise to rely on the CDMC's knowledge to inform the designers of their responsibilities and requirements.

Other methods of acquiring the requisite knowledge cited can be through experience, contractors and other professionals, as summed up by the following quote:

> "It's a mixture of reaction and action through previous knowledge."

On the job learning such as this, although a common form of any knowledge capture, could lead to practitioners simply carrying on with outdated systems and attitudes, as long as they have either not caused an incident or been identified as having fallen foul of the regulations.

PERCEIVED CHANGES IN DESIGN PRACTICE REQUIREMENTS FROM CDM 1994 TO CDM 2007

CDM 2007 focuses designers on the elimination and reduction of all risk at design stage rather than the consideration of risk under CDM 1994. There is requirement for the designer under CDM 2007 to first identify, then design out risk during the design process. Emphasis is placed on designer competence and communication rather than a prescribed risk assessment methodology. The Approved Code of Practice that accompanied CDM 2007 makes it clear that designers are not legally required to keep records of the design risk management process, but recognises the usefulness in recording design decisions for both audit and communication purpose:

> Too much paperwork is as bad as too little, because the useless hides the necessary. Large volumes of paperwork listing generic hazards and risks, most of which are well known to contractors and others who use the design are positively harmful, and suggest a lack of competence on the part of a designer (2007, p. 32).

A minority of the interviewees were clear that there had been no shift in their practice from CDM 1994 to CDM 2007. These designers also expressed belief that it was not necessarily their own responsibility to comply with at least some of the regulations.

There was a consensus that the approach in practice to CDM 1994 created an unnecessary amount of paperwork for the designer, which served little purpose in reducing hazards in the design. This approach was, in part, a reaction to the impact created by the introduction of the 1994 regulations; prior to 1994, very little consideration was being given on a formal level to design risk for health and safety. One technician summed up the different design approach under the 1994 regulations:

> "A lot of designers erred on the side of providing too much information which was not necessarily job-focused; a lot was generic and a lot covered risks that didn't apply to the design aspect of the job, such as suppression of dust, minimising of dust on the site, that sort of thing."

The misconception that designers should produce copious amounts of paperwork for the pre-tender health and safety file, ultimately led to generic risk assessment and last minute design consideration. As opposed to being an integral part of the design process, health and safety documentation was produced in the same way as much of the statutory information, at the last minute and to satisfy the project manager. This is summed up by one of the architects as such:

> "Under the 94 regs you've got this, more pressure to produce paperwork to someone. I will admit that, yes, it probably seems one of those things that you had to do - you know, a necessary evil - but you just get on and do it and it was lumped at the end with building regs and with everything else, tenders and bills of quantities."

More than one respondent indicated that the CDM 2007 regulations are an improvement when compared to the 1994 regulations. Many of the improvements, in practice, were the result of the creation of the new 'Construction Design and Management Co-ordinator' (CDMC) role, leading to earlier consideration of health and safety issues in the design process, and improved information co-ordination. It was expressed that CDMCs are managing the 2007 process better than the Planning Supervisors did for CDM 1994 regulations and that designers are communicating with the CDMCs far more than they did with Planning Supervisors under the 1994 regulations.

Whilst some respondents considered that they were proactive in their approach to hazards in design, most said that they look to the CDMC for guidance as some CDMCs actively encourage designers to clarify requirements or seek guidance on design items.

APPROACHES TO DESIGN RISK MANAGEMENT WITHIN PRACTICE

Six out of the seven interviewees stated that the responsibility of the designer under the CDM regulations was to remove health and safety risks during the design process. The primary driver for the designers to remove risk is the fact that it is a statutory requirement under CDM 2007, and was under CDM 1994. Overall, the responses, regarding individual responsibility to health and safety, are a positive reflection of the understanding of CDM regulations; though understanding of the detail of regulations was generally poor. Statements relating to this topic were commonly similar:

> "It's the designer's responsibility to ensure that as much risk as possible is designed out of the building at as early stage as possible, whether it be by ideally removing the risk entirely by designing out or by minimising the risk by having sufficient design features to make it safe."
>
> "Looking at the design you're producing and seeing what elements there are you can either take out or change to reduce risk, both to end users and construction teams during the design, so I would understand, and for the maintenance."

Interestingly, whilst indicating some understanding of the regulations and approaches to design risk management, those interviewed struggled to explain their *approach* to the regulations in detail. Commonly the process of implementation appears to have been approached on a subconscious level with a reliance on experience rather than the active use of systems. The designers were more likely to focus on risks that had caused problems in the past, including access to windows for cleaning, that had previously impacted them in practice. This experience-based approach is summed up by one technician with over twenty years' experience in practice:

> "Actually a lot of it does come with experience because there are so many issues and so many things to just reel off. And then there are memories of things but are only involved when you are dealing with specific issues".

FORESEEABLE AND RESIDUAL RISK

CDM 2007 places a duty on designers to, so far as is reasonably practicable, avoid foreseeable risks to the health and safety of any person engaged in the duties listed under the regulations and to eliminate hazards giving rise to risks and reduce risks from remaining hazards:

> Designers are required to avoid foreseeable risks 'so far is reasonably practicable, taking due account of other relevant design consideration' the greater the risk, the greater the weight that must be given to eliminating or reducing it (2007, p. 28).

Regulation 13 states that designers must ensure adequate information is provided at design stage for any aspects of the project, structure or materials which might affect health and safety.

Significant risks are referred to by the Approved Code of Practice as '*those which may or may not be obvious to those who use the design'* (p. 30). Reference to residual risk is made in paragraph 112 of the Approved Code of Practice (p. 25):

> Where significant risks remain when they have done what they can, designers should provide information with the design to ensure the CDM Coordinator, other designers and contractors are aware of these risks and can take account of them.

In interviews, the designers did not extensively discuss or clarify the different types of risk involved in the design process (foreseeable and residual). By default, residual risk was discussed in the context of what could and could not be designed out at source, although there were still references to construction and site management risks. It is unclear how the respondents are identifying residual risk in their design work and whether they are evaluating those risks. Summerhayes

(2008) questions whether there is even a requirement to evaluate risk under CDM 2007. It was not clear what contribution the designers are making once residual risks are identified and how they are proceeding to reduce that risk or whether they transfer those risks to others. A lack of clarity and detailed in response suggests that there is a lack of understanding around the definition of risk and the recommended procedures for dealing with risk at design stage.

ASSESSING AND RECORDING RISK

The Approved Code of Practice for CDM 2007 recognises the need to provide information for significant and project specific risks, for use during construction and maintenance activity. The HSE suggest using notes on drawings, written information provided with drawings and suggested construction sequences, but stresses the importance of keeping information brief, clear, precise and in a suitable form. The Approved Code of Practice also recognises that it is difficult after the work is complete to obtain information, and recommends that CDM Co-ordinators agree with designers how information is to be provided ascertaining to residual hazards.

In one exploratory interview an architect indicated that he relied on the technicians and other designers to assess the risk later in the design process. Although indicating a good understanding of the term ‘designer’, this practitioner focused upon items familiar to himself from experience, such as access for window cleaning. Other designers stated that they relied on pro-forma risk assessments to kick start the process; the use of checklists as an aide memoire was also raised by one technician. It was acknowledged that this reliance on previous experience has an impact on the design and specification of buildings; if the designer is sure that a system works they will use it time and time again.

The use of pro-forma risk assessments aside, none of the respondents discussed any legal requirements for recording foreseeable hazards or for maintaining an audit trail of design decisions; by default most do keep some records however. During discussions relating to the recording of risk, no respondents made the distinction between foreseeable risk and residual risk. There is evidence, however, that residual risk information is being shared between the design team. Discussions relating to the methods of record keeping highlight that hazards are being recorded; however, the different forms of risk (foreseeable or residual) are not being identified. There were two recurring reasons why individuals either record or consider recording design decisions in practice including:

- The risk of litigation and wider indemnity issues - "We are in quite a litigious society, that at some point you are going to be asked to justify your actions."
- To provide evidence in the event of an incident that the design has been given adequate consideration - "If an incident happens it’s a paper chase; if you go back through the files and there is no evidence of consideration of that particular problem then it’s ten times harder to defend yourself.

One of the interviewees stated that they never record design decisions for health and safety, but considered when pressed on the issue, that indemnity should be a consideration for keeping records.

Of the respondents recording design decisions for health and safety issues, the most commonly expressed methods employed were through minuted meetings and notes on drawings - both of which are recommended by Summerhayes (2008). Other recommended methods mentioned were letters and e-mails (2), file notes (1), project risk registers (1) and quality management system records (1). Methods suggested that are not recommend in relevant literature were design and access statements and schedule of risks in spreadsheet format.

It is evident from the interviews that a lack of knowledge surrounded the reasons for the recording of design decisions.

THE USE OF DESIGNERS' HEALTH AND SAFETY RISK ASSESSMENT – POST CDM 2007

Four out of seven respondents interviewed believed they were required to produce pro-forma risk assessments as part of their CDM 2007 responsibilities. Factors arose that contributed to the belief that this is a legal requirement of designers in practice. Most commonly, this is attributed to a limited understanding of both the responsibilities of the designer under the CDM regulations and knowledge relating to the differences between CDM 1994 and CDM 2007. This is demonstrated by the conviction of one respondent, an architect, who when questioned in regards to his requirements under CDM 2007 stated:

> "I know you are supposed to produce a designer's risk assessment."

The use of pro-forma risk assessments amongst those interviewed is grounded in the CDM 1994 regulations. Those using pro-formas were doing so as a continuation of the techniques developed in practice prior to 2007. All respondents had at some point been required to fill in matrix type assessments as highlighted by a technician with over twenty years experience:

> "Under 94 regulations, in various offices they had slightly different approaches, but essentially they were always similar in that you had to prepare a risk assessment for each individual risk."

For many, the reality of risk assessments under CDM 1994 and the continued use for CDM 2007 was, and continues to be perceived as a paperwork exercise rather than an undertaking to remove risk at the design stage:

> "But generally it… You know, repetition of the same old stuff; it didn't really help us take it seriously as a document, as a piece of health and safety legislation, it was just a box ticking exercise and I think to some extent it is still the same now."

Two separate architects highlighted that CDMCs were still requesting risk assessment forms as part of the designers' contribution to health and safety. A competent CDMC should not be requesting generic risk assessment information and should only request information for residual or significant risks. This underlines the need for designers to be aware of their responsibilities and contribution to risk assessment at design stage. It appears that generic risk information is still being requested by some CDMCs:

> Interviewer: Do you still do risk assessments?
> Respondent: Certain jobs yes but not always, drawings. We have got CDMCs who ask for them.
> Interviewer: For what sort of risks?
> Respondent: General design risk, I still get asked for them sometimes.

As part of the competency issue, it would seem that if a CDMC is asking for generic risk information, it questions their knowledge of the CDM 2007 regulations and competency to fulfil the role. The fact that some designers are unaware of the guidelines relating to pro-forma risk assessments also raises similar questions.

Other reasons cited for the use of pro-forma risk assessments during the interviews were to aid the assessment of all risk and as proof of design consideration for regulatory and indemnity purposes. The potential for pro-forma risk assessments to aid design decisions was discussed by more than one respondent, the use of pro-formas having merit if utilised in the assessment of design. This is demonstrated by the following quotes:

> "And in some ways they stop to make you think about each type of work or operation or the buildings location".

> "Almost use it as a tool to influence the design".

It might be considered likely that assessment forms would not be completed if not required by the regulations. There is there possibility that if a system that prompts the designer to consider health and safety at design stage is removed, then a less than perfect system might be replaced by no system at all. The perceived benefit of using pro-forma risk assessments was summed up by a technician with over twenty years' experience:

> "It makes you stop and think about each element. You can't just go through the whole thing, you have to stop and think about it. So that I think that the pro-formas that were used were pretty useful because you do have to address each item of work."

For some, pro-forma risk assessments were often an afterthought, even under the 1994 regulations; for others, it is a tool to inform the assessment of risk. A lack of understanding of responsibilities of the regulations indicates that many individuals keep doing what they have always done. The better informed respondents were aware of other methods for prompting consideration of health and safety in design and were less inclined to use pro-formas in practice.

CONCLUDING SUMMARY

CDM 2007 focuses designers on the elimination and reduction of health and safety risk at the design stage. The research set out to review the design risk management requirements of CDM 2007 and explore the design risk management practice and use of risk assessment by designers within a UK architectural practice. The findings of the research are specific to the case study practice but provide some interesting food for thought and further investigation. This insight into the designers' perceptions, knowledge and practice regarding health and safety management in the design stage has flagged up a number of aspects of interest and concern regarding design safety management practice in the UK. A number of these emergent aspects are worthy of further investigation:

- It was perceived by designers that CDM Co-ordinators are managing the 2007 process better than the Planning Supervisors did under the CDM 1994 Regulations.
- The designers commonly expressed the view that their H&S-related CPD was limited, often to only the two hours per year H&S CPD required by the RIBA Chartered Practice Regulations.
- Whilst indicating some understanding of the regulations and approaches to design risk management, those interviewed struggled to explain their *approach* to the regulations in detail.
- There appears to be a reliance on experience rather than the active use of systems.
- It was unclear how the designers identify residual risk in their design work and whether they are evaluating those risks.
- There was a lack of understanding around the definition of risk and the recommended procedures for dealing with risk at design stage.
- It is evident from the interviews that a lack of knowledge surrounded the designers' reasons for the recording of design decisions.

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SAFETY IN DESIGN APPROACH FROM DESIGNERS PERSPECTIVE

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ABSTRACT

Australian OHS legislation has been conspicuous for the absence of regulation around safety in design in relation to buildings and structures. Instead, its focus in the construction phase places the responsibility for safety squarely on the shoulders of principal contractors or sub-contractors.

In recent years, some Australian jurisdictions have shifted that balance to impose some of these duties onto the designers of buildings and structures, but there are differences in the detail and application of OHS laws between jurisdictions.

A consequence of this is the growing momentum to implement a national OHS Act and regulations that places a uniform duty on designers of buildings and structures. The draft model OHS Act requires designers to consider the health and safety of people who would construct, use, maintain and ultimately demolish the structures they design, and wherever practicable, to eliminate or reduce the hazards they may be exposed to.

Where hazards could not be eliminated, designers are required to pass on information so that others involved in construction projects may endeavour to eliminate or reduce the hazards, and ultimately manage the residual risk arising from them when they could be reduced no further.

In practise, many designers were routinely pursuing risk reduction long before the safety in design regulations came into force and the only additional requirement placed on them in this regard was to formally record their actions in order to confirm that their responsibilities and duty of care were discharged appropriately, thoroughly and demonstrably.

Keywords: OHS, Duty of care, Reasonably practicable, Hazards, Risks, Designer, Contractor, Client, Construction, Building, Structure, Eliminate, Minimise

LEGAL & REGULATORY FRAMEWORK

Australian health and safety law is governed by a framework of Acts, Regulations and supporting guidance material such as codes of practice and standards.

The Commonwealth government has a responsibility to ensure that there is an overall national framework that ensures safety, while the states and territories have the responsibility for making and enforcing laws on health and safety and for enforcing those laws.

Each state and territory has a principal Occupational Health and Safety (OHS) Act that sets out requirements for ensuring safe workplaces. These requirements include responsibilities known as ‘duty of care’.

A number of Australian states and territories have incorporated safety in design requirements into their OHS legislation, although its definition and the scope of designers’ duties is proving inconsistent across jurisdictions (e.g. Victoria focuses on operation and maintenance phases; Queensland focuses on the construction phase; New South Wales lacks any specifics in its OHS Act).

OHS Legislation follows this hierarchy within all jurisdictions:

1. Occupational Health & Safety Act.
2. OHS Regulations.
3. Codes of practice.

4. Guidance Material e.g. AS standards AS/NZS 4801:2001 Occupational Health and Safety Management System & Safety in Design Guidance Material.

The Australian OHS legislation is applied and enforced on a state-by-state basis. Each state and territory jurisdiction has different OHS legislation.

THE NATIONAL OHS STRATEGY 2002-2012

The National Strategy provides a basis for developing sustainable, safe and healthy work environments and for reducing the number of people hurt or killed at work. As a step towards achieving its national vision of Australian workplaces free from death, injury and disease, the National Strategy has set these primary targets:

- Sustain a significant, continual reduction in the incidents of work-related fatalities with a reduction of at least 20 per cent by 30 June 2012.
- Reduce the incidence of workplace injury by at least 40 per cent by 30 June 2012.

The strategy has also identified five priorities that will help all jurisdictions to achieve short and long term OHS improvement and nurture longer-term cultural change:

1. Reduce the impact of risks at work.
2. Improve the capacity of business operators.
3. Workers to manage OHS effectively prevent occupational disease more effectively.
4. Eliminate hazards at the design stage.
5. Strengthen the capacity of government to influence OHS outcomes.

WHAT IS THE 'DUTY OF CARE' OBLIGATION?

Duty of care requires everything 'reasonably practicable' to be done in order to protect the health and safety of others. Duty of care places into a legal form what is a natural moral duty to anticipate possible causes of injury and to do everything practicable to remove or minimise these hazards.

Within this understanding, employees have OHS responsibilities for their own safety as well as the safety of fellow employees.

REASONABLY PRACTICABLE

'Reasonably practicable' means doing your best within the constraints of a business environment and in the eyes of the law, and taking into account other relevant factors, for example:

- Nature and severity of the hazard.
- Knowledge of the severity of the hazard.
- Knowledge of suitable solutions.
- Availability of solutions.
- Common standards of practice.
- Cost of solutions.

RELATIONSHIP BETWEEN SAFETY IN DESIGN AND BUILDING CODES OF AUSTRALIA

The primary focus of the Building Code of Australia (BCA) is to ensure buildings and structures meet acceptable standards for structural sufficiency, safety, health and amenity (e.g. technical provisions used in design and construction to ensure appropriate smoke hazard management), as well as access and egress for building occupants. The BCA has no priority around safe design to minimise risks involved in construction phase.

Safety in design legislation requires that OHS issues be addressed in addition to the existing legislation and regulatory provisions such as the BCA.

SAFETY IN THE CONSTRUCTION INDUSTRY

By its nature, construction gives rise to many significant hazards that are reducible through effective management, but evidence confirms that OHS is not receiving due attention in the Australian industry.

- 15-20% of all workplace injuries happen on building sites.
- Lost time due to accidents usually accounts for five times the amount of time lost to industrial disputes in the building industry.
- In 1998/99 (the latest year for which figures are available) it is estimated that the industry lost 49,440 weeks due to employment related injuries, costing in the industry $109 million.
- For the past 10 years, there has been an average of 50 deaths per year, or one per week, on construction sites.

KEY OHS RISKS IN THE CONSTRUCTION INDUSTRY

Key OHS risks in the construction industry include:

Electrical safety:
- electrical installations and Residual Current Devices,
- proximity to exposed cables, and
- work near high voltage power lines.

Earthworks:
- excavation (risk of earth falls, engulfment in swampland, underground earth works & tunnels).

Fire and emergency:
- fire prevention and fire resistance,
- fire detection and fire fighting,
- emergency routes and exits, and
- other emergency facilities.

Structural safety:
- erection of metal or concrete frameworks,
- temporary fragility or instability of the structure,
- load bearing requirements, and
- stability and solidity of structure.

Movement of people and materials:
- safe access and egress,
- traffic routes and traffic control, and
- loading bays and ramps.

Manual handling:
- methods of materials handling, and
- assembly and disassembly of pre-fabricated fixtures and fittings.

Substances:
- hazardous substances and materials (including insulation materials and decorative materials), and
- exposure to irritant dust and fumes.

Work environment:
- ventilation (for thermal comfort, general air quality and specific ventilation requirements for the work to be performed on the premises),
- temperature,
- lighting (including plant rooms),

- acoustic properties and noise control (e.g. noise isolation and damping),
- seating & space for occupants, and
- floor surfaces for buildings.

Fall prevention:

- guard rail and edge protection,
- protection from falling objects,
- prevention of falls from heights,
- anchorage points for maintenance/cleaning,
- access to working spaces for construction, cleaning, maintenance and repairs, and
- Scaffolding & temporary surface characteristics such as fragility, silo resistance.

WHO ARE CONSIDERED TO BE DESIGNERS?

Responsibility for achieving safe design rests with parties or individuals who control or manage design functions. This includes anyone directly involved in the design activity, such as architects and engineers, and decision makers who influence the design outcome, such as clients, developers, principle contractors, contractors, manufacturers, directors and managers .

WHAT IS SAFETY IN DESIGN?

'Safety in design' is the early integration of hazard identification and risk assessment methods into the design process; it is intended to eliminate or minimise risk of injury throughout the life of the product being designed.

HAZARD & RISK

A hazard:

- is something with the potential to cause harm,
- usually involves actual objects, conditions or situations, and
- often involves energy or substances.

Risk is:

- an evaluation of the likelihood of harm arising from a hazard and the severity of that harm, and
- a judgement, usually based on experience.

SAFETY IN DESIGN – WHY DO WE DO IT?

'Safety in design':

- improves the health and safety of people who may have cause to use the product or the project being designed,
- ensures good engineering practice,
- provides benefit to our clients,
- meets community expectation, and
- can be a statutory responsibility.

DESIGNERS' DUTIES

A designer has an obligation to prevent or minimise risks in the design of the structure so that the design does not adversely affect the workplace health and safety of persons:

- during construction of the structure; and
- when the structure has been constructed and is being used that the design intended.

As previously stipulated, control of risk is a two-part process:

1. Designers endeavour to eliminate or reduce risk.
2. Contractors manage residual risk.

APPLYING CONTROL MEASURES BY CHANGING THE DESIGN

Applying control measures by changing the design could include:

- specifying for the use of less- or non-hazardous materials instead of hazardous materials,

- reducing the amount of work at height by using craned in pre-fabricated elements, and
- eliminating the need to use vibrating tools by specifying alternative methods of forming joints.

A simple example: 'design out' the need for ladders during construction, cleaning and maintenance operations for a building structure by:
- designing for use of stairways during construction,
- designing windows to be cleaned from the inside, and
- specifying materials that don't need routine painting, or design in safe access for maintenance.

CONSTRUCTION WORK IS:
Any work including:
- construction, alteration, renovation, repair, maintenance, demolition or dismantling of a structure,
- preparation for an intended structure, including site clearance, exploration, investigation (but not site survey),
- assembly or disassembly of prefabricated elements forming a structure,
- removal of a structure, any product, or waste resulting from demolition, and
- installation, maintenance repair, or removal of services normally fixed within or to a structure.

A STRUCTURE IS:
- any building, timber, masonry, metal or reinforced concrete structure, railway line or siding, tramway line, dock, harbour, inland navigation, tunnel, shaft, bridge, viaduct, waterworks, reservoir, pipe or pipe-line, cable, aqueduct, sewer, sewage works, gasholder, road, airfield, sea defence works, river works, drainage works, earthworks, lagoon, dam, wall, caisson, mast, tower, pylon, underground tank, earth retaining structure, or structure designed to preserve or alter any natural feature, fixed plant and any structure similar to the foregoing, and
- any formwork, falsework, scaffold or other structure designed or used to provide support or means of access during construction work.

Any reference to 'structure' can mean the entire structure or any of its components.

COMMUNICATING SAFETY IN DESIGN WITH CLIENTS
Designers are sometimes limited in their capacity to influence matters or activities that give rise to safety risks (e.g. limit by the client's directions or terms of the contractual arrangement). What is 'reasonably practicable' in each case takes these factors into consideration.

It is good practice for designers to:
- inform the client of any high risk in their design requirements that may affect the health and safety of people who will be using the building or structure as a workplace, and
- recommend appropriate alternatives, including any design modifications to eliminate or reduce risks arising from the design.

Useful techniques may include a combination of the following actions by the client:
- Conducing workshops and discussions with personnel from similar workplaces within the client company including Health & Safety Reps.
- Conducting onsite assessment of an existing similar workplace with feedback from users of the existing building.
- Researching information or reports from similar workplaces on hazards of the work and relevant sources and stakeholder groups.
- Conducting workshops with experienced personnel who will work in the new workplace.
- Conducting workshops with specialist consultants and experts.

Some of these techniques may not be possible e.g. where clients don't have business activities which involve similar workplaces.

SYSTEMATIC RISK MANAGEMENT

The process of systematic risk management involves the following steps:

- Identify the hazards.
- Consider the likelihood and severity of harm occurring and establish a risk rating.
- Change your design to eliminate or reduce risk.
- Re-evaluate the risk rating.
- Pass on information about the hazards to other parties e.g. client, contractor etc.

HAZARDS TO CONSIDER

Consider the position and design of structures in order to avoid site hazards. Such hazards could include:

- buried services,
- overhead cables,
- traffic movement to, and around, the site, and
- contaminated ground.

Design out health hazards by:

- specifying less hazardous choice of material (e.g. solvent free adhesive),
- avoiding processes that create fumes, vapours, dust, noise or vibration,
- specifying materials that are easy to handle (e.g. lightweight blocks), and
- designing block paved areas to allow mechanical handling/laying.

Design out safety hazards involving:

- the need to work at height, especially if poor access,
- fragile roofing materials,
- deep excavations in public areas or highways, and
- materials that could create a risk during construction.

Consider prefabrication so hazardous work can be done in more controlled conditions. For example:

- Design elements so sub-assemblies can be carried out at ground level and lifted into position later.
- Cut to size at an off-site location to limit dust.

Design in features that reduce risk (e.g. early installation of staircases to reduce the use of ladders).

Design to simplify safe construction. For example:

- Provide lifting points and mark the weight and centre of gravity of heavy or awkward items requiring slinging on the drawings and the items themselves.
- Make allowances for temporary works.
- Design column joints so connections can be made by standing on the floor.
- Design connections to minimise the risk of incorrect assembly.

AREA	CHALLENGE	DESIGN SOLUTION
Road Design	Live traffic colliding with construction plan equipment during construction phase	Provision of separation zone between live traffic and construction zones in stage construction planning and provision of appropriate safety barriers
Motorway maintenance	A motorway maintenance gantry had cross bracing 1.2m above the walkway which would have required maintenance staff to duck under it	A cantilever design was adopted to eliminate the bracing
	Access to a gantry on a motorway off slip road would have required parking in the highway	A lay-by was formed in the embankment behind the hard shoulder to allow vehicles to be parked with a pedestrian walkway up the embankment to allow direct access to the gantry without using the off slip road
	Safe access to maintain a drainage attenuation pond at a motorway junction	a hard standing was created so that maintenance vehicles could pull off the road in the direction of traffic and then reverse along a service road to the pond
	A handrail between a cycleway and footpath had to be fixed with bolts which would have left bolt heads protruding as a trip hazard	The handrail fixings were set at a lower depth which allowed the asphalt surfacing to extend over the bolt heads
Highways	Support was needed for a row of bollards to avoid interaction with existing services	A kerb line was moved to make room for a ground beam
	There was a requirement to limit traffic movement during site works	A traffic order to eliminate a right turn was brought into force early
	General safety for work involving highways	Avoid the need to work on central reservations and traffic islands
Bridge works	How to minimise work at height and reduce interruptions to traffic flows	Consider access for large cranes to minimise the number of lifts required
		Ensure provision of safe access for bearing inspection and replacement

Table 1: Specific examples - designing out risk.

ACTIVITY & HAZARD	LEVEL OF RISK	DESIGN INPUT TO ELIMINATE OR REDUCE HAZARDS, AND HAZARDS REMAINING	RESIDUAL HAZARDS
Manual Handling - repetitive lifting of heavy construction elements	Moderate	Max weight of concrete blocks kept to below 20kg	Yes
Steel erection - Working at height	Moderate	Structural form allows pre-connection of rafters at ground level prior to erection to eliminate some working at height	Yes
Steel erection - stability of long span beams	Significant	Provided additional lateral restraints that long span beams to eliminate risks of temporary instability during installation of floors	No
Working at Height - Risk of falling	Significant	Precast concrete floors have been specified, which provides a safe working platform for construction staff as soon as installation is properly completed. Precast staircases offer safe access to upper levels early in construction	Yes
Fragile roof coverings - Risk of falling	Significant	Composite panels have been specified by the architect to eliminate this risk for the majority of roof areas	Yes
Surface coatings and finishes to steelwork	Minimum	Water based paints specified wherever practical; Shop applied paint systems eliminate need for site application of primer systems to structural frame	Yes
Existing services - live uncharted services may be present on the site	Significant	No Design Input	Yes
Siting of mobile crane - risks of structural failure of tank units beneath crane outriggers	Significant	Specific notes have been provided on drawings to draw attention to this	Yes
Maintenance access to roof areas and gutters - especially rainwater harvesting gutter	Moderate	Hard-standing areas are provided around the building perimeter to facilitate access by specialist or other access equipment	Yes

Table 2: Project risk assessment practical examples.

RESOURCES
Safe Work Australia.
WorkSafe Victoria.
New South Wales Work Cover.
Work Cover Queensland.
Construction and Design Management Regulations, UK.

CONSTRUCTOR LED CONSTRUCTION HAZARD PREVENTION THROUGH DESIGN (CHPTD)

Thomas Mills, Department of Building Construction, Virginia Polytechnic Institute and State University

ABSTRACT

It is the contention of the author that preventing or reducing safety and health hazards in the U.S. construction industry by increasing the use of hazard prevention through design can most advantageously be pursued by approaching it within the Design Build/Design Manage project delivery system. This is supported by noting that close to one-half of the $400B annual U.S. non-residential construction is being delivered using a constructor-led design build delivery strategy and that 75% of the residential single family homes in the US are builder/vendor sales. One can also observe that in commercial that design-build is maturing into other delivery strategies including design-manage, design-assist, and integrated project delivery through teamed stakeholders. Owners are providing the lead in outsourcing expertise to construction professionals to manage not only the construction process but the design process as well. Hence as construction professionals assume a stronger leadership role in the overall delivery process, aspects of construction hazard prevention through design become more pronounced and under their lead.

This position paper addresses the current and advancing state of construction hazards prevention through design-for-safety in alternative delivery strategies and proposes a constructor led strategy. The reasons why a constructor-led strategy has the greatest impact, chance of success, advantages and barriers and proposes a 10 point strategy aimed toward implementation.

Keywords: Design for Safety, Design-build, Construction safety, Hazard prevention

INTRODUCTION

This position paper presents an alternative view to the traditional architect/engineer Construction Hazard Prevention through Design (CHPtD) focus that many Design for Safety (DfS) researchers are pursuing. The alternative is presented in an effort to consolidate the previous research and to propose that a more productive strategy in U.S. implementation is through a constructor-led implementation initiative. Derived from this investigation are 10 discussion points aimed at supporting construction practitioner implementation. The concept of constructor-led design-for-safety in the U.S. is supported by noting that close to one-half of the $400B annual U.S. non-residential construction is being delivered using a constructor led design build (DB) delivery strategy (DBIA, 2009) and that 75% of the residential single family homes in the US are builder/vendor sales (U.S. Census Bureau, 2009). One can also observe that commercial design-build is maturing into other delivery strategies including design-manage (DM), design-assist (DA), and integrated project delivery (IPD) through teamed stakeholders.

This paper in its support of constructor-led hazard prevention through design is presented in four distinct parts, Part 1 is a critical focus through the literature on the current design-for-safety thinking, Part 2 identifies from the literature the inherent weaknesses and barriers to implementing a traditional design-for-safety focus, Part 3 explores the viability of the alternative constructor-led design-for-safety, and Part 4 develops the focus for an implementation strategy.

Several recent studies state that, by altering the design, injurious construction accident or incident occurrences could be reduced by anywhere between 22% and 60% (as cited by Gambatese et al., 2008, Creaser, 2008). Although one may take exception to the inclusion of specific incidences there is no question that by approaching defined pieces of work with a design for safety mindset that a reduction in the opportunities for injurious health and safety incidents can be influenced. In no way should this mindset be equated to leading the design for safety process. It is also evident from the literature that construction worker initiated design for safety considerations have greater impact and are more likely to be implemented (Weinstein et al., 2005). Reinforcing the idea of a constructor led strategy can be deduced by the accident causation conclusions that constructor's drew with regard to the root cause of an accident or fatality in at least one of these studies (Gambatese et al., 2005). Thus there is evidently some divergence of opinions, particularly from the constructor viewpoint, on the impact that design has on the root causes of a construction accident. From the literature it is evident that construction site safety is the domain of the constructor and should continue to remain such. This insight supports constructor led implementation through awareness, timing, and workplan development. Few constructors would welcome designers to develop a strategy to improve site safety. The reasons are obvious and plainly stated in the literature. Of concern to this author is the growing effort to force inexperienced and less than knowledgeable design engineers into the role of construction site safety professionals (Gambatese et al., 2005, Toole, 2005, Toole and Gambatese, 2008). If designers wish to pursue this role then the author believes they should assume the risk and liabilities associated with their actions and solicit their errors and omissions insurance carriers to broaden their coverage for this practice.

PART 1 – TRADITIONAL DESIGN FOR SAFETY THINKING

Reflecting upon the early work of Hinze and Wiegard (1992) and assessing the current work of Toole and Gambatese (2008) one recognizes that the design-for-safety intent is to 'seek a means for sensitizing designers … to the need of providing for construction worker safety'. This same philosophy can be applied to the constructor as well. Since 1992 design-for-safety has been a progressive movement that has continued to expound upon a variety of common and recurring obstacles to implementing hazard prevention through design, namely lack of designer construction and worker safety experience, designer liability, and separation of contractual domains. Clearly what design and designers focused upon is product design, while construction is a team-based process utilizing creative means and methods to safely and profitably produce the designed product. That does not mean that product design cannot incorporate safety features, in fact that is the baseline origin of the design-for-safety philosophy that in the U.S. was first prompted by Ralph Nader's book Unsafe at Any Speed (1965) and followed through by the auto industry (GMC, 1965) and then expanded into highway design and construction (Schoppert, 1965).

The strategic thinking to incorporate design for safety through consulting designers has remained relatively consistent since first broached by Hinze and Weinstein (1992) and continues today as evidenced by the recent design-for-safety specific issue of the Journal of Safety Research (Howard, 2008). Among the leading U.S. design-for-safety researchers the focus remains solidly in the design domain and appears to undervalue the constructor. Although the author believes that constructor involvement is inadequately focused, these same researchers appear to support a greater opportunity for success through builder/constructor leadership. What is lacking is a body of literature that directs the strategy toward constructors.

There are two major thrust areas now being focused in the design for safety domain that stresses an even stronger designer led incursion into a traditional constructor led arena, one of which may be detrimental to actualizing and harmful to workers. These two thrust areas are 1) modeling hazard prevention through design implementation by emulating the Leadership in Energy and Environmental Design (LEED) certification model, and 2) using Building Information Modeling (BIM) to assist in improving the product design for worker safety.

The loosely defined, but implied implementation strategy that mimics LEED rating & certification focuses on establishing a design engineering certification that may eventuate into several realities, 1) certified design-for-safety professionals, that in all probability would have little actual construction experience or knowledge, but would secure certification, and 2) a checklist approach used by these certified professionals to address hazards. Although this is an admirable goal the author believes it will have little impact on improving construction site safety. On the contrary it may create a false sense of on-site safety with the unintended result of poorly addressed hazard identification. Currently those construction companies with good to great safety records achieve their records by incorporating safety professionals, are using diverse safety tools including checklists, zero accident techniques, hazard specific training, work plans that incorporate safety planning, and the use of qualified subs that follow similar procedures. Companies that have poor safety records, e.g., residential and small construction companies, will continue to approach safety in an unsafe business as usual approach. No form of non-market driven design-for-safety certification will improve these companies safety performance. Instilling a simple but complete implementation strategy that constructor's can adapt to their own processes offers another avenue for delivering a design for safety culture that can own the process.

The strategy of using Building Information Modeling (BIM) as an aid to addressing designed for safety features offers an excellent research area but has its drawbacks. BIM is still in its infancy and is predominantly focused by the building design profession for visualization of the designed product and by the constructor for clash/interference detection and checking. Another consideration for 'smart' models, those capable of adding intelligence, is that they are poorly managed for purposes other than parametric design, geometric control, and the production of 2D drawings for field use. This leaves design for safety out in the cold. Additionally, it is apparent that the industry standard BIM products are focused on product design with very few construction plant objects such as scaffold, shoring, sheeting, anchorage points, nets, hoisting equipment, opening protections, etc. available. These objects are needed elements to incorporate the construction process into a predominantly object (product) focused software. Once an objects library exists construction and design can consider how to integrate these tools into workplans that utilize designed safety features.

PART 2 – BARRIERS TO EXPANDING THE TRADITIONAL CONSTRUCTION DESIGN-FOR-SAFETY THINKING

This section will only focus on two barriers that seem fundamental to constraining the current strategy of designer-led construction hazard prevention through design. These are fundamental in characterizing the nature of the design and construction disciplines. The first consideration is the argument of product versus process design, and the second is the question of controlling means and methods. By recognizing these barriers one can apply their inherent natures in support of constructor implementation.

Product design versus process design

Before one is able to design for safe construction one must understand construction's essence. As both architect and construction manager the author believes he speaks with authority. Design is different from construction. Many designers, including architects and facility design engineers focus in the domains of functionality, performance, and end user requirements. This product design focus envisions permanency of the product and differs tremendously from the temporary nature that is the essence of construction. Construction is an engaged process that features a dynamic and temporary plant. Illingworth's provides the most insightful and perceptive description of construction when he notes that in any form of construction there are only two fundamental activities, 1) the handling of materials and equipment, and 2) by a skill workforce positioning those materials to produce the whole (Illingworth, 2000). This premise quickly separates out the difference between product and process design. This leads the author to the conclusion that construction safety is by nature the domain of construction professionals not design professionals. This doesn't mean that designers should avoid any sensitivity to construction worker safety. They should be sensitive but in a supporting capacity. They cannot and should not be considered as lead construction safety professionals. Toole (2005, 2007) recognizes this condition and has proposed that the engineering profession can offer support by being safety auditors or better yet by providing design for safety strategies and solutions, particularly as members of construction teams. This author also believes that the latter presents the better opportunity to enhance a constructor led approach but also believes that by promoting designers in the role of design for safety certified professionals and field safety auditors can be at risk of creating additional layers of burdensome oversight by professionals that lack the requisite knowledge and skills to be effective. One final consideration in the product versus process discussion is that safe solution sets in a design led approach will naturally coincide (by discipline) with physical product definitions e.g., checklists, etc. will be oriented toward physical components (e.g., roofs) and not worksite hazard classifications (e.g., fall to lower level). Tools that link workplan hazard identifications and not product definitions have a stronger capacity to facilitate hazard reduction.

Control of construction means and methods

By contract, historical precedent, and commonly accepted industry practices the control of construction means and methods remains the domain of the constructor. The author believes this will and should remain the case. In addition to the question of liability (Behm, 2008), the more fundamental question is one of practicality, efficiency, and safety. To shift the responsibility of means and methods undercuts the fundamental ability of the constructor to develop creative and effective means and methods (defined by workplans) that advance the profession and also provide a competitive edge in safe and productive work. Support for the means and methods of construction remaining with the constructor are evident throughout the literature (Coble and Blatter, 1999, Gambatese et al., 2008, Toole, 2005). The literature has many examples of instances that design induced considerations are beneficial to reducing on-site hazards, among these are inadvertently or poorly designed masonry walls, heavy object designs, and deep trenches (Behm, 2005, Gambatese et al., 2005). Means and methods will remain the domain of the construction professional and as such the constructor is in the position to implement design-for-safety during the development of work flow and subsequent work plans. Additionally the decision to implement a specific means and methods strategy on the same project will vary from constructor to constructor and is therefore impractical if not impossible for a designer to accurately determine the appropriate strategy. Therefore, the integration of design for safety concepts into constructor produced workplans tied to a field logging and feedback system are valid implementation components.

PART 3 – VIABILITY OF CONSTRUCTOR LED HAZARD PREVENTION THROUGH DESIGN

One only needs to review the literature to validate the future of implementing an effective design for safety strategy lies with constructor leadership. Weinstein, et.al., (2005) clearly identifies the strength that exists when emanating from the constructor. They identify that among other considerations the likelihood of a proposed design change being implemented is significantly higher 79% versus 20% if recommended by trades' contractors. Additionally, they report that trade contractors have the knowledge to 'pinpoint significant design impacts' that may be overlooked by design professionals while designers are unable to adequately address ergonomic hazard prevention. The decision on hoisting methods are contractor driven and to mandate otherwise would be burdensome and in instances where incorrectly specified could result in worker injury. Construction safety leadership is best left to the people that profitably practice construction. In fact consideration should be given to limiting the design to meeting a standard of care in providing specifications and drawings that establish standards for performance and meet code requirements, set geometric control, and size equipment based on engineered calculations. Greater emphasis by designers in the construction process leads into the abyss of control and supervision a risk that that U.S. designers traditionally avoiding by contract language. On the contrary the constructor traditionally assumes the risk of job site safety hazards and avoiding job site injuries and fatalities is in the constructor's best interest. The above has a direct impact on project profitability and identifying best practices for integration into future design for safety solutions.

One of the early premises of this paper is that design-build, design-manage, and design-assist projects offer better opportunities to influence and incorporate design for safety strategies into project design and procurement. In order to realize this opportunity the task becomes one of implementing a research to practice (R2P) focus that translates academic research on design for safety to the construction field. Notwithstanding the results of the NIST (2002) study that there is no significant difference in design-bid-build or design-build in safety performance, the author believes that a constructor-led focus is a more viable implementation strategy for moving safety forward than preparing designers to implement. The NIST study concluded that on-site safety results from the fact that construction safety must address a variety of strategies regardless of the delivery method in order to ensure a safe work site. Much of this is due to the fact that constructor's develop a broad project safety plan that addresses creating a safe worksite for workers, while using subcontractors, working with different design consultant's documents, yet to be determined means and methods, evolving temporary plant issues, and a variety of differing work packages. Thus designing for safety from the design professional position can only be advisory in nature and of limited scope. To truly affect a design for safety change the concepts must originate from and be 'owned' by the construction team. Both Coble (1999) and Toole (2007) have expressed insight into the strength of constructor led design for safety through design-build projects. Toole particularly addresses the concept of hazard mitigation, using five criteria focused on decision making, within a design-build environment and solely as a design consultant, and concludes that in all the applied instances that an engineer linked to the design-build environment would proactively address the hazard when otherwise they may not. As a result of the inherent nature of these considerations a constructor led strategy involves issues of profitability and risk mitigation, feedback loops, the acceptance of workplan responsibilities, and timeliness of implementation.

PART 4 – STEPS TOWARD IMPLEMENTING A CONSTRUCTOR-LED HAZARD PREVENTION DESIGN-FOR-SAFETY STRATEGY

Previous research consistently indicates that effective design-for-safety is most likely to be addressed when initiated early in the project (Hinze and Wiegand, 1992, Weinstein et al., 2005). This insight quickly nullifies traditional design-bid-build and reinforces design-build and integrated project delivery as the preferred method to achieve design-for-safety implementation. Thus one of the keys to implementation is timely initiation of the process with construction expertise at the table. In a most design-build projects the constructor takes the lead and thus is managing design consultants that are on the same team and frequently share in the same profits. Many times these design consultants are also major subcontractors, e.g., mechanical, electrical, plumbing, heating, ventilations, concrete and thus not only supply design but supply a workforce. They originate both product and process. This allows awareness, timely decision making, in-house work plan origination, acceptance of the concepts, mutually allocated risk sharing for maximizing profitability, monitoring and feedback among design and construction.

Based on previous research reasonable insights into the considerations that make design-for-safety a value added consideration for designers has been adapted to constructors. A consolidated 10 point strategy to implement constructor-led hazard prevention through design has been derived by the author from a review of the literature and re-interpreted to apply to a constructor. These 10 points are stratified and include a feedback loop to address continuous improvement in the design-for-safety process with the intent of growing a design for construction safety culture. The intent is that the considerations identified in Table 1 are conducive to implementing a constructor led design-for-safety strategy and can be used to begin discussion on an alternative and parallel course with the contemporary approaches being directed toward a designer-led design-for-safety culture. The author believes the proposed 10 point strategy is particularly applicable to projects that are approached from a design-build, design-manage, design-assist, and integrated project delivery perspective and can be adapted to residential builder/vendors as well.

1	Awareness	Awareness is critical to address maximum inclusion of all the participants and secure buy-in of the design-for-safety process and its benefits. Awareness becomes pervasive to the team and should concentrate in two major areas: 1) Awareness of the importance of the entire participant supply chain working collectively to improve worker safety. 2) Identification of the strengths each delivery method brings to improving on-site worker safety through early product and process design involvement.
2	Timing	Timing has a direct impact on design-for-safety implementation (Weinstein et al., 2005). Placing this in the forefront allows maximum inputs from all the participants and leads to downstream risk mitigation.
3	Acceptance	Acceptance is an affirmation that liability exists for all parties and that by collectively accepting the risk individual liability is reduced and a concentration on proposing and implementing safe work solutions can be implemented.
4	Profitability	A business case can be made for profitability as a driver that extends to all parties. This can be evidenced by a reduction of worker compensation claims, a

		reduction in lost time incidences, increased productivity, reduced insurance premiums, less errors, and less rework.
5	Agenda	It is essential that design-for-safety be placed on all agendas, including constructability review, procurement, operations, commissioning, and closeout. By formal agenda placement design-for-safety becomes institutionalized and creates a culture of addressing worker safety at all levels. Potential hazards are identified, resolved, or passed forward in a Hazard Identification Folder that stays with the project similar to commissioning documentation.
6	Tools	Tools are organizational design-for-safety capital assets; they are acquirable and can take the form of checklists, design manuals, best practices databases, graphics, and BIM. Standing considerations in constructability and procurement reviews will use these tools and lead to a Best Practices Tool for evolving worker safety considerations when developing workplans.
7	Workplans	This is unconditionally the domain of the construction work designer as they develop the workplan, Job Hazard Analysis (JHA) and rolls a design job hazard analysis (DJHA) into the workplan. Best practices are draw from the Best Practices Folder allowing design-for-safety to be incorporated further downstream into Project Operations. Although not limited to construction, Liberty Mutual Insurance indicates that over 74% of the most debilitating work place injuries result from three originators; 1) overexertion, 2) slips and falls, and 3) struck by/against (Braun, 2008). Simply considering these three hazards construction workplans can be developed that address process and product design improvements that mitigate or eliminate the risks associated with these specific hazards.
8	Logging	Incorporate design-for-safety within incident logging. Establish and use an identification metric that allows tracking incidents to hazards to design features.
9	Integration	Integrate design-for-safety with an organizations quality management system which if frequently based on best practices, feedback loops, and continuous improvement.
10	Feedback	Establish a formal mechanism to feedback lessons learned and instill Best Practices into design-for-safety implementation.

Table 1: Constructor-led design-for-safety implementation points.

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A PILOT STUDY IN BOTSWANA'S CONSTRUCTION INDUSTRY ON DESIGNERS' WILL AND CAPACITY TO DESIGN FOR HEALTH AND SAFETY

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ABSTRACT

Designer's role on health and safety (H&S) performance improvement is a subject that has received much attention than any other aspect relative to the designer. However, much research has been on the incorporation of H&S in designs and how designers influence H&S. There is little research on the designer's will and capacity to contribute to H&S performance improvement especially in Southern Africa and Botswana in particular. This paper seeks therefore to highlight this aspect as a way of addressing one of the barriers to H&S performance improvement

The purpose of this paper is to present findings of a small pilot study conducted among construction designers to establish their will or motivation and capacity to contribute to construction H&S in Botswana. A questionnaire survey was conducted among construction designers to establish willingness and capacity to incorporate H&S in their designs.

Findings on the will to contribute to H&S, relate to designers incorporating H&S in their designs, external influence to consider H&S and mandate from the client to consider H&S are presented. Designers' capacity relate to education and training and their experience on matters relating to H&S. The pilot study indicates an inadequate level of will and capacity for designers to consider H&S in their designs.

A better H&S performance improvement can only be achieved with the designer's active participation. Results from the survey on designers' will and capacity highlight the importance of considering this aspect of designers. Designers' will and capacity is inadequate and it shows in their inconsideration of H&S in current designs. A proposal is made to look at ways to improve designers' capacity as well as ways to motivate them to consider H&S.

Keywords
Capacity, construction, designers, H&S, will

INTRODUCTION

One of the efforts that have for some time been considered as a means to improve H&S on construction sites is the aspect of designing for safety. According to Gambetese et al (2005) designing for safety is an intervention identified by many as a breakthrough idea for improving construction site safety and which is gaining support in the construction industry.
Traditionally, H&S hazard mitigation measures have been implemented solely by contractors during the construction process and many believe that additional actions can and should be taken earlier in the project, during the planning and design phases (Hecker et al, 2005). Many researchers on H&S agree that H&S is not an issue that can simply be left to contractors alone. Designers must be involved (Behm, 2005; Hinze, 1999 and Suraji et al 2006). According to Hinze et al (1999), it is naive to suggest that designers have no role in construction H&S. Hinze et al (1999) maintains that decisions made by a designer have a direct impact on H&S of construction workers. Mackenzie et al (1999) also cited design decisions as being one of the causes of accidents on construction sites. A lack of full participation by designers in construction H&S can have a negative impact on the standard of H&S in the industry.

There are however questions as to whether designing for safety is a breakthrough idea for H&S interventions on site even though its popularity is gaining ground. A similar question on the viability of designing for construction safety was raised and investigated by Gambetese et al (2005). After this investigation, they concluded that designing for safety was a viable intervention for safety. However barriers currently exist which limit its implementation.

Having established that designing for safety is a viable intervention for H&S and compelled by the fact that designing for safety does not seem to be done in Botswana and indeed even in United States of America (Gambetese et al, 2005), the need to investigate designer's will or motivation and capacity to design arose. This paper therefore reports on findings from a pilot study on designers' will and capacity to design for H&S in Botswana's construction industry. This study is therefore complementary to all studies cited above but specifically to that conducted by Gambetese et al (2005).

DESIGNING FOR SAFETY

When H&S is considered in the design of structures or when designs are appraised in terms of H&S, action plans are developed to ensure that risks are engineered out of the system before they are able to cause injury, disease, damage, or even loss of life on site. Behm (2005) defines design for construction H&S as being the consideration of site safety in the design of a project. Specifically this includes: modifications to the permanent features of the construction project in such a way that construction site safety is considered; attention during preparation of plans and specifications for construction in such a way that construction site safety is considered; the utilisation of specific design for construction safety suggestions; and the communication of risks regarding the design in relation to the site and the work to be performed.

Similarly, according to Hecker et al (2005), interventions to eliminate hazards before they appear on the jobsite are commonly known as designing for construction safety. Hecker et al (2005) explains that the foci of designing for construction safety efforts are typically the incorporation of construction knowledge in the design effort and consideration of safety early on and throughout the project. Equally, Hinze et al (1999) advocates for a holistic approach of designing for the entire life cycle of a project, including the construction process. He contends that effectively addressing construction safety issues means the designer must consciously assess the implications of each construction phase on safety as the facility is being built. In addition, he suggests that a thorough risk assessment of each design component should be done (Hinze et al, 1999).

All above definitions on designing for H&S can be summarised by Hale et al's (2007) definition that design should include the design specification and requirements at one end and the instructions and procedures for use at the other. However, this conclusion also has implications for the definition of "design errors'. Hale et al (2007) contend that we should not therefore talk of "design errors" but rather of errors in a specified step in the design process.

Safe design therefore means a design that allows and conditions, as far as feasible, safe use across the whole life cycle including demolition and disposal (Hale et al, 2007).

Design for safety therefore calls for an extensive knowledge on H&S as opposed to a mere general awareness of the subject.

CONTRIBUTION OF DESIGN TO ACCIDENTS

Safety in design is driven largely by a logical conclusion that systems development begin with design and so design offers the earliest and hopefully the cheapest place to intervene and get it right (Frijters and Swuste, 2008; Hale et al, 2007 and Hecker et al, 2005).

According to Hale et al (2007), the factors that compel designers to consider H&S in their designs include:

- Ethical considerations and concern for the organisation's reputation;
- Liability claims resulting from damage and injury; and
- At a legal level it is an increasing emphasis on the liability of the designer for incorrect design decisions. However Hale et al (2007) contend that this liability is limited in most cases whether under strict liability or tort law systems, to what the designer has control of and can reasonably be expected to do.

Although design for H&S may be as a result of the above factors, benefits or the impact of designing for safety are well documented. The following selected studies reveal that design has an influence on H&S on construction sites.

- An investigation across aviation and nuclear industries by Kinnersley & Roelen (2007) confirmed that 50% of all accidents have root causes in design;
- Gibb et al (2004) in 47% of cases reviewed, changes in design would have reduced the likelihood of accidents;
- Behm (2004) found that design was linked to accidents in approximately 22% of the 226 injury incidents that occurred from the year 2000 to 2002 in USA's Oregon, Washington and California. He also found that 42% of the 224 fatality incidents in the USA from the year 1990 to 2003 were also linked to design;
- Hecker et al (2001) also identified elements in design, planning, scheduling, and material specifications as probable contributors to working conditions that pose risks to musculoskeletal injuries during the actual construction process; and
- UK's HSE examined 100 accidents and found that up to half of the accidents could have been mitigated through a design change (HSE, 2003).

According to Kirwan (2007), it is clear that the roots of accidents are sometimes at an early design stage. Accidents have their roots in the design process and this appears to be a common fact across all industries.

BARRIERS TO DESIGNING FOR SAFETY

According to Gambetese et al (2005), some of the factors that have contributed to designers' lack of motivation to design for H&S and thus a barrier to H&S improvement include the following:

- Weak or absent regulatory requirements for designers to design for the safety of construction workers;
- OSHA's placement of responsibility on the employer (typically the contractor) in the USA;
- Liability concerns among architects and engineers;
- Narrow specialisation of construction and design;
- Limited availability of safety- in- design tools, guidelines and procedures;
- Limited preconstruction collaboration between the designer and the contractor due to the traditional contracting structure of the construction industry; and
- The limited education architects and engineers receive on issues of construction worker safety and how to design for safety.

The last point above poses even a bigger problem in designing for safety. There is little knowledge by designers on problems such as how the operation or construction will be undertaken (Kirwan, 2007). Kirwan (2007) argues that there is often little detail if any on the procedures to be followed or controller (person to implement the design) working practices proposed for the concept. This according to him amounts to a lack of a mature operational concept, one that is sufficiently detailed to allow safety hypotheses (e.g. what would happen if….?) to be answered (other than - well it depends how we operate or implement it'). This problem coupled with the requirement that safety assessment of new concepts requires incorporating expert judgements where data are not available or not representative. There is need therefore for designers to be adequately equipped in H&S (Kirwan, 2007).

Hale et al (2007) raises a further problem or hindrance to achieving a total design for safety. He argues that the nature of design as a distributed process raises the same sort of concerns as the division of labour that characterised the Taylorian approach to production and assembly line manufacture. This led to problems because no individual participant in the process has the overview of, or the sense of ownership for, the product being made. Such Taylorian production lines only work when there is a strong central planning and control function, which ensures this overview and the necessary communication and optimisation. Hale et al (2007) maintains that the same lack of ownership of the total design and the problems of interfaces between the different actors can be seen in the design process and thus pose a problem or barrier to H&S improvement.

Despite the above barriers, the overall conclusion is that the design stage is all important for achieving a lasting safe system. The almost 50% ‘residual’ rate for design contribution to accidents suggests that designers, safety and human factors, personnel and other stakeholders need to work closer together to bring this rate down, and therefore prevent more accidents (Kinnersley & Roelen 2007). However questions arise as to how this can be achieved.

DESIGNING FOR SAFETY AS AN INTERVENTION

Consideration of H&S in design of facilities is a very significant step in working towards H&S performance improvement. Kirwan (2007) argues that since accidents often have their roots in design, the sooner safety starts the better. In particular, hazards or hazard causes identifiable early on may become more difficult to find or correct later, with the risk that they become latent errors in the system design. In Europe as a result, building designers have a legal obligation to take working conditions throughout the project into account in their designs. The obligation contained in Directive 92/57/EEC is now incorporated in most EU Countries’ legislation.

Although designing for safety has not been widely adopted by many designers, Gambetese et al, (2005) contend that designing for H&S is a viable intervention in construction. However they noted various barriers that currently limit its implementation including: the structure of the construction contracting process; a lack of knowledge and acceptance of the concept; designer education, training and construction experience; competing project objectives; and motivation to implement the concept (Gambetese et al, 2005).

Notwithstanding the above barriers, designers can have an impact on a significant number of injuries and fatalities by considering construction H&S in their designs (Weinstein et al, 2005).

One of the benefits noted by Kirwan (2007) of an early involvement by designers is that it will lead to designers also thinking about H&S from the start rather than thinking that it is something that comes later and not their job or concern. Other residual benefit which is very important and has a lasting impact and influence on H&S is the new culture that is created. According to Kirwan (2007), H&S culture can be enhanced by early consideration of H&S in the design process. Not only do the designers become more exposed to safety and its mission and practices but other stakeholders from the project managers to contractors taking part in early simulations, realise that H&S is being addressed in a useful way and thus reinforcing its importance for all concerned and its continual presence throughout the entire system life cycle.

However in order for designing for safety to be effectively used as an intervention, albeit not on its own, the following interventions in the sections below need to be considered.

There is need to address procurement systems. Gambetese et al (2005) noted that the type of project delivery method can impact the extent to which H&S is addressed in the design. The forms of project delivery essentially alter the roles played by the different parties and most importantly the allocation of responsibility (thus liability) is also redistributed. According to Gambetese et al (2005), the traditional design-bid-build approach and others of a similar nature keep the parties apart and there is presumably no payback for the designer to address construction worker safety. This way, the designer is a stand-alone entity and as an isolated entity, designers often revert to their traditional role of not getting involved in addressing safety (Gambetese et al, 2005).

Where there is no existing organisation with a powerful central role in managing the parallel design processes, there is then a task for government or such other client in bringing together the players in the design process to define and coordinate their roles (Kirwan, 2007). This view is supported by Hale et al (2007) and explains that for designs within the diverse systems with many uncoordinated players, the issues of responsibility for predicting risks and making choices to control them is very important and is sometimes identified. However according to Hale et al (2007) the allocation of responsibilities and above all the possibility of checking and enforcing that those responsibilities are carried out is almost nonexistent. Hale et al (2007) further acknowledge that the best practice for coping with this issue is bound to differ across different systems but argued that there should be more explicit attention to this question in the sectors with less developed design processes.

The above is supported by Gambetese et al (2005) who also contends that the owner is the key to getting the designer involved in the safety process because the owner can alter the way the project should be procured and address specific issues regarding safety in the contract as well as the coordination.

In addition to all above, opportunities must be created for designer-constructor interaction in the course of specific projects (Cosman, 2004). Weinstein et al (2005) established that trade contractors provide valuable input in design and programming and to a certain extent; other team members rely on trade contractors for practical advice on how to modify the design to make it safer.

Further, designers must also be convinced of the role they have to play through university and continuing education and industry wide campaigns. Cosman (2004) argues that action needs to be focused on resolving the discontinuities between the knowledge about design implications on H&S, the skills to deliver better designs and the drivers affecting the scope and conduct of design activities. Design review by designers with H&S knowledge can lead to enhanced safety outcomes even within more traditional design-bid-build procurement methods (Weinstein et al 2005).

PILOT STUDY

A pilot study was conducted to try and establish designers' will and capacity to design for H&S in Botswana.

Senior partners of Architectural and Engineering consulting firms registered with the Botswana Institute of development professions (BIDP) were selected for participation in the study. It was deemed suitable to interview senior partners of the registered firms because they are employers and also ascribe to certain norms demanded by their professional body. There are ten (10) registered architectural and engineering consulting firms on the current list that are based in Gaborone, Botswana. All firms were selected as participants to the study.

A structured questionnaire was used to collect information on a number of projects that these firms have been involved in, on whether H&S was one of the project deliverables, on the frequency with which their clients assign the responsibility of managing H&S to them as well as on whether they consider H&S in designs and what the motivation has been on designing for H&S if at all it had been done before. Most questions in the questionnaire were based on a five point Likert rating scales of frequency, agreement or importance. This method was considered appropriate for this type of a study. However, a more multifaceted and rigorous methodology will be followed in the next phase.

Questionnaires were administered by way of email to 10 senior partners of BIDP registered consulting firms. Results from the questions were compiled and analysed against what literature informs. Based on this analysis, conclusion and recommendations have been reached.

Out of the 10 questionnaires that were sent, 8 questionnaires were returned. This represents an 80% response rate.

Although a BIDP website list of registered consulting firms was used, it is acknowledged that there are many consulting firms that are currently practicing and provide services to many organisations including the Government. The sample used therefore may not be representative of all consulting firms in Botswana. The generalisation of findings of the study to the entire spectra of consulting firms in construction is therefore limited considering the small sample size. However, for the purpose of this pilot study, it will give an indication of what the will and capacity is regarding the concept of designing for H&S in the construction industry.

FINDINGS

The survey instrument had three sections which comprised of questions on motivation for H&S design, capacity of designers to design and also questions on the current practice regarding H&S design.

Motivation

The following factors identified from literature were considered to be motivators for designers to design for H&S:

- Legal requirements;
- Community requirement;
- Professional ethics;
- Client emphasis;
- Status of H&S deliverable on the projects;

- Inclusion of H&S in client briefs; and
- Client mandate to designers on H&S.

An evaluation of the factories Act of Botswana reveals that it is not necessarily a requirement for designers to design for H&S. Findings from the questionnaire survey also found that four of the respondents never really designed for H&S. Actually, only one of the respondents cited legal requirements as the reason for designing for H&S. Further, none of the respondents cited requirements by their professional body as well as the communities in which projects were undertaken (Table 1.0). One of the respondents cited personal conviction as reason for doing so whilst none cited the number of accidents in the industry.

Table 1.0 Motivation for designing for H&S

Motivation	Response(No.)
Never really designed for H&S	4
Legal requirement	1
Requirement by professional body	0
Requirement by communities	0
Requirement by municipal councils	2
Personal conviction	1
Number of accidents	0

The other motivation for H&S design is the level of importance placed on H&S by the client. Respondents indicated that of the projects that they had been involved in the last three years, none of them had H&S as an important deliverable. Further, four of the respondents felt that clients considered H&S not to be important or just fairly important. Responses on the question of the extent to which H&S is highlighted in clients' briefs were that three respondents felt that there was a moderate emphasis on H&S. As can be seen in Table 2.0, six of the respondents indicated that clients mandated them to ensure that contractors complied with the H&S regulations. Only one of the respondents cited design for H&S as one of the mandates from the clients whilst the other respondent indicated that they had never received any mandate concerning H&S on the project.

Designers also perceived that they do not really benefit from a better H&S as much as the other parties do. According to designers, contractors ranked first followed by clients, all stakeholders and lastly designers (Table 3.0).

Table 2.0 Clients' mandate to designers

Mandate	Response (No.)
Design for H&S	1
Ensure compliance of contractors	6
Conduct H&S inspections	0
None	1

Table 3.0 Perceived party's benefit from H&S (1 not & 5 very much)

Party	1	2	3	4	5	Rank index	Rank
Contractor	0	0	1	1	6	3.625	1
Client	1	0	3	0	4	2.750	2
All stakeholders	0	2	3	3	0	2.125	3
Designer	4	3	1	0	0	0.625	4

Designers' capacity and practice

Designers' capacity to design for safety relates to the amount of enablement that they have and the confidence. The following knowledge areas were assessed in order to inform on designers' capacity to design for H&S:

- General H&S awareness;
- Adequate knowledge on H&S to enable designers to design, manage, assess H&S risks, advice clients and take full responsibility; and
- Specialised training on H&S.

Five of the respondents indicated that the knowledge they have on general H&S awareness is average. A similar number of respondents indicated that H&S knowledge adequate to enable them manage a project as well as provide advice to clients is average. It was however interesting to note that over 60% of the respondents indicated that their H&S knowledge to adequately design for H&S was above average. As can be seen in table 4.0, three of the respondents indicated that their H&S knowledge to adequately design for H&S was above average whilst two of the respondents indicated that it was excellent. Regarding taking full responsibility, four respondents indicated that their knowledge was below average and the other four indicated that it was simply average.

On whether any member of their organisations had received specialised training in H&S, five of the respondents indicated that they had whilst three indicated that they did not have. However seven of the respondents indicated that they did not have a specific person or section that was responsible for H&S. Four of the respondents also indicated that they had never really designed for H&S.

Table 4.0 Designers' knowledge in H&S

Knowledge area	poor	Below Ave.	Ave.	Above Ave	Excellent	Rank index	Rank
Adequate for design	0	2	1	3	2	2.625	1
General awareness	0	0	5	2	1	2.500	2
Adequate to asses H&S risks	0	2	2	3	1	2.375	3
Adequate to manage H&S	0	1	5	2	0	2.125	4
Adequate to be able to advice clients	0	1	5	2	0	2.125	4
Adequate to cost for H&S	0	3	3	1	1	2.000	5
Adequate to take full responsibility	0	4	4	0	0	1.500	6

DISCUSSION

Designers' will / motivation

The will or motivation for designers to address H&S in their designs stems from both internal and external factors. Internal factors include both what designers perceive to be benefits to themselves and their organisation as well as personal conviction on the cause. External factors include those factors that in a way compel designers to consider H&S in their designs.

An evaluation of responses on whether designers felt that they benefited directly from a better health safety record revealed that they actually considered contractors to be the parties that benefitted more directly from a better H&S record. Designers considered themselves to be the least beneficiary and thus ranked last (Table 3.0). It can be argued that because designers did not feel that they benefitted directly from a better H&S, can be reason enough not to some extent motivate them to design for H&S. It is argued that motivation is much more likely to be driven by perceived direct benefits from designing for H&S to them, other than anything else. In this case however, designers consider contractors, followed by clients, other stakeholders and lastly designers to have direct benefits from a better H&S. It can also be argued that it is no wonder much responsibility and focus is placed on contractors. Actually four of the respondents in this survey, equating to 50% felt that designers should not be held responsible for site safety.

Findings on what enthused designers to design for safety also revealed that personal conviction on the cause did not rank highly. Only one respondent cited personal conviction as the cause for designing for H&S whilst about 50% of the respondents indicated that they had never really designed for H&S (Table 1.0). Taking for example two pillars supporting a beam to represent benefits as one pillar and personal conviction to represent the other pillar and the beam to represent motivation to design for H&S, collapsing of one pillar or a compromise in its character may result in the coming down of the beam - in this case the motivation. Both pillars need to be in a good state and to an acceptable standard without compromise to their characteristics. Lack of personal conviction is as much important as perceived benefits. It is argued that motivation or the will to design for H&S would be highly compromised if one of the support factors collapse or one of its characteristics is compromised.

A number of external factors that would motivate designers were highlighted earlier in literature and include legal, professional bodies', community and local authority's requirements, client emphasis during the briefing, client mandate to designers and to some extent the current practice. Findings showed that designers are not obliged to design for safety. Client emphasis of H&S in the design brief and the mandate given to designers does not seem to be adequate enough to persuade designers to design for safety. Focus seems to have been placed on contractors as six of the respondents equating to 75% indicated that the client mandate to the designers was for them to ensure that contractors complied with H&S regulations (Table 2.0). Only one respondent indicated that their clients had mandated them to design for H&S. A clear mandate from clients for designers to specifically design for H&S is a great motivation.

As for the prevailing culture as a vehicle for motivation, findings showed that four of the respondents, about 50% of designers had not necessarily designed for H&S on their past projects. Not designing for safety on a project or actually on all previous projects has a negative impact on motivation to design for the subsequent projects. This creates and perpetuates a culture of not designing for H&S. Further, seven of the respondents indicated that they did not have a dedicated person or section that was specifically responsible for H&S. A positive H&S culture seems to be lacking in most of the organisations included in this study.

Capacity

Capacity to design for safety is an important factor in designing for safety. Capacity has to do with competence. Competence to design for H&S is attained by obtaining knowledge through tertiary education and or through specialised training on the subject. An assessment of current knowledge by designers on various aspects of H&S revealed that most of the designers that were interviewed do not posses knowledge that is adequate for them to be described competent to design for H&S. On average almost 68% indicated that their knowledge on various aspects of H&S was average or less (Table 5.0). This response is also in agreement with responses on the level of knowledge possessed by designers to take full responsibility on H&S. Four of the respondents equating to 50% indicated that their H&S knowledge to take full responsibility was average and the other 50% indicated that it was actually below average (Table 4.0). This though appears to be contradictory to responses on whether respondents themselves or any other member of staff from their organisation had specialized training in H&S. Five respondents indicated that at least one member of staff in respondents' organisations, had received specialized training in H&S. It is argued that a person having received specialized training will certainly not posses average or below average of the required knowledge on the subject area. However, the contradiction could probably be explained by the fact that this particular question also referred to other staff members whilst questions on what knowledge respondents possessed referred to respondents only.

Table 5.0 Average response of average and below average of knowledge

Knowledge area	Response (No.)
General awareness	5
Adequate for design	3
Adequate to cost for H&S	6
Adequate to manage H&S	6
Adequate to asses H&S risks	4
Adequate to be able to advice clients	6
Adequate to take full responsibility	8
Average %	**68**

Further, five of the respondents indicated that their knowledge on H&S general awareness was average. However, most respondents indicated that they possessed adequate knowledge to enable them design for H&S (Table 4.0). This response was interesting as more than 60% described their knowledge fit for general awareness of H&S to be average and or below average. It is therefore ironic that more than 60% respondents considered their knowledge to be adequate to design for H&S. Actually this is also contradictory to their other response on whether they possessed H&S knowledge adequate to take full responsibility and advice their clients. Table 5.0 reveals that six of the respondents equating to 75%, indicated that their knowledge was either average or below average.

Capacity also has to do with capability. Capability is the means by which a certain goal or task is achieved. In terms of designing for H&S, means could be having a specialized section or person in an organisation that can ably design for H&S. Seven of the respondents indicated that they neither have a specific person nor a section that is responsible for H&S. Designing for H&S is also a highly specialized design aspect. It is argued that it is not every designer that is able to design for H&S. In the absence of a specialized section or person, it is highly unlikely that an organisation would have the capacity to design for H&S. It is no wonder, 50% of the respondents indicated that they had never really designed for H&S in their past projects (Table 1.0).

CONCLUSION AND RECOMMENDATION

Literature informs that for designers to be motivated and be described to have capacity to design for H&S, designers should:

- Have received training in H&S;
- Have extensive experience on H&S design and supervision;
- Be compelled to design for H&S by the legal framework and personal conviction;
- Be compelled by a positive H&S culture in both client and designers' organisations;
- Receive a clear mandate from the client on designing for H&S;
- Be aware of the status and impact of accidents in construction industry; and
- Have a strong conviction that H&S should be their responsibility in as much as it is every stakeholder's responsibility.

The pilot study on designers' will and capacity revealed that:

- Most of the time, designers are not mandated to design for H&S;
- The motivation for designers to design for H&S is low or lacking;
- The legal framework, professional bodies and the community requirements do not compel designers to consider H&S in their designs; and
- Most designers' lack the requisite knowledge on H&S to adequately design for H&S.

Findings from this pilot study seem to suggest that designers will or motivation and capacity to address H&S in designs is inadequate. Designers are a very important party to achieving a higher standard on H&S on construction sites. It follows therefore that means have to be devised to improve designers' capacity as well as motivate them to continuously consider H&S in their designs. One consideration, of which this pilot study is part, is an investigation into the client centred model to improve H&S and thus have issues to do with designers dealt with in this model.

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AN INVESTIGATION OF THE VIABILITY OF ASSESSMENT OF SAFETY RISKS AT DESIGN OF BUILDING FACILITIES IN AUSTRALIA

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ABSTRACT

Previous research has identified the design aspect of building facilities as being a significant contributing factor to construction site accidents. The aim of this research is to understand the perception, current practices, barriers and impacts of identifying, assessing and mitigating safety risks at design of building projects. Postal surveys were conducted in Sydney Australia. The research results showed that identifying, assessing and mitigating safety risks at design stage of building facilities is a viable, valuable and beneficial concept. However, the majority of designers (architects and engineers) lacked knowledge of and had not implemented such concept/process. Impacts such as extended time and increased cost were discovered as main concerns faced by designers. Although many respondents were willing to take up the responsibility of addressing safety risks during design, it is evident that there is lack of formal training to address the issue. It was identified that the barriers of lack of understanding potential benefits, and inadequate skills and resources were the major factors precluding designers from carrying out assessment of safety risk at design stage, while liability exposure and the nature of subcontracting was not deemed a significant barrier in implementing the concept, as identified by other researchers.

Keywords: Safety risk, Design evaluation, Building facility, Designing for safety

INTRODUCTION AND RESEARCH AIMS

The construction industries have unacceptably high rates of injuries and fatalities. For example, the workers' compensation statistics indicated that the Australian construction industry's incidence rate was 28.6 per 1000 employees in 2003-4 which was almost twice of the overall industry average of 16.4 per 1000 employees (ASCC 2006a). It also experienced a high fatality rate of 6.5 fatalities per 100,000 employees in 2003-4, which was almost three times higher than the national average for all industries of 2.3 fatalities per 100,000 employees (ASCC 2005). The US experienced similar statistics while situation in China was even worse (Zou et al 2007, and Zou and Zhang 2009). These recent empirical evidences suggest that the construction industries are more unsafe than other industries; and that it is an area needing significant reform if injuries and fatalities are to be mitigated.

The design phase is an important stage in building project procurement. It has an important influence on how the building is constructed. Research (Hadikusumo and Rowlinson 2002, NOHSC 2003 and 2005, HSE 2004, BLL 2004, Wienstein et al 2005, Gambatese et al 2005, and ASCC 2006) has shown that in construction project management, many safety risks may be eliminated or mitigated and opportunities seized at the design stage if proper analysis and assessment is carried out. UK's HSE (Health and Safety Executive 2004) shows 47% of injuries/accidents could have been prevented if proper checks were provided during design stage. The Australia NOSHC's report highlighted the importance of minimising safety risks and maximising opportunities at design stage (NOSHC 2005); Hinze (2005) suggests that consideration of construction workers' safety and practice should be salient at design stage.

According to ASCC (2006), “safe design (aka designing for safety)” is a process defined as the integration of hazard identification and risk assessment methods early in the design process to eliminate or minimize the risks of injury throughout the life of the product being designed (ASCC 2006). It aims at eliminating health and safety hazards and minimizing potential health and safety risks by involving all decision makers that will be involved in the life cycle of the designed product. In particular, it considers design implications in the full life cycle of the designed product and begins at the conceptual and planning phases with an emphasis on making choices about the design, methods of construction and materials to be used which enhance the safety of the designed product. The Australia Safety and Compensation Council (2006) issued “Guidance on the Principles of Safe Design for Work” and the NSW State Government Workcover Authority also provided “CHAIR (Construction Hazard Assessment Implication Review) Safety in Design Tool” in 2001. But the actual implementation of these guidelines and toolkits remains unknown.

Why consider safety risks at design stage?
In addition to the reasons mentioned in the Introduction section, there are four main reasons why safety risks should be assessed and mitigated at design stage of building projects, which are discussed as follows:

Firstly it is a requirement established by Acts and Regulations in many countries. For example, the United Kingdom’s Construction (Design and Management) Regulations (HMSO 1994) requires designers and clients in the UK construction industry to eliminate hazards in design phase in order to make buildings safer to construct, clean, maintain and demolish; the American Society of Civil Engineers (ASCE) states “engineers shall have responsibility for recognising that safety and constructability are important considerations when preparing construction plans and specifications”; in Australia, several states, including Queensland, South Australia, Western Australia and New South Wales, place similar responsibilities on designers (Bluff 2003), such as *Occupational Health and Safety Act* 2000 (NSW) and *Work, Health and Safety Act* 1995 (QLD).

Secondly, in construction project management, many risks could be eliminated (and opportunities created) if proper analysis is carried out at the design stage (ASCC 2006b). According to Australian NOHSC (2003), 42% of the 210 identified workplace deaths definitely or probably had design related issues involved. Likewise, WorkCover NSW indicated that 63% of all fatalities and injuries can be attributed to design decisions or lack of planning (NSW WorkCover 2001). The report by Health and Safety Executive (HSE 2004) shows 47% of the safety injury/accidents could have been prevented if proper checks were provided during the design stage. Zou *et al* (2006 and 2007) claimed that designers should carry out comprehensive investigation of site conditions, articulate the clients’ needs in a technically competent way and within the limitation of the clients’ resource, work collaboratively to develop sound program schedule and cost planning and minimize defective designs

Thirdly identifying and eliminating risks at design stage is a key to effective cost and managerial control (Andres 2002) and many benefits may be achieved, such as improved productivity, avoidance of expensive retrofitting to correct design shortcomings, and significant reduction in environmental damage, and attendant costs (ISTD 2003).

Finally, as claimed by ASCC (2006b), ‘assessing safety risk at design’ provides a number of benefits, including prevention of injury and disease, improving usability of products, systems and facilities, improving productivity and reducing costs.

Current methods in designing for safety (assessing safety risk at design)
A number of different approaches and tools have been identified in the literature review that allows for safety risks to be identified either during the designing process or via a design review process. These processes include design reviews and checklists used to identify safety risks in a design. Designers and engineers in charge of designing should include safety as one of the key tasks during design along with aesthetics, and functionality as the brief (Hinze and Wiegand 1992). Clients also impact on construction safety through their involvement. Gambatese (2000) found

various ways which owners can actively address safety and positively influence project safety performances through: (1) Ensuring that safety is addressed in project planning and design, (2) Assigning safety responsibility during construction, (3) The project characteristics, (4) addressing the selection of safe contractors, (5) inclusion of safety requirements in the contract, and (6) owner's active participation in safety during project execution. Gambatese (2000) further suggested, that to the extent possible, owners through their project representatives, should participate with the contractors in all project safety activities, including but not limited to, new employee orientation, safety meetings, jobsite safety audits and accident investigations, training, and incentive program and other safety related programs.

Barriers for assessing safety risk at design

Despite the importance and benefits of safety design, there are still many barriers for considering safety risks at design stage. According to Hinze and Wiegand (1992), Gambatese (1998), Gambatese (2003), Hecker, Gambatese & Weinstein (2004), and Toole (2004), barriers to implementing "designing for safety" include:

- Weak or absent regulatory requirements for architects and engineers to design for the safety of the construction workers
- Occupational Safety and Health Administration's placement of safety responsibility on the employer (typically the constructor)
- Liability concerns among architects and engineers
- Narrow specialization of construction and design
- Limited availability of safety-in-design tools, guidelines, and procedures
- Limited pre-construction collaboration between the designer and constructor due to the traditional contracting structure of construction industry
- Limited education architects and engineers receive on issues of construction worker safety and on how to design for safety

Research aims

The aims set out in this research are to:

1. Establish the liability and benefits of safety risk identification and assessment tools and processes during design of building projects.
2. Identify current methods, practices, perception and barriers of systematic safety risk management processes used by architects and engineers during design in Australia.

RESEARCH METHOD

Literature review and survey questionnaires are used to achieve the research aims. The method of sampling selection employed in the survey questionnaire was based on Area Sampling and the Random Sampling methods, which is cost effective and easy to implement. 200 samples were chosen to represent the population of concern. The sample size was split in to 6 mutually exclusive segments. In this case, location was used to segment the sample population. The number of samples given to the segments is derived by the assumption that architectural firms are more densely populated in the Sydney CBD area and is less populated as it moves out from the Sydney Metropolitan area. The sample given to each segment is shown in Table 1.

Areas	*Number Sent Out*
Sydney Metropolitan	40
Sydney North	30
Sydney East	30
Sydney West	30
Outer West	20
Sydney South-West	20
Total	200

Table 1: Locations of surveys sent.

The questionnaire was designed to be efficient in conveying the question to the participant and recording data. Relevant literature was referred to when developing the questionnaire, for example, the questions used by Gambatese et al (2005a) was included in this survey. This will allow cross nation comparisons. It is separated into 4 parts: Section 1 aims to identify characteristics of the population of concern, experience and involvement with the concept, and barriers affecting their involvement in assessment of safety risk at design. Section 2 provides participants 6 statements, which relates to the perception of safety risks and changes to design during the design stage to improve overall safety (Questions 1 to 6), and how they perceive each statement. A 5-point Likert Scale ranging between 'strongly agree' and 'strongly disagree' is used to determine the respondent's perception towards the statement. In Section 3, participants were asked a series of 'yes' or 'no' (Questions 7 to 20) questions, which relates to the participant's involvement in identifying risks and modifying designs to improve safety. In Section 4 (ie Question 21), participants were given a list of barriers to assessment of safety risk at design and were asked how they perceive each item by indicating on a 5-point Likert Scale ranging between 'strongly agree' and 'strongly disagree'. While in Question 22, a list of performance characteristics of assessment of safety risk at design were given and respondents were asked how they perceive each item by indicating on a Likert Scale ranging between 'very positive and 'very negative'.

RESULTS AND DISCUSSIONS

Of the 200 surveys sent out to participants, 49 responses were returned, which equates to a response rate of 24.5%. The participants were from a variety of architectural and building backgrounds. The majority (62%) of respondents were from Architectural Consulting Companies while the remaining is made up of a mix of Engineering (10%), Design & Construction (12%), and Construction (16%) (Refer to Table 2). The participants were categorised as architects (47%), Directors (20%), Engineer (19%), Design Consultant (9%) and Others (5%) (Table 3).

It was also noted that their design experience outweighed construction experience in the 'less than 5 year' experience group and the '5 to 10 year' experience group. But from '10 to 30 years' of respondents' expertise lay in the construction experience outweighs design experience (Figure 1).

Firm Type	*percentage*
Architecture	62%
Engineering	10%
Design and Construct	12%
Construction	16%
Others	0%
Total	100%

Table 3: Types of respondents' organisation.

Position	Percentage
Director	20%
Senior Design Manager	0%
Architect	47%
Engineer	19%
Design Consultant	9%
Others	5%
Total	100%

Table 2: Respondents' position.

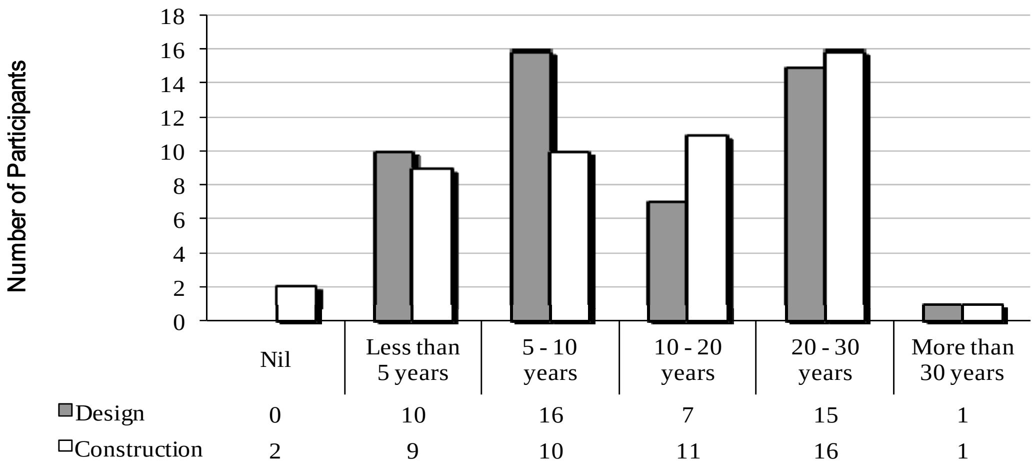

Figure 1: Design/construction experience, years.

Perception on assessment of safety risk at design

The general perception towards assessment of safety risk at design was evaluated using Statements 1 to 6. Table 4 summarises the responses to the perception towards assessment of safety risk at design.

There is a general consensus for participants to understand the concept of assessment of safety risk at design and the associated benefits. A total of 57% of responses agreed that safety issues are easier to identify at the design stage (refer statement 1). In addition, 75% agreed that construction site safety would improve if designs involve the consideration of worker's health and safety (refer statement 2). The data is skewed towards the positive response region, which indicates respondents do acknowledge that site safety can be improved by designing with occupational health and safety in mind. However, it is also of particular concern that 12% of the respondents did not agree with statement 2. It may be due to a number of barriers or limitations that exist when considering designing with safety in mind. We will investigate the barriers of implementing safety risk assessment in later section.

About half (51%) of the respondents perceived the development of appropriate design solutions to be a feasible option in addressing safety risks and potential hazards of a project (statement 6). There was a tendency for respondents to select the neutral category (35%). Design changes made during design stage are perceived to be easier (statement 3, 74%), less time consuming (statement 4, 53%) and more cost effective (statement 5, 63%). This reiterates the benefits of applying safety risk identification and mitigation by making appropriate design changes in the design stage. It also underlines the common perception that changes are more feasible in the preliminary stage where designers have more control over design changes and influence on safety. Statements 4 and 5 also relate to impacts of implementing design changes at design which will be discussed in later section.

Statements	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*
Statement 1 - "Issues relating to site safety are easier to be identified in the design stage as opposed to the later stage of the project."	12%	45%	27%	14%	2%
Statement 2 - "Site safety can be improved by designing building elements with Occupational Health & Safety for site workers in mind."	22%	53%	12%	12%	0%
Statement 3 - "Design changes can occur relatively easier in the design stage as opposed to the later stage of the project."	33%	41%	10%	14%	2%
Statement 4 - "The time used to resolve design issues are shorter in the design stage as opposed to the later stage of the project."	6%	47%	33%	12%	2%
Statement 5 - "Design changes made in the design stage are more cost effective than in the later stages of the project."	20%	43%	29%	6%	2%
Statement 6 - "Safety risks and hazards can be reduced for the entire project by addressing Occupational Health & Safety issues and developing appropriate design solutions at the design stage."	10%	41%	35%	10%	4%

Table 4: Respondent's perception towards assessment of safety risks at design (n=49).

Knowledge and current practice of assessment of safety risk at design

The aim of this section is to gauge the participant's knowledge and experience on the concept and method of "assessment of safety risk at design" and the feasibility of implementing the concept into practice. These questions used in this section were sourced from a previous study by Gambatese et al (2005a). Table 5 presents the results of Questions 7 to 20.

Knowledge and experience of assessment of safety risk at design

The results show that the majority of participants (65%) have not heard of nor have knowledge of the concept of "assessment of safety risk at design" (refer Table 5 Question 7). Those who have knowledge of this concept (35%) may be more inclined to include such concepts in their work or seek to build a foundation where additional knowledge and methods can be developed and implemented. This question is significant as it is one of the criteria for designers to implement assessment of safety risk at design. Further to this, 78% of respondents had not had any experience with external consultation in addressing safety risks during the design stage. This reiterates the lack of understanding and awareness of the concept of assessment of safety risk at design. Those who indicated ‘Yes’ in Question 8 were asked a follow up question: *“How would you describe the experience in relation to your work?”*

The answers showed that about half of the respondents (55%) have had a positive experience with a construction health and safety consultant. There were still 36% experienced negatively. It would be particularly useful to investigate further into the cause of this negative experience. 37% of participants have been approached previously to address construction workers’ health and safety (refer Table 5 Question 12), but only half of these requests were addressed (refer Table 5 Question 13). Those who had not addressed construction worker’s health and safety in the design stage may not have been equipped with the knowledge and skills to do so. This is evident in Question 16, where a majority of respondents (76%) had not been formally trained to address construction worker health and safety. This may have considerable implications where training can be improved in the area of design with the consideration of human activities required to construct a building. Additional coaching and exposure to the concept would assist in developing the knowledge needed to perform safety risk identification and assessment. Respondents who did not perform such task may also feel that it is not an area within their scope of expertise, or may not understand the value of addressing on-site safety.

A majority of participants (67%) were comfortable in discussing issues regarding construction workers’ health and safety issues during the design stage (Table 5 Question 14), and it is shown in Question 20, where 71% of participants were willing to address safety issue at the design stage. This result is a positive step in encouraging designers to implement assessment of safety risk at design.

Questions	*Yes*	*No*
7. Have you heard of the Design for Safety Concept?	35%	65%
8. Have you ever worked with or hired a construction health and safety consultant in design phase?	22%	78%
10. Have you ever, made design decisions that improved construction worker’s healthy and safety?	47%	53%
11. If yes to question 10, do you have a formal process to follow that allows for consideration of construction worker’s health and safety?	9%	91%
12. Have you ever been asked to address construction worker’s healthy and safety in the design stage?	37%	63%
13. If yes to question 12, did you actually carry out such task?	50%	50%
14. Do you feel comfortable talking about construction worker’s health and safety issues at design stage?	67%	33%
15. Have you made any design modification in the design stage to eliminate a potential safety risk that would impact construction worker’s health and safety?	51%	49%
16. In your formal education and training, have you had any coursework that addressed construction worker health and safety?	24%	76%
17. Besides your firm, if applicable, are you aware of any design firms that address construction worker's health and safety? If yes, please name	0%	100%
18. Do you believe that addressing construction worker’s health and safety in the design stage will increase your liability exposure?	10%	90%
19. Do you believe that the nature and culture of the construction industry precludes you in any way from addressing construction worker’s health and safety in design stage?	33%	67%
20. Are you personally willing to address construction worker’s health and safety in design stage?	71%	29%

Table 5: Knowledge and current practice of assessment of safety risk at design.

Design decisions and modifications to improve safety

The results show that half (53%) of respondents had not made design decisions improving construction workers' health and safety (refer Table 5 Question 10). Although majority of respondents agree that addressing safety issues during the design stage can reduce safety risks and hazards, as indicated previously, fewer respondents have taken actions to actually improve the health and safety of construction workers. One reason may be that respondents do not know how to implement or apply such concept in to practice. Further to this, participants were assessed whether they have made modifications to designs in eliminating safety risks and hazards, and the results showed that 51% conceded that they have carried out such task (refer Table 5 Question 15). The results show that 91% of respondents do not have formal process to address safety issue in the design stage.

Impacts of implementing assessment of safety risk at design

The impacts associated with the implementation of assessment of safety risk at design were tested in Question 22 in the survey. The results are shown in Table 6.

Impacts	*Very Positive*	*Positive*	*Neutral*	*Negative*	*Very Negative*
Safety	18%	65%	16%	0%	0%
Cost Saving	6%	27%	47%	18%	2%
Quality	8%	24%	67%	0%	0%
Productivity	4%	39%	24%	31%	2%
Time	4%	31%	22%	41%	2%

Table 6: Impacts of implementing assessment of safety risk at design.

The results showed that safety performance improvement could be greatly impacted through the implementation of safety risk assessment during design (83% positive response). The next performance characteristic may be affected is quality improvement. Although the data shows 67% neutral response to the increase of quality improvement, there is a 33% response to a positive increase in quality. It is difficult to argue a direct link between safety and quality, but it may be suggested that due to the increase of safe work ethics, less mistake may be produced and thus the increase in quality. Cost saving improvement shows a 33% positive response and a 20% negative response. However, the result shows a 47% neutral response. Thus, it is perceived that cost saving performance has minimal implications when safety risk assessment is implemented. The result for productivity improvement received 43% positive response, 33% negative and 24% neutral responses. Comparing both the negative and positive responses, it is perceived that productivity may be improved. The result of time performance improvement shows 43% negative response compared to 35% positive response. This could be due to more time is required during the preliminary phases of designing, reviewing and evaluating possible design rectifications and solutions.

Barriers to implementing assessment of safety risk at design

Barriers identified in literature review were tested in Question 21 of the survey questionnaire. Participants were asked how they perceived the given barriers in implementing assessment of safety risk at design.

Table 7 summarises the responses.

The major barriers identified in the survey are as follows: 59% of respondents are lack of understanding of potential benefits and agreed that it is a barrier for them. 49% respondents agreed that inadequate skills and knowledge is another barrier to implementation. This reinforces the fact that training and/or formal education is lacking in this area. About half (51%) of the respondents agreed that inadequate resources is a cause of failure to implementation. To date there is no formal system or process in place allowing designers to identify and improve construction safety during the design stage. Insufficient time accounts for 45% of responses. Increase cost accounts for 39% of responses.

Barriers	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*
Inadequate Resources	8%	43%	27%	18%	4%
Lack of Understanding of Benefits	18%	41%	16%	20%	4%
Inadequate Skills & Knowledge	10%	39%	35%	20%	2%
Insufficient Time	14%	31%	31%	22%	2%
Increased Cost	6%	33%	41%	18%	2%
No evidence to Support Theory	2%	20%	39%	33%	6%
Negative Attitude towards Change	6%	10%	49%	29%	6%
Fear of Increasing Liability	2%	10%	35%	47%	6%
Nature of Subcontracting	2%	29%	24%	39%	6%

Table 7: Barriers to implementing assessment of safety risk at design.

CONCLUSIONS

The primary aim of this research was to understand the current practice and limitations of safety risk identification and assessment during project design phase, in the Australian construction industry. This was achieved by wide coverage questionnaire survey, which seeks to gauge the perception, knowledge, practice/experience, barriers, and impacts of implementing identification, assessment and mitigation of safety risk at design stage of building projects.

The research results indicate that a majority of designers have no knowledge about assessment of safety risk at design, and thus are not equipped to perform such task. This is due to a general lack of information, guidelines, and formal training available on this concept, and the fact that is has not become a mainstream process throughout the construction industry. Impacts such as extended programme time and increase cost were discovered as major concerns of designers in Australia. The major barriers identified were lack of understanding of the potential benefits, inadequate skills and resources. Despite these barriers, the participants were judged to be knowledgeable in the fundamental aspects of the concept and are willing to address construction safety issues during design. Assessment of safety risk at design is a valuable and beneficial concept that can help mitigate safety risks in a project. Understanding the values and benefits should be the first step into overcoming the fear in implementing the concept.

Promotion and additional research of the concept as well as the associated benefits would help in shifting the mindset of designers and clients and build the knowledge and acceptance of this concept. Training and education will help overcome the barriers of inadequate skills, knowledge and resource. While insufficient time and increased cost is seen as a concern to most clients and architects, it is a variable that can impact the project both positively and negatively depending on how it is controlled by the people in control.

The areas of focus for future research should be the development of implementation strategies for conducting assessment of safety risk at design and validation of the effectiveness of these strategies. This should be done in accordance with the relevant Guidelines, Principles and Toolkits set by the Federal and State Governments and Professional Bodies.

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UTILIZING AN ANALYTIC HIERARCHY PROCESS (AHP) TO ASSESS CONCRETE SAWS WITH SILICA DUST REDUCTION EQUIPMENT

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ABSTRACT
Alternative construction procedures must be evaluated in the context of safety, as well as other objectives. There are numerous methodologies that have been developed to assist in decision making; however, there are limited cases in which these decision making procedures have been applied to assess alternative safety procedures on the construction site. This paper reviews potential methodologies to assess alternative construction procedures with varying safety controls, and recommends the use of an Analytical Hierarchical Process (AHP), which is commonly used in engineering. The AHP is described and the applicability illustrated in a construction case study, in which alternative methods to protect workers from respirable silica dust exposure during concrete saw cutting activities are evaluated. Each saw is evaluated in terms of safety, productivity, usability and cost. A concrete saw equipped with a Local Exhaust Ventilation (LEV) system to reduce silica exposure was determined to be the best choice given the selection criteria.

Keywords: Alternative analysis, Safety analysis, Concrete saw, Silica exposure, Analytic hierarchy process

INTRODUCTION
On-going research presents new techniques, procedures, and equipment to improve worker safety in the construction industry. New safety practices may have direct and quantifiable benefits for a specific construction process; however, new practices must be evaluated in the context of multiple objectives beyond safety. When multiple safety practices have similar safety benefits, additional evaluation is needed to determine the optimal safety practice for the specific construction operation.

The objective of this paper is to review existing decision making processes and recommend a process for evaluating alternative safety practices in construction. The proposed decision making methodology is illustrated through a case study of alternative methods to protect workers from silica dust exposure during concrete saw cutting activities.

BACKGROUND
Construction projects are generally unique, and each job may have specific risks and constraints, which vary throughout the duration of the project due to the changing nature of the jobsite and the participation of different subcontractors throughout the project. The unique and dynamic nature of each construction project results in many decisions being made on the construction site.

Decision making includes intuitive elements, which may be difficult to quantify, as well as logical or structured elements, which may be quantitatively assessed. The assessment of both the intuitive and logical elements is also affected by the experience of the decision maker, which can be an important factor in the alternative selected. Another element which may be an important factor in a decision is the element of uncertainty, which has been formally integrated into decision analysis. Effective decision making is an important part of construction, and successful project managers apply their knowledge and experience in every decision they make. Some research indicates that in situations with higher time pressure, higher stakes, or increased ambiguities, experts use intuitive decision making rather than structured approaches and may make successful decisions without thoroughly or formally weighing alternatives (Badiru 2006).

While many of the decisions in construction are made in the field under time constraints, and may be unstructured and intuitive, other decisions are more structured and are made in advance. These decisions may be enhanced through the use of a formal decision making process. This paper focuses on the analysis of alternative construction procedures, which is conducive to a very methodological approach. Within this framework, a brief review of traditional decision making methodologies is provided below.

Decision making is the process of selecting one option from multiple options. The difficulty of the process may be increased due to uncertainty about the information provided, or due to the need to balance multiple objectives (Badiru 2006). In the simplest framework for a decision regarding worker safety, safety is the only criteria by which alternative practices are evaluated. In this case, the decision process is straight forward and the equipment, technique, or procedure that provides the greatest safety protection is chosen. A decision making process which is based on a single dominating attribute, in this case safety, is referred to as a lexicographic strategy (Badiru 2006).

In practice, decisions regarding worker safety are typically more difficult, and must consider additional criteria beyond safety in the decision making process. In some cases, it is possible to maximize across multiple criteria; in fact, some researchers suggest that safety and productivity can be compatible (Hinze 1978). However, in many cases, maximizing with respect to one objective may reduce the attainment of a second objective. For example, to maximize worker safety on a road construction job, the entire roadway could be closed to traffic. This would increase worker safety, however it may not be practical due to the competing objective of maintaining a working transportation system.

In order to make a decision regarding the most appropriate safety practice in a framework with multiple objectives, Multiple Criteria Decision Making (MCDM) processes have been developed. Also referred to as multi-criteria decision analysis, MCDM is widely used in a wide variety of applications in both the private and public sectors, for everything from resource allocation for corporations and non-profit agencies (Phillips 2007), to alternatives analysis for environmental sensitive projects (Getzner 2004).

Within MCDM discipline, there are a number of different methods, one of which is the Analytic Hierarchy Process (AHP). This method was developed by Thomas Saaty almost forty years ago, and has been widely used for decision making when discrete alternatives are identified and must be evaluated with respect to multiple criteria (Saaty 1982). The AHP has been widely used in engineering analysis, and was recently used in the analysis of crane safety (Shapira 2009). The AHP is recommended for the evaluation of alternative safety practices in construction for a number of reasons:

- The methodology is simple and straightforward, and does not require software or other specialized knowledge or tools.
- The methodology breaks down the problem into elements, which can be discretely assessed.
- The methodology utilizes weighted factors for the criteria; this provides flexibility because the weighted factors can be modified to reflect changing priorities.
- The methodology provides a flexible model that reflects both judgment and values in the decision process.
- The methodology provides the constructor with a transparent and quantifiable way to assess multiple options and assure that the required safety is maintained.

ANALYTIC HIERARCH PROCESS (AHP)

The first step in translating a decision into the AHP framework is to describe the decision and relevant factors in the environment by breaking the situation down into criteria. The criteria must be extensive enough to thoroughly describe the problem, and in some cases it is appropriate to elaborate on criteria by providing sub-criteria.

The criteria provides the basis for quantitative assessment of the problem, and in order to compare each alternative with respect to all the criteria, a weighting factor is used to indicate the relative priority of the criteria. There are multiple ways in which the weighting factors can be determined, for example, weighting factors might be based on expert opinion, paired comparisons, or on a statistical analysis of each criterion's impact on outcome (although it is unusual to have reliable statistical data for most problems). The AHP process is illustrated through the following example.

CASE STUDY: APPLICATION OF AHP TO SILICA SCAVENGING SYSTEMS FOR CONCRETE CUT-OFF SAWS

Highway construction operations often require concrete sawing for a number of reasons, including repair, removal of material, or to limit crack propagation. Concrete sawing is often performed using a hand held cut-off saw exposing the workers to respirable dust (Figure 1.0 (a)). The dust contains silica, which is found in sand, clay, and stone materials (OSHA 2009). The inhalation of silica dust may cause the disease silicosis (OSHA 2009). As a result, the United States (U.S.) Occupational Safety and Health Administration (OSHA) has adopted enforceable Permissible Exposure Limits (PEL) for respirable silica dust. Exposure limits are expressed in the form of a concentration (mg/m^3) using a Time Weighted Average (TWA) over an 8 hour work day.

Three sawing methods are evaluated in this case study, as described below and shown in Figure 1:

- Dry method: Traditional method used, has no dust control (Figure 1 (a)).
- Wet method: Saw is similar to the dry method, however a continuous stream of water is sprayed on the blade and around the cut surface to reduce dust. The water is provided via a small pressured water tank, as shown in Figure 1 (b).
- Local Exhaust Ventilation (LEV) method: The LEV method is a vacuum system, powered by the saw motor. The vacuum pulls the dust from around the blade and collects it in a bag (Figure 1 (c)).

All three methods were tested during roadside curb cutting operations during actual construction. Curbs along a roadside are cut every 6 to 10 feet to prevent cracks from propagating along the curb.

(a) (b) (c)

Figure 1: Concrete cut-off saw methods: a) Dry method b) Wet method c) LEV method.

Defining the Evaluation Criteria

The first step in implementing the AHP method is to define the evaluation criteria. The four criteria used in the analysis of the alternative sawing methods are described below and are shown in Figure 2:

1. Safety: Worker safety and compliance with OSHA requirements are a top priority.
2. Productivity: Productivity quantifies the efficient use of manpower, which is important to maximize profits and maintain a competitive position in the industry.
3. Cost: Costs include both the capital and operating costs.

4. Usability: Usability refers to the ease of use as well as the functionality of the equipment in different environmental conditions without the need for additional equipment.

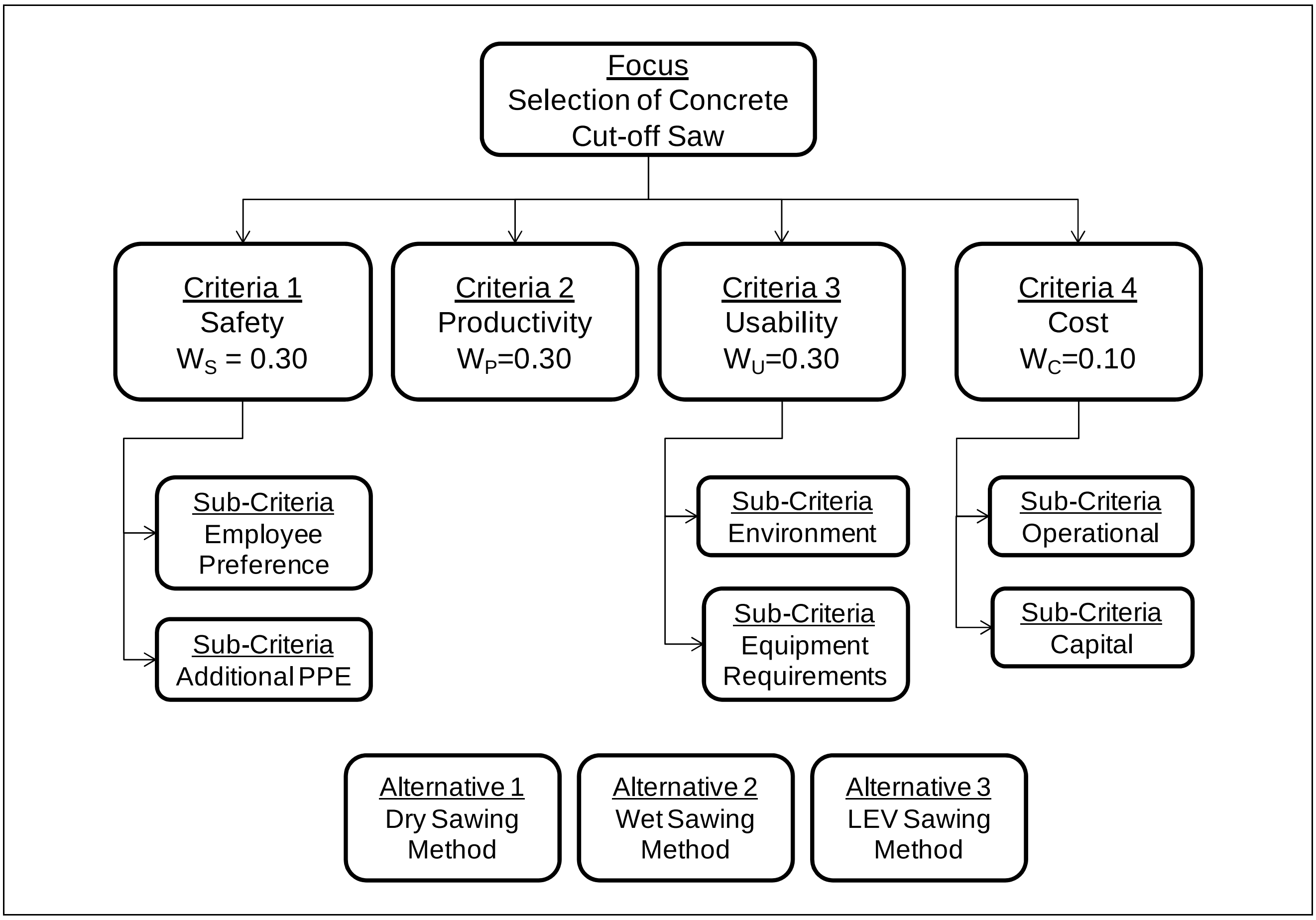

Figure 2: AHP diagram for concrete cut-off saw with weighted factors.

Assigning a Weighting Factor

In order to implement the AHP, a relative weight indicative of the importance of each of the evaluation criteria must be determined. In this case study, the contractor supporting the research was interviewed to assist in determining the weighting factors. Based on this input, safety, productivity and usability were the most important criteria and were assigned a relative weight of 0.3; cost was also important but was not ranked as high, and was assigned a relative weight of 0.1.

Sub-Criteria

Three of the criteria had sub-criteria, indicative of the fact that more than one factor was considered in the evaluation criteria; sub-criteria are shown in Figure 2. For the case study, a simple scale of 1 to 5 was used to evaluate both the evaluation criteria and the sub-criteria for each alternative, where: 5 = Excellent, 4 = Very Good, 3 = Good, 2= Fair, 1=Poor. A discussion of the four evaluation criteria for each of the three alternatives is presented below.

Safety

In this case study, all three sawing methods can be operated within OSHA requirements, ensuring a safe work environment. However, each method produces a different level of respirable silica dust and therefore requires work practice controls, engineering controls, and/or additional PPE.

To indicate the relative exposure to silica for each method, the concentration of respirable silica for a construction worker for 2 hours of an 8 hour day was determined and compared to OSHA PEL requirements, as shown in Table 1 (Middaugh 2009). The wet and LEV sawing methods are both below the OSHA PEL concentrations for silica exposure. The dry method exceeds the PEL requirements set by OSHA and would require respiratory protection. Based on the respirable silica concentration, a half-mask respirator would be required to reduce the workers exposure to silica below the PEL. If a half mask respirator is required, the company will have to initiate a respiratory protection program for the workers using this type of concrete saw. A respiratory protection program is a significant expense for the company as further discussed in the cost section. Also, the use of engineering controls to reduce the respirable silica is preferred to a respirator, whenever possible. As noted in OSHA 1910 section 134 (OSHA 1910.134, 2009): "When effective engineering controls are not feasible, or while they are being instituted, appropriate respirators shall be used pursuant to this section." This difference in the required PPE for the three methods is reflected in the sub-criteria for safety.

The second sub-criteria for safety was employee preference. Based on the contractor's experience, safety features that are burdensome or uncomfortable will often not be used. Preliminary observations regarding preference indicate that workers do not like the dry method due to the excessive dust generated, and workers do not like the wet method because it runs water onto their feet (in cold conditions, wet boots can be very uncomfortable). The LEV method reduces dust but does so without the addition of water around their feet. Based on the safety sub criteria, the LEV method exceeds the other two methods followed closely by the wet method.

	(a) TWA Respirable Silica Concentrations (mg/m^3)[A]	(b) Compared to OSHA PEL of 0.10 (mg/m^3)	(c) Cut Rates (cuts/min)
Dry Cut-off Saw	0.24	Exceeds PEL	1.9
Wet Cut-off Saw	0.04	Below PEL	1.5
LEV Cut-off Saw	0.05	Below PEL	1.3

[A] Estimated 8 hr TWA for 8 hr Work Shift with 2 hr Continuous Sawing

Table 1: TWA respirable silica concentrations and cut rates for saw methods.

Productivity

Productivity was very important to the contractor for the selection of the equipment to be used for sawing operations. The productivity for each system was defined as the actual work hours per installed quantity (Park 2005).

	Dry	Wet	LEV
Safety	1.25	4.5	4.75
Productivity	5.00	3.25	3.50
Cost	2.00	3.25	4.75
Usability	5.00	2.50	5.00
Total	3.58[A]	3.4 [B]	4.40 [C]

[A] Calculated based on weighting factors shown in Figure 2: 0.30(1.25) + 0.30(5.00) + 0.1(2.00)+ 0.3(5.00) = 3.58
[B] Calculated based on weighting factors shown in Figure 2: 0.30(4.50) + 0.30(3.25) + 0.1(3.25)+ 0.3(2.50) = 3.40
[C] Calculated based on weighting factors shown in Figure 2: 0.30(4.75) + 0.30(3.50) + 0.1(4.75)+ 0.3(5.00) = 4.40

Table 2: AHP ranking for each alternative.

Video recordings of all three sawing methods were used to determine the amount of time required to complete a saw cut, which was the basis for productivity and is shown in Table 2. Based on this data, the dry method was the most productive, followed by the wet method, and finally the LEV method. Even thought the two saws used by the wet and dry method were identical, the wet method took longer because a water storage device had to be attached to the saw and moved for each curb cut. The water stream also had to be turned on and off after each curb cut. The LEV method was the slowest because the speed of the saw was reduced due to the addition of vacuum system, requiring the operator to spend more time on each curb cut.

Usability
Usability is an important factor because the system must be flexible enough for different environmental conditions, and must be usable without additional equipment; these two factors constitute the sub-criteria for usability.

Both the dry method and LEV could be used in virtually any environmental condition, and neither required additional equipment. The wet method, however, was more limited in the category of usability. The wet method requires a nearby water source in order to have a continuous stream of water. The current system requires the worker to fill the small water tank after approximately 8 cuts. If water is available nearby, this is fairly simple, however, it does reduce productivity. If water is not available nearby, the worker can either fill up multiple tanks prior to the curb cutting work, or a water truck can be used. The need for a water truck reduces the usability of the wet system (it also increases cost, which is reflected in the cost criteria). The wet method is also of limited use in cold environments; colder temperatures can cause the water to freeze within the canister and hosing. Overall, the dry and the LEV method were approximately equal, and both were superior to the wet method in terms of usability.

Cost
The cost for each alternative reflects both the capital and operating costs, which were weighted equally in this analysis. Considering capital cost, the dry method was the least expensive and the wet method and the LEV method were slightly more expensive due to the additional equipment. All of the systems were in an acceptable cost range in terms of capital cost. The operating and maintenance cost of the LEV method was the lowest. The operating cost of the wet system was higher due to the cost associated with a water truck. The operating cost of the dry method was also higher due to the costs associated with the half-mask respirator. These associated costs include; developing a company respiratory protection program, employee medical clearance to wear a respirator, employee training for use of the respirator, and an annual fit test for the respirator (OSHA 1910.134, 2009). Overall, the LEV was determined to be the most cost effective.

Overall Assessment
The overall assessment for each alternative is shown in Table 2. It is calculated using the weighting factors shown in Figure 2, and the criteria rankings discussed previously and shown in Table 2. As can be seen, the LEV alternative is the best alternative based on this analysis, followed by the traditional dry method and the wet method. The ratings of the dry method and the wet method are relatively close and it should be noted that OSHA recommends the wet method for an engineering control to reduce respirable silica dust (OSHA 2009). This analysis does indicate that the LEV method holds promise and should be evaluated further.

CONCLUSIONS
Construction requires many decisions, most of which are made on-site and are intuitive based on the experience and knowledge of the construction manager. Decisions regarding best safety practices benefit from a more quantitative and structured approach and the AHP is demonstrated to be a useful tool to assess the alternative approaches considering multiple objectives. The use of the AHP to compare traditional dry sawing, wet sawing, and a LEV system indicated that the new LEV system is superior based on the criteria safety, productivity, cost and usability. These results illustrate the utility of the AHP process for safety decisions in construction.

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ACCIDENT AVOIDANCE IMPORTANCE FOR BUILDING DEMOLITION

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ABSTRACT
Building demolition, as compared to building construction is always carried out as quickly and cheaply as possible. The nature of limited time and resources of the demolition project sometimes translate into poor work planning and safety precautions. In recent years, demolition work has become more complicated due to the high diversity of building types and there are various demolition techniques and strategies. It is important to have a clear understanding of the type of building to be demolished, the method to be used and risks involved to ensure proper work planning. Using historical data on demolition related accidents; this paper discusses the classification of injuries and causes of the accidents. To conclude, strategies for better understanding of demolition work and good practices of site safety are recommended.

Keywords: Building demolition, Safety, Workplace accidents, Injury

INTRODUCTION

Safety is a major concern in the construction industry. Work related injuries and fatalities cause great loss to the industry. In Australia (ABS, 2006) and New Zealand (Statistics New Zealand, 2003), construction industry is recorded as the third highest rate of injuries among other main industry. Being one of the most high risk occupational areas in the world, workers in construction industry face a wide range of physical hazards. These include working at elevated areas, mobile machinery, electricity, various tools and power tools.

Accident avoidance is always an ultimate goal in safety related researches. Construction safety researches cover many topics; one of the main topics is safety management where researchers investigate management practices and policies that can improve safety performance. Other researches include safety hazard identification and integrating safety with construction schedule where all safety consideration can be included at the early stage of construction (Carter and Smith, 2006). There are also researches on accident causes and analysis, where here researchers investigate into the causes of accident to understand how it happened so that measures to avoid it can be taken (Hinze et al., 1998; Ale et al., 2008). Safety culture and awareness among construction organisation and personnel are also being studied, in this field of research, it is found that safety awareness, knowledge and safety training are key important elements to promote safety culture (Zou and Zhang, 2009; Mohamed, 2003).

Similar to construction, building demolition also possesses certain safety risk. Since the nature of demolition work is different from construction work, it is believe that demolition work imposed slightly different safety hazard. However there is no study focus on demolition safety. A better understanding of the safety risks in demolition work is therefore needed to avoid demolition related accidents in the future.

This paper aims to classify the causes of injury related to building demolition works. Firstly, the nature of demolition work is briefly described. Then, construction industry fatal injuries narratives are investigated, injuries related to demolition are extracted and the causes of injuries are classified. From here the trend of demolition related injury is identified and concluded that it is different compared to construction. Potential measures for accident avoidance are outlined at the end of this paper.

BUILDING DEMOLITION METHODS

The demolition process is the opposite of construction. Construction involves putting up a structure while demolition involves pulling it down. The most common reasons for demolition job are the building age and the safety condition of the building. When a building is no longer fulfil its purpose, it will be demolished to make way for new building to be constructed. Demolition work use to be a simple job. It can be handled by a few men with unsophisticated equipment. Nowadays building structure has evolved becoming more complicated and so does the demolition work. There are many ways to demolish a building. The selection of demolition method must consider the building size, structural types and building location. The general rule is the safest and simplest method that can do the job is the one selected.

Generally, demolition work can be carried out either manually or mechanically. Manual demolition work involves the uses of intensive labour and normally it will take a longer time to accomplish. This type of demolition is also known as deconstruction, where building component will be dismantled systematically in the reverse order of construction process. The main advantages of this method are, it will produces building materials that are in good quality, easily to be sorted and readily to be reused or recycled. Mechanical demolition on the other hand involves the uses of heavy machineries such as excavators and bulldozers to pull or push down a building. Less labour is required for mechanical demolition and the job could be handled rather quickly. This method however produces mixed debris of building materials which normally to be sent to landfill area (Pun et al., 2006). Sometimes contractor used both of this method on a building demolition project. The combination of these two methods often called hybrid demolition technique. Using this method, the contractor will gain advantages from both methods describe above where the project could be carried out quickly, less labour intensive and can gain some income from salvaged material.

From here, it is seem that building demolition when compared to building construction is always carried out as quickly and cheaply as possible. The nature of limited time and resources of the demolition project sometimes translated into poor work planning and safety precautions.

ACCIDENT FREQUENCY DURING DEMOLITION ACTIVITIES

Accidents do happened during building demolition process but accident records specifically on demolition project are not available. Demolition accident records are normally included in the construction injuries databases. Work related injury report or database from Australia and United Kingdoms is used as an example to support this study. Initial indication of demolition related injuries come from Australian Safety and Compensation Council's reports on "Work-Related Injury Hospitalisations, Australia 2002–03 and 2003–04" where it indicated that 66 cases of injuries happened at demolition site (Table 1). The percentage of injuries related to demolition work is relatively low (0.4%) as compared to injuries happened at construction site which is 2,611 cases or 17.6%.

Place	Number of cases	%
Factory & plant	5,923	39.8%
Construction area	2,611	17.6%
Mine & quarry	1,240	8.3%
Shipyard	172	1.2%
Oil & gas extraction	74	0.5%
Demolition site	66	0.4%
Power station	52	0.3%
Others industrial & construction area	1,677	11.3%
Unspecified industrial & construction area	3,054	20.5%
Total	14,869	100.0%

Source: (ASCC, 2007)

Table 1: Places of injury occurrence for industrial and construction area, Australia 2002-03 and 2003-04.

Another available record of demolition injuries is from a survey conducted by British Market Research Bureau's (BMRB), "The Construction Workers Survey" participated by 5,813 construction workers between January 2005 and April 2006 indicate that 15 cases or 3.2% incidents happened at demolition site (Table 2). Similar to the data from ASCC' report, the number of injuries is relatively low as compared to other construction projects. However, BMRB survey also indicates that incident rate at demolition projects is relatively high (2.91 accidents per project). From this data, it is believed that demolition work imposed a higher safety risk to the worker as compared to normal construction work.

Project where accidents occurred	No of cases (%)	Ratio Acc/Proj
New building	104 (22.2%)	0.69
Refurbishment/repair	120 (25.7%)	0.95
Civil engineering	24 (5.1%)	0.73
Demolition	15 (3.2%)	2.91
Roads and paving	21 (4.5%)	1.50
Roofing	15 (3.2%)	1.07
Painting and decorating	12 (2.6 %)	0.65
Electrical work	21 (4.5%)	1.13
Cable/pipework	7 (1.5%)	0.75
Exterior cleaning - buildings	6 (1.3%)	6.50
Bridge building	6 (1.3%)	2.89
Building services	19 (4.1%)	0.68
Other	97 (20.8%)	2.97

Source: (HSE, 2008)

Table 2: Project where accidents occurred, United Kingdom.

ACCIDENT CAUSES DURING DEMOLITION ACTIVITIES

When there is an injury happened, normally the reporting system will identify what type of accident and how does it occur (Abdelhamid and Everett, 2000). According to OSHA (1990), how the accident occurs is classified into five categories which are falls, struck-by, electric shock, caught in or between and others. Some researchers think that the accidents investigation normally stops at premature level since why the accidents occur are not addressed (Choudhry and Fang, 2008). However there are many accident causation theories had been developed such as domino theory in 1930 by Heinrich H. W. and multiple causation model by Petersen D. in 1971. There are also human error theories to explain accident causes.

Causes	Demolition		Construction		Total	
	Number of cases (%)		Number of cases (%)		Number of cases (%)	
Falls	13	1.97%	312	47.34%	325	49.32%
Electricity	0	0.00%	57	8.65%	57	8.65%
Transport	5	0.76%	105	15.93%	110	16.69%
Collapse	25	3.79%	46	6.98%	71	10.77%
Struck-by	2	0.30%	52	7.89%	54	8.19%
Miscellaneous	2	0.30%	40	6.07%	42	6.37%
Total	47	7.13%	612	92.87%	659	100%

Table 3: Comparison of injury causes for demolition and construction works.

For the purpose of this study, the data from Health and Safety Executive (HSE), UK "Summaries of Fatal Accidents for 1997/98 – 2004/05 is used as an example to identify injury causes related to demolition work. From the construction fatal accident narratives listed in the report, accidents related to demolition work are identified and sorted into 6 categories which are falls, electricity, transport, collapse, struck-by and miscellaneous. As shown in Table 3, the highest cause of fatality related to building demolition is collapse of the building structure (3.79%) followed by falls (1.97%), transport (0.76%), Struck-by and miscellaneous both at 0.30% and there is no cases caused by electricity (0%). It is seems that the trend of demolition related accident causes is different as compared to the trend of overall construction accident causes which goes by falls being the highest causes at 49.32%, followed by transport (16.69%), collapse (10.77%), electricity (8.65%), struck-by (8.19%), and miscellaneous (6.37%).

Further investigation on the main cause of injury which is collapse of building structure; indicate that 72% of the accidents happened because the workers are unable to determine the stability of the structure, 20% injury caused by workers being at a wrong place during demolition work and another 8% are caused by structure being knocked down unintentionally. Investigation on falls reveals that 53.8% of injuries are caused by falls through fragile material, 30.8% are by falls from edges and opening. Falls from ladders and falls from scaffolds or work platforms are both at 7.7%. All transport related injuries are caused by accidents involving site plant such as bulldozer, excavator and telescopic handler. Two Struck-by injuries are caused by lifted object and dismantled building component and miscellaneous injuries are caused by fire. These entire figures are summarized in Figure 1 below.

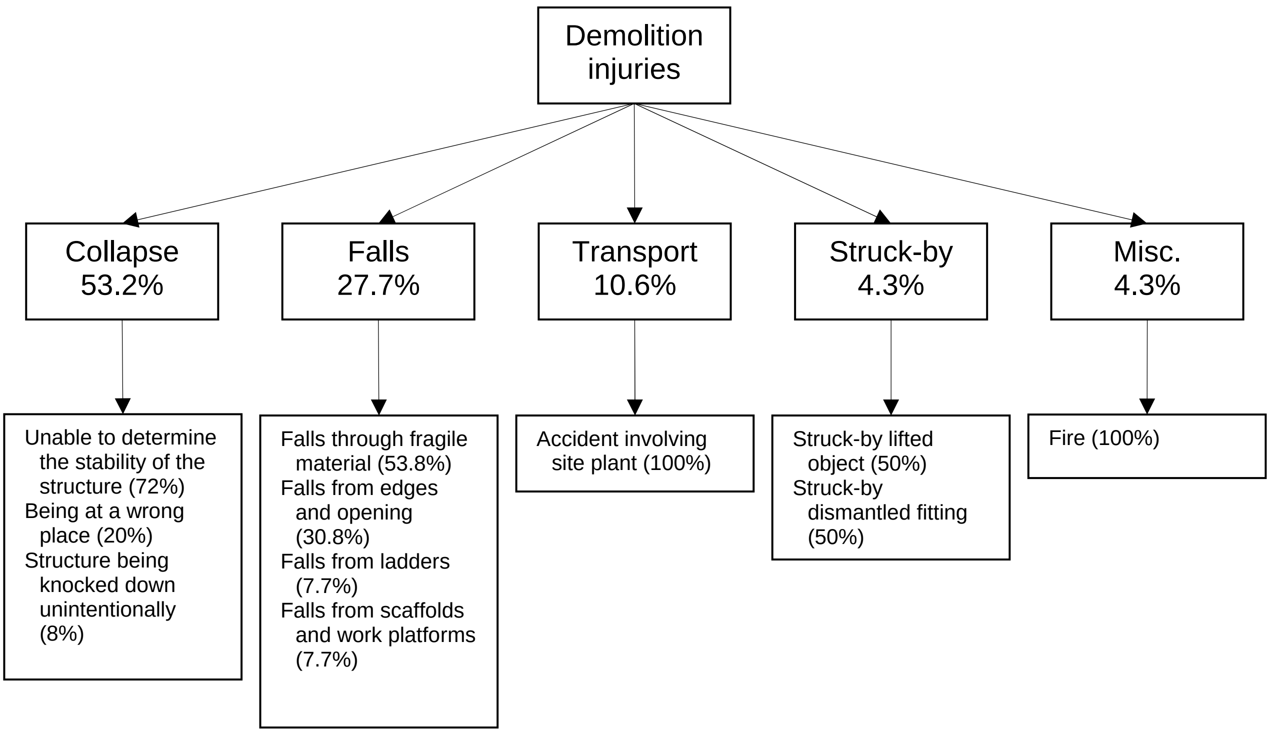

Figure 1: Summary of demolition related injury causes.

IMPORTANCE TO AVOID ACCIDENT DURING DEMOLITION WORKS

The number of accident in construction industry and also during building demolition can be considered as high. However, accidents can be avoided with the implementation of suitable safety measures. Accident avoidance in demolition project must begin with an understanding on the possible causation of the accidents. Basically accident happened due to two main factors which are unsafe conditions and unsafe practices. Unsafe conditions are referring to work environment at construction site and unsafe practices are related to workers attitudes and behaviours towards safety, knowledge, awareness and compliance on safety procedures. Most authorities recommend that accident can be reduced by better supervision, work planning and organisation. Petersen D. suggest that to avoid accidents at construction site, inspection procedures must be improved, conduct proper training to all workers, make better assignment of responsibility and proper planning prior to job execution (Choudhry and Fang, 2008).

In relation to normal practice at demolition project, the implementation of a strategic pre-demolition quality system that includes all safety requirements that will follow through from the planning to the execution of the demolition project will ensure that all parties involved adhere to the quality standards of the demolition process. As with all projects, successful planning concludes with successful projects, therefore implementing and the use of early quality strategies maintains early control with minimal cost and possible safety consequences.

The demolition quality system may be divided into 7 sections that includes there own sub headings. Clarity of all areas of the demolition project will enable prevention of demolition accident and underpin safety. The 7 sections are scope of demolition, planning and statutory requirement, hazardous material audits, hazardous material removal, methodology of demolition, isolation of works, and qualification of contractors.

Within each section there are compulsory safety requirements through the relevant Act, Regulations and codes. Furthermore to safety, organizational safety plans are required to coincide within the sections.

From the study we can see that the main cause of demolition accident is worker being struck-by collapsing building structures. It is seems that many demolition workers are not well converse of the structural nature of what is being taken down. Therefore a supervisor for demolition work must be someone that knowledgeable and highly experienced not just only in demolition but also in building construction. Before carry out the demolition work, the supervisor should examine building plan of the properties and if the plan is not available, he should make his own survey so that the building structural type can be identified and the demolition work can be properly planned. From this observation, a suitable demolition method can be selected and once the overall work plan has been lay-out it should be explained and discussed with all workers and other site operatives. During this briefing, not only the sequence of operations should be explained but it should also include the safety risk involve and safety measures to be taken. In carrying out the work that has been planned, it is best that supervision and guidance to worker are done continuously.

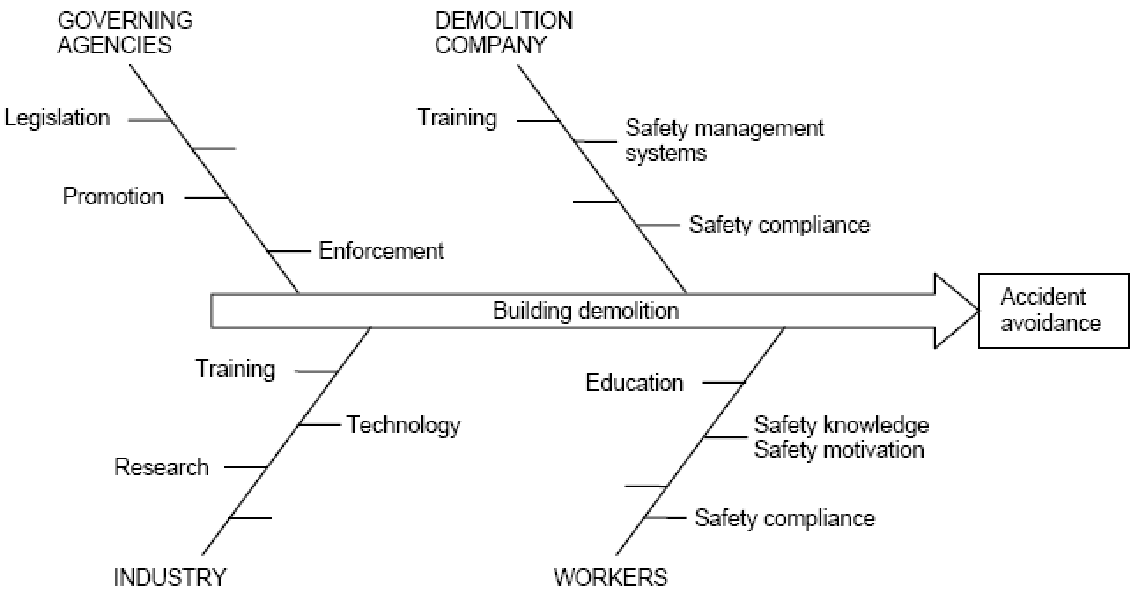

Figure 2: Potential measures towards accident avoidance in building demolition.

On a larger scale, potential measures towards accident avoidance in building demolition can comes from different level of organisations such as governing agencies, industry, demolition companies and lastly the workers or the individuals that involve with demolition work himself. Figure 2 suggest potential measures from different level of organisations. Governing agencies produce regulations, and by-laws related to safety. Later it will promote and enforcing it. The industry player can focus on research, introduce new technology and also conduct a promotion or education program towards safety. Demolition companies can embrace safety management systems which include safety policy and objectives, safety standards, planning and organization of work and also conduct safety training for all workers. All these measures are related to one another to achieve the ultimate goal of accident avoidance.

CONCLUSION

Demolition work is different from construction work; it is the direct opposite of construction work. There are various demolition methods available. Two of the most common methods are deconstruction and mechanical demolition. Even though demolition method selected is always the simplest and the safest method, there are accidents happened during demolition work being recorded. The number of reported demolition related accidents is relative low as compared to construction's accident but the accident rate is actually higher. While the result of this study is based on a very limited data; nevertheless it has shown that there are differences between injury trend in demolition work and construction work. Collapse of building structure is a main cause of injury in demolition work while falls is a main cause of injury in construction work. Further investigation on the collapse of the building structure indicates that accidents happened because of the inability to determine the stability of the structure by the workers. Safety pre-caution consideration during demolition work must be different from normal construction work with greater attention on how to bring down building structure safely and to avoid unintentional collapse. Collective measures from governing agencies, industry, demolition companies and workers are very importance to avoid accident from happening. However, further study on these measures and more research on demolition related injury should be conducted in the future to give better understanding on the risk involve and how to manage it.

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USING TECHNOLOGY TO WARN CONSTRUCTION WORKERS OF DANGER

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ABSTRACT
Collisions between personnel on foot and heavy equipment or materials on a construction site can be characterized as a contact collision and are a common type on a work site. Pro-active real-time safety technology is needed to improve the safety of a work zone by alerting workers when they are in danger. Furthermore, technology may assist to collect (previously unrecorded) data on “near-misses”. The technology that is used in this paper uses the radio frequency wave spectrum to alert workers in real-time when they are in danger. This new approach leads to improve the overall safety performance in construction and elsewhere through improved learning and education by providing relevant information to decision makers at all levels. Various experiments are described that have been conducted in order to gain better understanding of the potential of several competing technologies.

Keywords: Danger warnings, Plant and equipment, Collision, Radio technology

INTRODUCTION
A construction work zone is mostly a dynamic place consisting of heavy equipment, materials, and personnel that are in motion to each another. The sometimes unstructured or almost random movement can lead to incidents between two objects. These incidents are then characterized as contact collisions and are often a threat to the safety of personnel that is in too close proximity to equipment. These collisions can be attributed to various problems that begin with the closeness in which vehicles and workers operate. Pratt, et al., explains how workers are often unloading materials from a vehicle for an extended period of time, and operators become unaware that workers remain in proximity. Workers become unaware of their surroundings due to fatigue and task repetition, which causes lower awareness and loss of focus on surroundings. These situations are dangerous for all workers, and machine operators must deal with machine blind spots, too. Therefore, there needs to be an alert that will alarm workers from their specific tasks and alert them to their surroundings.

Current safety statistics have been published by the Census of Fatal Occupational Injuries (CFOI) for 2007, while the report will not be completed until the spring of 2009, initial investigation shows that there is significant fatality rates for personnel being struck by vehicles. 21% of all occupational fatalities occur in the construction industry which accounts for 1,178 people. Within the construction industry, most fatalities of workers being struck by objects occurred in heavy construction and to specialty contractors (10% and 13% of all fatalities respectively). Statistics showed that 6% of all occupational injuries were from workers being struck by vehicles (CFOI, 2007; Garrett & Teizer 2009) nformation shows that there is a need for a “second chance” warning device that alerts workers that they are in danger.

Fosbroke (2004) published on the Construction Research Program created by NOISH which identifies the following contributing factors to the issue of contact collisions. There is lack of knowledge of specific risk factors; all data collected on incidents is collected after-the-fact and no real-time information is gathered during the incident such that the specific safety needs on a site have yet to be sufficiently identified. There is insufficient adaptation of intervention technologies used in other industries; the train industry and mining industry have both been implementing various safety technologies that if adapted could be used in the construction industry (Fosbroke, 2004). There is a lack of scientific evaluation for newly and existing intervention technology; emerging safety technology needs to be evaluated through research of current methods along with case studies and data analysis. These issues will be addressed in this research through the evaluation of current safety practices, uses of technology in safety, creation of proactive safety technology using active Radio Frequency Identification (RFID), and subsequent evaluation of the technology.

BACKGROUND

Technology can be seen as the first and last barrier of safety. The Causation Model for Accidents (Figure 1) has been adapted from the Swiss Cheese Model (Reason, 1990). The model shows how in each level of construction there are “holes” in the initial safety plan; as the plan advances to the construction phase the lack of safety planning results in more “holes,” and thus higher probability of incidents. The Construction Industry Institute (CII, 2003) reported that “the findings show that the better safety records occurred when site specific safety programs were prepared for the projects”. Therefore, better front end planning will result in safer worksites.

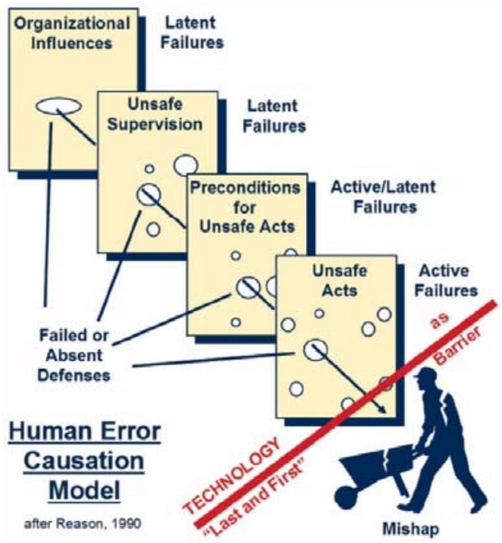

Figure 1: Human error causation model (after Reason, 1990).

There are many different technologies emerging in the construction industry; each technology has the potential to help improve site safety conditions. Technology can be used as a final barrier by giving workers a “second chance” of escape using a warning device. Information from the “near-misses” that occur through the alert can be collected and used to change future safety plans at the beginning of a project. Effective implementation will strive to close up the “holes” and decrease the number of accidents on worksites; the technology(s) will become a first barrier tool of safety. OSHA regulations are not enough to prevent these kinds of collisions from occurring. The Center for Disease Control (CDC), Pratt, et al. (2001), conducted a study in 2001 that categorized the various kinds of fatalities that occur on a construction site, both along a highway and off a highway. All gathered information is after-the-fact data (Pratt et al. 2001).

The statistics presented earlier from CFOI coincide with the statistics from previous years; it is evident that not much has improved in preventing workers from being killed by vehicles. The following information was also gathered from the CFOI but was compiled by Pratt et al. (2001) for NIOSH and displays statistics between 1992 and 1998. The study found that out of the 465 vehicle related fatalities, 318 of the fatalities were workers on foot. The type of vehicle they were struck by was most commonly a type of truck (60%) followed by a construction machine (30%). 110 fatalities were machine operators, most of those accidents occurred to a worker operating a construction vehicle (53%), and followed by a truck. The remainder of the fatalities occurred to supervisors and other personnel. The majority of the fatalities (51%) occurred when the vehicle was in reverse mode; this can be attributed to the large amount of blind spots that are prevalent in the backside of a vehicle (Pratt et al. 2001). During 2006, the CFOI reported 369 workers were killed by a motor vehicle during highway construction that accounted for 7% of all occupational deaths. 560 workers were reported killed by being struck by an object that accounted for 10% of all occupational deaths. There is limited data on the specific happenings of an occupational fatality. Of those incidents that did not result in fatalities, most workers were severely injured which resulted in missed days of work (Pratt et al. 2001). Figure 2 is an image of an unsafe situation; a worker on foot is working in between two pieces of heavy equipment and is unseen by the machine operator. This situation could lead to an accident as described earlier.

Figure 2: Hazardous situation on work sites measured using 3D laser scan image.

CURRENT SAFETY PRACTICES

There are different methods of maintaining safety on work zones including the modification of behavior methods employed on the work zone, passive safety technology, and active safety technology. Passive technology does not use any sensing technology once installed, for example, helmets, goggles, or safety vests. Active technology uses sensing technology and works in two different ways; the first is with two or more sensors that transmit information to each other and the second is the use of cameras that identify objects through image processing. Within active safety technology there is a distinct difference between reactive and proactive safety technology; reactive technology collects data in real time that can then be analyzed to determine the best way to change future situations to make improvements and proactive technology works in real-time to alert personnel of the dangers occurring at that moment.

Pratt et al. (2001) discovered that the first method to improve safety on a work zone is by altering the behaviour of the individuals on the safety zone. All ground workers and operators should be trained on how to use their tools and equipment, and machine operators should be trained not only how to use their machine but also how to work around the construction site since they too move on foot throughout the site. Supervisors should monitor workers performing their tasks and operators checking their machines to ensure they are in optimum working condition. By mandating refresher courses or by giving incentives for taking refresher courses the contractors and owners can ensure that each worker is up to date on their training (Rental Product News, 2007). Furthermore, pre-work fitness, driving performance, and physiological factors should be monitored on all machine operators to ensure there is no driver impairment.

SAFETY TECHNOLOGIES

The aforementioned safety techniques have been unable to eliminate contact collisions on the work site, because accidents occur daily. Active safety technology comes in two forms: Reactive and proactive. Reactive safety technology may include the use of video cameras, where the cameras would allow supervisors and owners to assess project on a daily basis. Assessments may include features like the impact of the weather, accurate accident investigations, and asset tracking. This information can then be used as a way to improve the productivity of the work site, monitor the safety by noting any potential hazards, and note any breach of regulation by workers and sub-contractors (Abeid & Aditi, 2002). Cameras can also be used in a proactive method; by transmitting the feed-back to a hub and incorporating the data with a 2D algorithm, the tracker can choose a worker, material, or piece of equipment to track in 3D real-time. This method gives a clear picture of the object selected and allows the tracker to monitor any potential threatening situations that could endanger the work zone.

Laser scanning is also a reactive method to improving the safety of the worksite. A laser scanner collects a three-dimensional point cloud of objects in its field-of-view. An accurate 3D model of the entire worksite can be assessed in the same ways video cameras work. By taking digital images of project sites in real-time, all project coordinators are able to monitor the progress through a virtual environment. Owners can then locate tasks or areas that are unsafe and inform workers of the issue without entering the site. Laser scanning will be used in this research as a way of discovering the blind spots on different pieces of equipment (Jaselskis, et al., 2005).

Radio Frequency Identification (RFID) can be coordinated to be used as a proactive safety measure. Traditionally RFID has been used as a method of coordinating a site by “tagging” various materials, equipment, and personnel as a way of tracking all the moving parts of a construction zone. This method has allowed supervisors and owners to monitor the movement and analyze ways to improve the site by increasing efficiency, but is a reactive use of RFID. RFID transfers data in real time, and is capable to observe real-time movements. However, this technology is moving forward and is being implemented as a method of proactively preventing collisions. An antenna, which reads the RFID from various distances depending on the tag being used, can be mounted within a truck along with a small alarm. When the antenna reads the tag the alarm will be triggered, which will alert the machine operator that a worker on foot is nearby. This research focuses on the use of RFID technology in proactively alarming workers when equipment, ground personnel, and materials are in close proximity of each other.

The system employed in this research uses active RFID technology and is comprised of an in-cab device and a hand-held device. The in-cab device contains a single antenna, reader, and alarm; this part is called the Equipment Protection Unit (EPU). The hand-held device contains a chip, battery, and alarm; this part is called the Personal Protection Unit (PPU). The battery on the hand-held device potentially allows for the tag to intercept the frequency at approximately 30 meters. Once the tag intercepts the frequency the alarm in the hand-held device is triggered and the information on the chip is sent back to the reader. When the reader intercepts the information the alarm within the in-cab device is triggered and both worker and operator are sufficiently warned that they are in close proximity. This sending and receiving of information is instantaneous; the whole process occurs in real-time.

PREVIOUS STUDIES AND CURRENT APPLICATIONS

Similar studies have been done with RFID in both work site productivity and safety. The North-South Bypass Tunnel Project in Brisbane, Australia that is currently in progress and plans to be completed by 2010, implemented passive and active RFID tags for different purposes. The passive tags were used as entry key cards to access the facilities of the construction site. The active tags are being used to track employees throughout the 4.8 km tunneling project. RFID technology improved safety by monitoring the location of all workers and was able to locate and identify anyone who was injured or missing within the tunnel. Furthermore, the tags contain important technical information involving the specific skills of each laborer such that specific workers can be located quickly, if needed. The active tags were found to be very useful in the tracking of employees to improve safety and efficiency simultaneously, so much so they were soon implemented as asset tracking by tagging all equipment (Jaselskis et al., 2005).

NIOSH created a prototype called HASARD that uses a magnetic sensing system. Magnetic waves are emitted from a transmitter and whenever the magnetic wave is interfered with an alarm is triggered. The system is oriented in such a way that the transmitter is a magnetic loop that is coiled to condense the system and decrease the amount of power emitted yet still making it effective (Teizer, 2008). The prototype was tested for six months in a mine; a mine was chosen for the test because of the extremely harsh conditions (Teizer et al., 2007). The sensors were placed on people and walls to prevent collisions from a Continuous Miner (CM), a machine used to mine underground. The signal was found to penetrate through all coverings and could be calibrated to be used above ground as well.

Aker Yards, a shipping yard in Turku, Finland, has implemented RFID tags to monitor workers as they embark and disembark along the entry bridges to the various ships. This allows for fire and rescue to monitor in real-time the head count of all personnel on the boats in case of an emergency. Also, it allows for fire and rescue to quickly realize if someone has been on the boat for an exorbitant amount of time, in which they could be injured or trapped in some area of the ship. The tags were placed inside the helmets to prevent any contact of the tag with anything else; the tags also held important information about the worker including a picture to verify the person found was the right person in the helmet (Jaselskis et al. 2005).

Radio Frequency Identification Technology has been implemented into the health industry to track patients throughout the hospital and holds pertinent information about each patient to prevent misdiagnosis and improper care. Furthermore, it has been combined with asset management in tagging materials and equipment. RFID technology was chosen because it does not interfere with hospital equipment and machinery (Jaselskis et al, 2005; Teizer, 2008; Teizer et al., 2007a; Teizer & Kahlmann, 2008; Teizer et al. 2007b; Teizer, et al., 2005; Teizer, 2007; Teizer et al., 2006a; Teizer et al. 2006b; Teizer & Vela, 2008b).

RFID has also been seen in warehouses, mines, and train depots being used as a safety mechanism. In warehouses, forklifts pose a large threat to the safety of all workers due to blind spots and the small spaces in which they work; additional blind spots are created in such tight areas of operation. To warn workers on foot, warehouses have put RFID technology at corners that trigger alarms when a forklift is in proximity of the sensors. Furthermore, the forklifts can be tracked throughout the warehouse and monitored for any potential dangerous situations. The mining industry places readers on walls and tags the equipment within the mines to prevent operators from colliding into the wall.

RESEARCH OBJECTIVE AND METHODOLOGY

The primary purpose of this research is to increase work zone safety in heavy equipment operations by utilizing embedded radio frequency technology. Secondly, real-time pro-active warning devices also record information that once recorded can be analyzed to improve existing safety education and training programs. A major focus of this research is on sensing technology that will be deployed on ground personnel and equipment operators in order to detect and recognize hazardous situations, e.g., workers being too close to heavy equipment. In such an event of being too close, visual, acoustic, and vibration technology can be activated in the form of alarms. Several steps were undertaken to develop a test bed to design and validate several technologies that have the capability of issuing real-time pro-active alerts to ground workers and equipment operators. These steps include: (1) Identification of blind spots of heavy equipment; (2) Passive RFID alert device (SmartHAT) and active RFID alert devices (Teizer et al 2007c, Teizer et al. 2008, Walia & Teizer, 2008; Teizer & Vela, 2008; Sadeghpour & Teizer, 2009; Fullerton et al., 2009; Venugopal & Teizer, 2008; Teizer & Castro-Lacouture, 2007; RFID, 2008; Schiffbauer, 2001; Schiffbauer & Mowrey, 2001). Each of these technologies is explained further in detail.

Steps one and two pursue the idea of understanding the frequency and location when workers enter or are getting too close to heavy construction equipment. Steps three and four offer potential alert technology that activate once workers are located close or within a threshold safety radius of heavy construction equipment.

In the experimental validation phase of the alert technologies, first, blind spot measurements were taken for heavy equipment. The most common types of machines were selected for blind spot measurements including dump and articulated trucks, excavators, motor graders, rollers, wheel loaders, etc. Next, the trajectory of workers was recorded to understand the frequency of instances of being too close to heavy construction equipment. In a final step, the passive and active alert technology in optimal (laboratory) and field (job site) conditions were tested. The points at which the alarm is triggered yield the largest theoretical safety zone the system can create.

EXPERIMENTS

The following paragraphs detail the experimental procedure in two stages and present the results.

Blind Spot Measurements of Machinery

Figure 3: 3D geometry of different poses of roller spots.

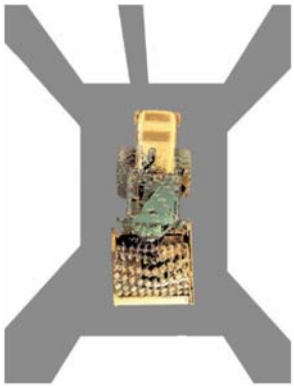

Figure 4: Schematic blind spots.

The blind spots of common construction equipment including, but not limited to, excavators, rollers, dozers, dump-trucks, and cranes, may be determined through the use of 3-D laser scanning. A complete 360-degree laser scan of each machine will be collected, and each completed scan will yield a virtual model, in which anyone can navigate around on a computer. These 3-D models will aid in determining all blind spots (direct and indirect) of the machinery in different types of scenarios and poses, including operator height differences. Direct line-of-site is what the operator can see in front of him/her without the use of cameras or mirrors. When direct line-of-site is blocked it is termed a direct blind spot. An indirect blind spot is an area of visibility that is obstructed even with the use of cameras or mirrors. Once these blind spots have been determined, the necessary safety zone can be established for each machine. The safety zone is the area in which an alarm sounds, alerting both the operator(s) and worker(s) that the safety zone is breached, and a collision is probable.

DESIGN OF PROXIMITY DETECTION AND WARNING DEVICE (FULLY PASSIVE UHF RFID WITH ACTUATION FOR SAFETY APPLICATIONS)

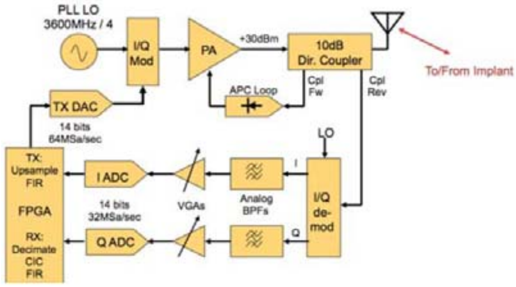

Figure 5: UHF backscatter modem circuit SmartHAT system.

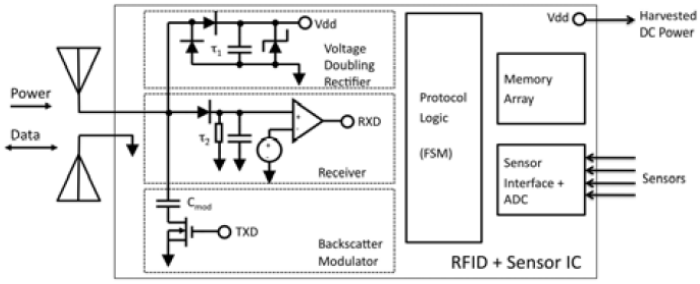

Figure 6: External RF transceiver (reader) for the developed for the SmartHAT system.

Fully passive, battery free long-range UHF RFID systems have recently been developed primarily for asset tracking and supply chain management applications. These systems have two components. The first is a tag, or transponder, which in the SmartHAT system is integrated with a worker's plastic hard hat. It contains a long range power harvesting and bidirectional communication circuit that does not require an on-board battery as it harvests its operating power from an incoming radio signal (see Figure 5). The second is a reader, which is a transceiver device, similar in principle to radar, which sends power by means of a radio frequency signal to the SmartHAT transponder. The reader device also transmits and receives control information to the SmartHAT transponder by observing the magnitude and phase of the reflected signal from the transponder- this signal vector yields the desired data transfer. The chief advantage of the fully passive SmartHAT transponder is that it is battery free. Safety warning effectiveness is not compromised by premature battery failure including failure over time or temperature extremes as may be observed in a construction scenario. Because there is no need to change the battery, the transponder can be fully plastic-encapsulated and thus resistant to environmental degradation or accidental damage.

The current SmartHAT transponder design is based on discrete component technology; to reduce the cost and manufacturing complexity of the SmartHAT device a single chip circuit is in development that will yield lower power consumption, and thus longer communication range, as well as a smaller, more rugged physical package.

DESIGN OF EXPERIMENTS FOR VALIDATION

Through the examination of safety needs on a construction site, which was determined from background information and blind spot measurements, a prototype for a safety device was devised. The following describes the technology that was manifested.

PRELIMINARY TESTING (STAGE 2)

Laboratory like conditions were created to initially test the prototype. The tests were done outside on clear days in open areas free of obstructions and without any outside interference. A commercial 1" Robotic Total Station (RTS) was used to take distance measurements. The RTS records the distance at which the wireless antenna reads the tag, and the reference frame established by the User allows for approximate angles/azimuths for each point recorded, with respect to the antennae "field of view." The RTS was placed in the center of the field along with the EPU, and a tester walked around with the Data Collector and PPU. The following steps were taken to test the technology:

1. Reference frame established on the RTS.
2. Tester starts about 35-40 ft away from reader and heavy construction equipment.
3. Tester walks toward the RFID reader holding the RFID tag in line-of-sight to reader, while also holding the prism rod for the RTS.
4. Tester stops when RFID Reader "reads" the tag.
5. Tester records the distance from tag to RFID reader.
6. Tester moves to the next angle until map is complete.

This process was followed to establish a base perimeter around the EPU, before any obstacles were put into place. The manner in which the EPU would be placed on the equipment and the PPU would be placed on the worker was also determined for use in stage 2.

PRELIMINARY TESTING (STAGE 3)

The system was then tested in field like conditions; harsh construction settings with equipment and obstacles were used to mimic the day-to-day setting in which the device was intended to be used. Machinery was kept stationary but was set in close proximity of materials, other equipment, and lab personnel acting as workers. The EPU was set inside the cab of the equipment and the PPU was placed on a person. The technique used to take measurements of the alarm sounding was the same technique used in Stage 1, except the checkpoints were at about every 30 degrees instead of 20 degrees. The proximity warning device was tested on a forklift, excavator and dozer. The reader was placed inside the cab of the machine. Figure 7 displays the results obtained by an active RFID experiment. The grey area is the unsafe zone, the general blind spots area – the area in which the alarm must sound. Outside that area the worker is in the safe zone. The orange lines represent the points where the proximity alarm sounded. The worker never entered into the unsafe zone. The dozer and excavator were in close proximity of each other and a worker was standing between them as seen in Figure 2.

FIELD TRIALS (STAGE 4)

The next step is to implement the system into a long-term field trial. The prototype will be integrated into the safety measures on a construction site of a project. A long-term case study will demonstrate the defaults of the prototype in dealing with the rigors of a construction site, the ability for it to stand up to various weather conditions, different tasks such as excavations and multiple story projects, and different obstacles that have the ability to obstruct or diminish the signal will be shown. Then the impact of safety will be measured by calculating the number of "near-misses" that occur through the use of the proximity detection system.

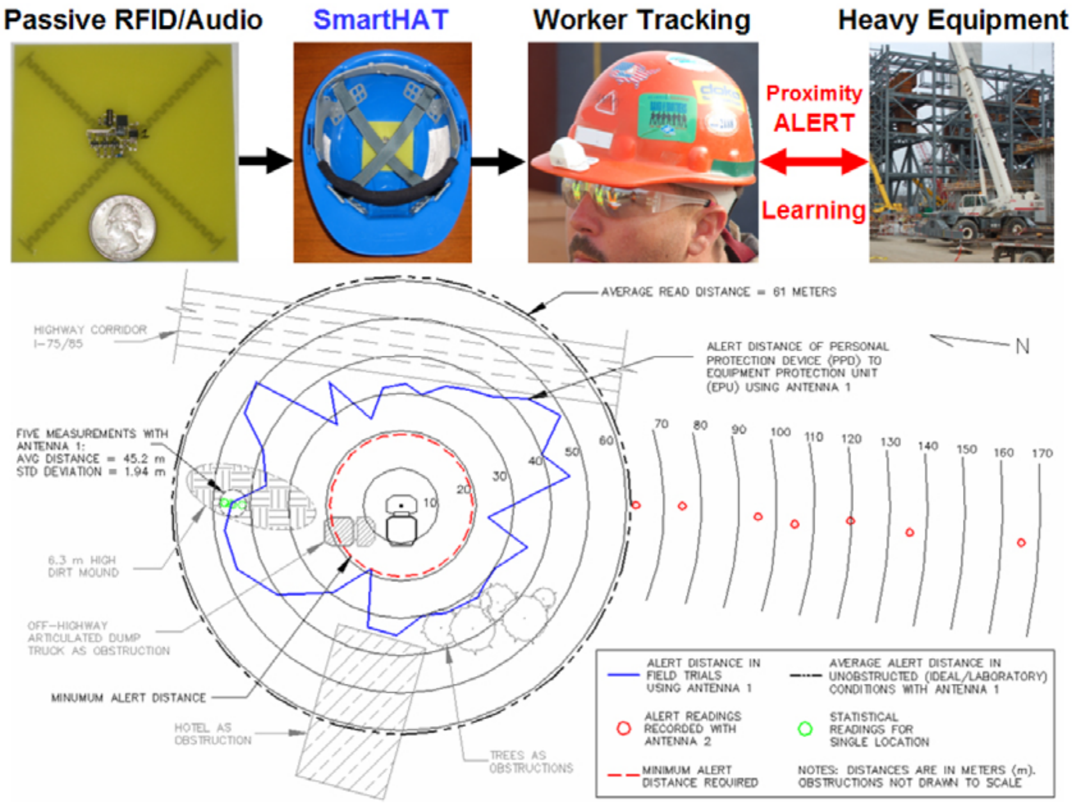

Figure 7: Proximity of ground personnel to heavy construction equipment when safety alert activates

FURTHER EVALUATION

Once testing of the sensors is completed the technology will be assessed. Interviews will be conducted with the workforce to establish what kind of safety the workers feel is needed on the construction site. The interviews will hopefully discover what kind of intervention the workers are willing to have, how much monitoring and watching they do not mind having, and what they think of the proposed technology. The interviews will determine if workers think pro-active-real-time-warning-system will make a difference, and if they think the PPU is a comfortable, good style of protection device. Also, the impact of the device on safety will be evaluated along with a cost-benefit analysis. Limitations could be the form factor of the technology (size, weight, and mounting position), general worker objections to wear a device, and others. Initial field trials with the technology indicate: Since proximity alert devices do not reveal the location of a worker, rather give an alarm, workers (so far) do not mind wearing the device. Changes to where the devise is mounted (on or inside a helmet or on an arm?) and what form it has, however, are necessary before any product is commercialized.

CONCLUSIONS

From the preliminary results and background review the proposed alert technology has proven to have the possibility of being effective in aiding the safety needs in the construction environment. The SmartHAT and other alert devices can detect the presence of workers being close to heavy construction equipment such as excavators and dozers. Based on signal strength the passive and active RFID alert devices have the potential to simultaneously activate and warn ground workers and equipment operators from being too close to each other. In various environments, auditory, visual, and vibration alarms have been tested loud and strong enough. The technology further has the capability to record previously unrecorded data of close-calls aka. near-misses. Further research is necessary to improve signal noise and loss ratio for the passive RFID alert device (SmartHAT), and extensive field trials are to be conducted over longer time intervals to analyze SmartHAT as well as other real-time pro-active alert technology. Data can then be recorded, analyzed, and used to improve positioning of workers and equipment and assist in the development of new safety concepts, such as advanced safety education and training courses that include visualization technology.

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INVESTIGATING THE POTENTIAL RELATIONSHIPS BETWEEN PROJECT MANAGER SKILLS AND PROJECT SAFETY PERFORMANCE

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ABSTRACT
Past research on construction project safety has mainly been focused on safety risks, safety culture, and safety system development. This research aims to reveal project manager skills that could influence project safety performance. It is proposed that project managers need to have four essential skills, namely conceptual, human, political, and technical skill. Through a comprehensive review of relevant literatures, this research argues that project manager skills influence project manager's safety leadership, which ultimately influence project safety performance. A theoretical framework has been developed and future research will focus on collecting empirical data to test these relationships.

Keywords: Construction project safety, Project manager, Conceptual skill, Human skill, Political skill, Technical skill, Project management

INTRODUCTION

In the past, construction projects were considered successful when they achieved three fundamental objectives namely completed on time, accomplished within the budget, and meeting the quality requirements. Nowadays, these fundamental objectives have evolved to include two other objectives, namely safety and sustainability (Khalfan, 2006; Lester, 2007).This research focuses on project safety performance because construction industry has been known to kill and injure more of its workers annually than almost any other industry (Lingard and Rowlinson, 2005). Data for Australia in 2006/2007 showed that construction industry fatality rate was three times higher than the average industry rate (ASCC, 2008). This number suggests that safety is very essential in construction projects due to its potential to bring miseries and deaths to fellow human beings. Furthermore, safety has become a factor that is required by law, thus under no circumstances can safety be compromised (Lester, 2007; NSW Government, 2009).

Achieving project safety performance is one of key performance indicators that determines project success. Project safety performance can be defined as incident and injury free (IIF) during the construction process. In another case, it reflects a strong safety culture fostered among the project team and other project stakeholders who uphold shared value and belief that all incidents and injuries are preventable (Zou et al., 2006). One of the responsibilities of the project manager, as the key person who is responsible for the success or failure of every aspect in the construction projects, is to ensure that the required project safety performance is met during construction (Heerkens, 2002).

Adequate knowledge and skills are crucial for project managers to carry out their tasks. It is well known that there are three essential skills for managers, namely conceptual, human, and technical skill (Robbins et al., 2009). In the field of project management, El-Sabaa (2001) and Goodwin (1993) supported the importance of these skills for project managers. In addition, this research argues that political skill is also essential for project managers, although its importance has seemed to be overlooked. Pinto (2000) stated that political processes dominate the field of project management due to its nature, thus political skill is critical for project managers.

Many studies have been conducted to explore about safety in construction projects, such as construction safety risks (Zou et al., 2007), safety culture and safety climate (Cox and Cheyne, 1999; Glendon and Litherland, 2001; Seo et al., 2004), and safety management (Abudayyeh et al., 2006). However, there is lack of research that explores the influence of project manager skills towards project safety performance, thus this research intends to fill in this gap. By conducting a comprehensive literature review, this research aims to identify project manager's tasks in relation to project safety performance and reveal project manager skills that could allow the project manager to fulfil these tasks, thus influence project safety performance. A theoretical framework was developed to demonstrate the complexity of project manager's tasks and the skills required to perform those tasks. The research proposes that project manager skills influence project manager's safety leadership, which ultimately will influence project safety performance. The next stage of the research is to collect empirical data to test these relationships.

PROJECT SAFETY PERFORMANCE

Safety is always a critical factor in construction projects because lack of safety can result in accidents, which may lead to human suffering and deaths. This is a condition that cannot be justified by any means. Holt (2005) stated that accidents can incur additional costs and cause project delay, which will put unnecessary burdens to project budget and ruin target completion date. One should also consider that lack of safety can lead to prosecution and civil claim that will incur more costs and cause adverse publicity. Furthermore, Holt (2005) explained that there are two factors that can directly cause accidents, namely unsafe acts and unsafe conditions. These two factors can be flourished when there are poor safety management system and social pressure that does not consider safety as an important issue.

Safety culture and safety climate are terms mentioned frequently when people are discussing about safety. Safety culture is a part of organisational culture and it can be defined as the shared values or beliefs that characterise safety in organisations (Seo et al., 2004). On the other hand, safety climate is the way people behave, think, and feel about safety issues. The difference between the two is that safety culture exists at a higher level, related to overall organisational policies and goals. On the contrary, safety climate exists at a more localised level and serves as the tangible outputs of organisation's safety culture. Safety climate indicates how people perceive and describe the importance of safety issues for the organisation and how local arrangements are implemented to reflect this (Cox and Cheyne, 1999; Seo et al., 2004).

Many studies have agreed upon the importance of safety climate to measure safety performance, thus safety climate is used in this research as the indicator of project safety performance (Glendon and Litherland, 2001; Seo et al., 2004). The advantages of measuring safety climate are: it can identify safety problems before they develop into accidents and injuries, it can focus on safety efforts to improve problematic areas which may improve other organisational functions, it serves as a valuable tool to identify trends in the organisation's safety performance, and lastly measuring safety climate does not spend much money and time (Seo et al., 2004).

Project manager is the highest position in the project level, thus it is project manager's responsibility to manage the overall performance of the project, which includes safety. Fewings (2005) supported this by saying that in a construction project, the project manager is responsible for the implementation of company's safety policy and the coordination of project safety plan. Furthermore, project managers are project leaders, thus they should be able to create and change project climate. By giving special attention to safety, project managers can become leaders to improve project safety performance (Office of the Federal Safety Commissioner, 2007). Dingsdag et al. (2006) provided a list of safety management tasks that project managers need to perform to provide safety leadership. There are 27 tasks separated into six categories as shown in Table 1.

Based on the discussion above, Figure 1 presents the deduction of this research on how project managers can influence project safety performance. The senior management of the company provides supports by creating and communicating company's safety culture throughout the organisation. This safety culture is translated into a safety management system for its implementation in the organisation and projects. As a leader, the role of the project manager is to provide safety leadership by performing their safety management tasks. This safety leadership leads to positive project safety climate, which will promote the elimination of unsafe acts and conditions as well as accidents.

Category	Safety management tasks
Proactively identify, assess, and determine appropriate controls for safety risks	Carry out project risk assessments.
	Consider and perform safety reviews for constructability, operability, and maintenance.
	Undertake formal safety review of tenders.
	Develop project safety management plans.
	Develop project safety procedures and instructions.
	Carry out workplace and task hazard identification, assessments, and control (Safe Work Method Statement).
Effectively communicate and consult with stakeholders regarding safety risks	Provide general safety information and provide basic safety instruction.
	Facilitate group safety discussions and meetings.
	Contribute in planning and delivering toolbox talks.
	Participate in site safety committee.
	Consult on and resolve safety issues.
	Speak to senior management about safety issues in the workplace.
	Challenge unsafe behaviours/attitude at any level when encountered.
	Make site visits and speak directly to workers about safety in the workplace.
	Recognise and reward people who have positively impacted on safety.
Monitor, report, review, and evaluate safety program effectiveness	Carry out formal incident investigations.
	Carry out basic project safety system element audits.
	Carry out formal inspections of workplace and work tasks.
Engage with subcontractors in safety performance management	Monitor subcontractor safety activities and performance.
	Identify and include suitable safety requirements into subcontractor packages.
	Evaluate safety performance of subcontractors.
Identify and implement relevant components of the safety and workers' compensation management system	Understand and apply general legislative safety requirements.
	Apply full working knowledge of the organisation's safety management system.
Provide leadership and manage staff and subcontractor safety performance	Help to mentor staffs and follow their progress in relation to safety.
	Conduct employee safety performance appraisals.
	Work with staffs to solve safety problems.
	Discipline staffs for poor safety behaviours and attitude.

Table 1: Project manager's safety management tasks (Source: adapted from Dingsdag et al., 2006).

PROJECT MANAGER SKILLS – CHPT CONSTRUCT

Project managers are facing varied and complex tasks on daily basis. They are the key persons who are responsible for the success or failure of every aspect in the construction projects (Heerkens, 2002). Furthermore, construction projects require a collaboration of individuals from different backgrounds and teamwork to achieve project objectives. Consequently, project managers also need to manage and lead these people (Lewis, 2003). Adequate skills are vital for project managers to manage these multifaceted tasks. Table 1 demonstrates the multiple tasks that project managers must implement to achieve safety performance. This research argues that project managers need four skills, namely conceptual (C), human (H), political (P), and technical (T) skill to perform their job. These skill sets will be discussed in details in the following sections.

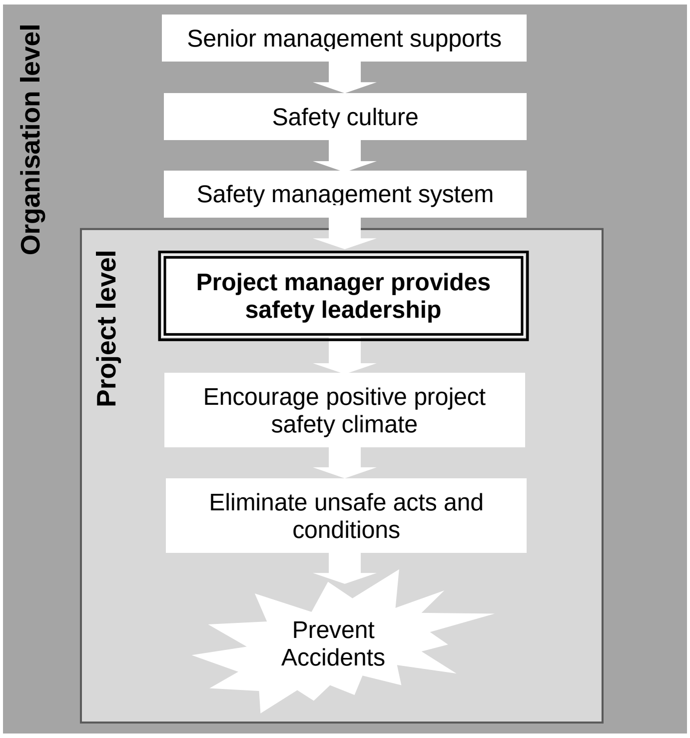

Figure 1: Project Manager's role in project safety performance.

Conceptual skill

Conceptual skill is the ability to envision the project as a whole. The skill recognises that various functions in the project depend on one another where changes in one part could affect other parts (El-Sabaa, 2001). Project managers need conceptual skill to think about abstract situations, to see the project in a big picture, to understand the relationships between different departments, and to imagine how the project fits into its broader environment (Robbins et al., 2009).

This research has found three competencies that form conceptual skill construct. The first competency is *integration*, which includes all processes required to ensure that all project components are properly coordinated. The second competency is *scoping*, which limits and controls the works included in the project. Scoping is critical to ensure that all the works of the project is included (Project Management Institute, 2008). The last competency is *visioning*, which is simply the competency to observe the project as a whole and visualise the relationship of the project with the company, the construction industry and the community. This competency is particularly important to address abstract and external issues as well as constraints that could jeopardise the completion of the project (Goodwin, 1993).

In relation to safety, the research argues that conceptual skill is essential for project managers to realise the impacts and necessities of good safety practices on the workers and their family, the company, the community, and the achievement of project objectives. It helps project managers to understand that safety is really an important and integral part of their project. Furthermore, conceptual skill allows the project managers to address safety issues from a life-cycle perspective rather than limiting it only during the construction stage. For example, they could influence the designer to consider the implication of the design on safety during the construction and management of the building facility.

Human skill

Human skill is the ability to work with and through other people (Goodwin, 1993). There are many stakeholders involved in a construction project, such as the client, consultants, subcontractors, upper management, team members, and community. A stakeholder is a person or organisation that has an interest in the project or the outcome of the project. In this case, a stakeholder may affect or be affected by project processes or outcomes. Each stakeholder has different expectations and project managers need to manage these expectations (Rosenau, Jr. and Githens, 2005). Managing stakeholders' expectations requires sufficient human skill on the part of the project managers. Furthermore, during the construction process, it is people who perform the works, thus an understanding of human skill to manage these people is vital. This research argues that there are three competencies, namely leadership, emotional intelligence, and interpersonal skill that form human skill construct.

The first competency, *leadership*, is the process of influencing a group of people to achieve goals. Leadership is important because leaders in organisations are people who make things happen (Robbins et al., 2009). Leadership is vital for project managers to bring different stakeholders together and influence them to do what must be done to achieve project objectives (Lewis, 2003). Many studies indicated that transformational leadership is an effective leadership style because it produces levels of employees' effort and performance that goes beyond what would occur with the common transactional approach (Robbins et al., 2009).

Emotional intelligence (EI) is the second competency of human skill construct and it is defined as "the capacity for recognising our own feelings and those of others, for motivating ourselves, and for managing emotions well in ourselves and in our relationships" (Goleman, 1998: pp. 375). Many studies have showed the importance of EI in organisations (Sunindijo et al., 2007). Goleman (2001) identified four dimensions of EI: self-awareness, self-management, social-awareness, and relationship management. Self-awareness means to recognise oneself feeling at the moment and use it in decision making. Self-management is the ability to regulate distressing effects, such as anxiety and anger, and to restrain emotional impulsivity. People high in social-awareness can recognise other people's feelings and read nonverbal cues for emotional currents from others. Lastly, relationship management is the ability to attune oneself to or influence the emotions of others.

The last competency is *interpersonal skill*. Some people in organisations suffer from relationship issues when they relate with their peers, subordinates, and even superiors because they have lack of interpersonal skill. Strohmeier (1992) identified four common interpersonal problems that need to be managed by project managers. The first problem is motivation because typically project managers have lack of formal authority and influence, which can cause difficulties to motivate others. The second problem is conflicts, which are normal occurrences in every organisation. There are many stakeholders in a construction project, thus the potential of conflicts is much higher. Communication is the third interpersonal problem. Due to the involvement of many stakeholders, communication problems, such as insufficient flow of information, the unavailability of information, and misunderstanding, are frequent in construction projects. The fourth and the last problem is teamwork and cooperation. Many project stakeholders are suffered from egotism, which frustrates cooperation and communication. Within a project team, frequently there is lack of willingness to cooperate as well as an inability to cooperate.

This research argues that human skill is required to influence project safety performance because people are the ones who perform the works, thus project managers need human skill to communicate the importance of safety, lead the implementation of safety management system, and motivate and inspire people to work safely. Furthermore, project managers need human skill to manage stakeholders' expectations related with safety.

Political skill

Ahearn et al. (2004: pp. 311) proposed that political skill is "the ability to effectively understand others at work, and to use such knowledge to influence others to act in ways that enhance one's personal and/or organisational objectives". It also includes the ability of performing sensible environmental scanning to understand the complex social, legal, culture, economical, and political systems that affect the achievement of project objectives. Block (1983: pp. 21) defined project politics as "the actions and interactions between project team members and people outside the team that have impact on the success of the project". In this case, project managers are the focal point of this interaction and political skill is particularly crucial for project managers to interact with people outside their direct control, but who have impact on project success. Some people deem that the conduct of politics is distasteful and organisationally damaging. However, several studies indicated that the effective use of political skill is important for project managers because projects are inherently political arenas where competing interests, limited resources, coalition building, and the exercise of power and influence happen all the time to get things done (Ferris et al., 2000; Pinto, 2000).

The main difference between political skill and human skill is that political skill is specific to interaction aimed to achieve success in organisations (or projects). The interactions can take place anywhere, but the main goal is the organisational influence and success (Ferris et al., 2000). Ferris et al. (2005) proposed four key competencies or dimensions of the political skill. *Social astuteness* is the first competency. It is argued that people with high political skill are astute observers of others and they are keenly attuned to diverse social situations. They are sensitive to others, thus they are considered as ingenious and clever in dealing with others. The second competency is *interpersonal influence*. Another characteristic of people high in political skill is their convincing personal style that exerts a strong influence to people around them. They are flexible and they can appropriately adapt their behaviour to each situation in order to extract certain responses from others.

Another important competency of political skill is the ability to develop and use diverse networks of people or *networking ability*. People included in the networks are considered to hold assets deemed as valuable and necessary for attaining successful personal and organisational functioning. People with high networking ability are often expert negotiators, deal makers, and at ease with conflict management. The fourth and the last political skill competency is *apparent sincerity*. This competency is the key to influence others because it focuses on the perceived intentions of certain behaviour exhibitions. In this case, the influence attempts will be successful when there are no ulterior motives behind the behaviour exhibited. People high in apparent sincerity inspire trust and confidence because they do not appear to be manipulative or coercive.

In some cases, safety is relegated below other project objectives like time and cost. The research argues that by exercising political skill, project managers is able to demonstrate genuine interest towards safety, which will influence others to realise about the importance of safety in the project, thus convince them to put safety as a priority. Furthermore, political skill is a clever way to achieve behaviour coordination and eliminate many barriers that might disrupt safety performance. It inspires trust, confidence, and support. It also orchestrates and facilitates the interaction among team members that can boost safety performance (Ferris et al., 2007).

Technical skill

Technical skill is the job-specific knowledge and techniques that are required to perform specific tasks proficiently (Robbins et al., 2009). Based on various literatures, there are six technical competencies that are essential for project managers (Fisk, 1997; Pritchard, 2001; Project Management Institute, 2008; Westney, 2001). The first competency is *scheduling*, which involves an understanding to determine the dates when different activities will be performed, recognise activities that drive other activities, and determine when the activities are due. *Budgeting and cost management* is the second competency, which involves determining the types and quantities of resources needed to perform various project activities, developing cost estimation for all resources, allocating the budget to individual work activities, and controlling changes to project budget.

Quality management is the third competency of technical skill construct. The activities of quality management include identifying relevant quality standards and determining how to meet them, evaluating project performance periodically to provide confidence that the project will meet the standards, and monitoring specific results to determine their compliance with the standards as well as finding ways to eliminate unsatisfactory performance. The fourth competency is *document and contract administration*, which is about the understanding of procedures for implementing construction contracts according to the accepted practices and regulations within the construction industry. In addition, the system for keeping records and reports of everyday activities should be managed carefully.

Risk management is the fifth competency of technical skill construct. To be competitive, an organisation must be proactive in managing the risks to ensure successful achievement of project objectives. There are four steps in risk management: risk identification where project team and stakeholders identify and categorise risks, risk assessment to assess the impact of each risk category to the project, risk analysis which indicates which cost or schedule elements require the most contingency and which risk categories contributed the most to contingency, and lastly developing risk mitigation steps and assign them to team members. *Procurement management* is the sixth and the last competency. It includes the processes required to attain goods and services from outside the organisation or from external parties. Depending on the application area, these external parties can be consultants, subcontractors, vendors, or suppliers.

In relation to safety, the research argues that project managers need to exercise their technical skill to ensure all site activities are implemented in proper and safe manner. For example, project managers needs to use their risk management competency to identify, assess, and manage safety risks. Furthermore, technical skill can assist project managers to develop new and safer methods to work. Understanding of cost management and scheduling also make project managers realise the severe impacts of accidents towards their project.

PROPOSED THEORETICAL FRAMEWORK

Based on the discussion in the previous sections, this research has developed a theoretical framework as shown in Figure 2 to show the whole picture of the relationships between project manager skills and their tasks. There are five common project stages before the project is completed and handed over to the client. They are initiation, design, procurement, construction, and commissioning. The final outcome of these stages is a project that meets required standards and specifications of time, cost, quality, safety, and sustainability, which have been increasingly considered as fundamental objectives of construction projects.

The framework also presents different project stakeholders that can influence the outcomes of the project, thus the expectations of these stakeholders need to be managed. In the organisation level, there are top management, bosses, team members, and people from other departments. In addition, the project manager needs to pay attention on the company culture as well as the system and technology used in the organisation. In the construction task environment, the project manager has to consider external project team members like consultants, designers, subcontractors, and the client. Other project stakeholders in the construction task environment are government with their laws and regulations, the community that lives around the project, and public. Lastly, the project manager should also be concerned about external environment, such as economic, political, sociocultural, technology, global condition, and the demographic where the project is built (Robbins et al., 2009). All of these stakeholders and external factors can influence the outcomes of the project, which include project safety performance. Without proper consideration and management, they can easily jeopardise the project. It is part of project manager’s responsibilities to manage these issues.

The framework also shows project manager skills required to perform these tasks. This research proposes conceptual, human, political, and technical skill (CHPT construct) as the essential project manager skills. Competencies that form each skill construct have also been discussed in the previous sections and included in the framework.

When focusing on project safety performance, it has been mentioned that project managers should provide safety leadership in their project. Project managers need to perform 27 safety management tasks listed in Table 1 to provide this safety leadership. By performing these tasks, it is expected that project managers can create positive project safety climate, which serves as they key indicator of project safety performance. Furthermore, this research argues that project manager skills are essential to perform these safety management tasks successfully. Figure 3 shows the relationships between these three aspects. Project manager skills serve as the input and they influence the performance of project manager’s safety leadership, which is expressed in the form of safety management tasks. Ultimately, safety management tasks that have been performed successfully will lead to the achievement of project safety performance, which is measure by project safety climate. This is the key contribution of this research and the next stage aims to collect empirical data, investigate the validity of the framework and determine, if any, the relationships between the three aspects.

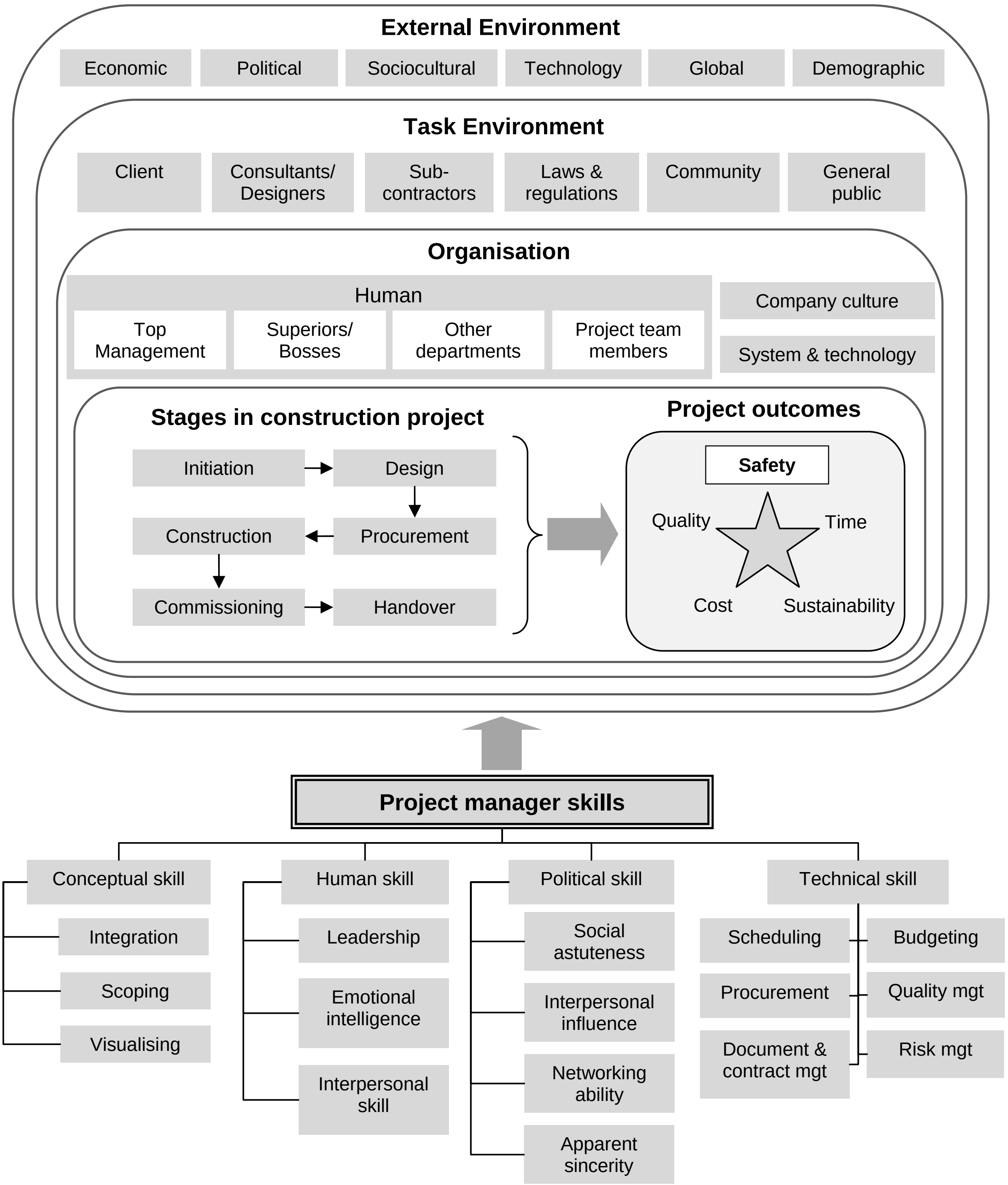

Figure 2: A theoretical framework demonstrating the complexity of project manager's tasks, project manager skills required to perform the tasks, and project outcomes.

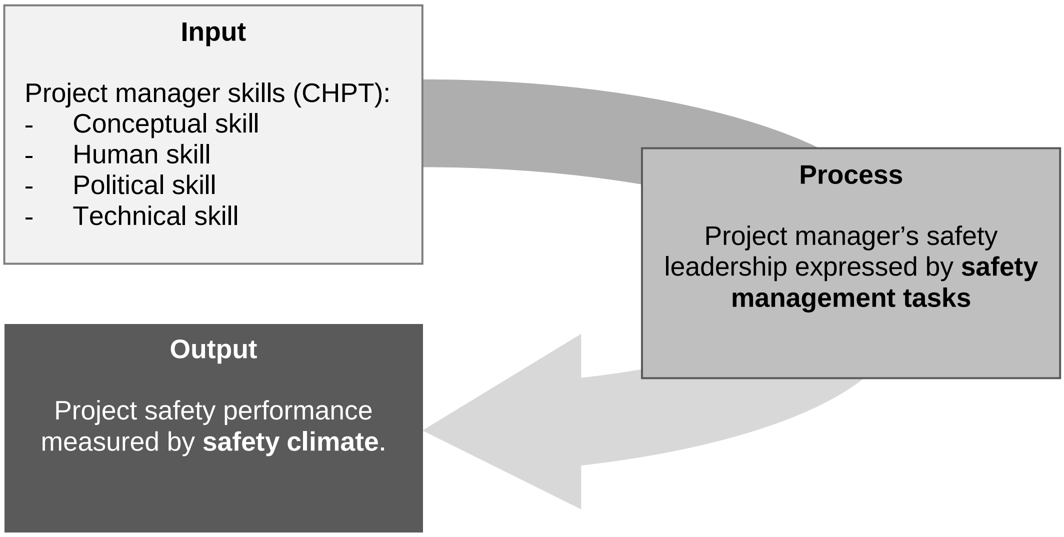

Figure 3: Proposed relationships between project manager skills, safety leadership, and project safety performance.

CONCLUSION AND FUTURE STUDIES

The role of the project manager in project safety performance is to provide safety leadership, which is expressed by performing 27 safety management tasks. In order to manage these tasks, project managers need to acquire four sets of skills, namely conceptual, human, political, and technical skill (CHPT construct). This research has explored each skill in detail and proposed competencies that form each skill construct. It is argued that project manager skills influence project manager's safety leadership, which ultimately will influence project safety performance. The next stage of the research will collect empirical data to investigate the validity of these proposed relationships.

A theoretical framework has also been developed to demonstrate the complexity of project manager's tasks and essential skills to manage those tasks. The framework offers a wide range of possibilities for future studies. For example, each skill and each competency could be explored individually to investigate its impacts towards project safety performance or any other project outcome. Furthermore, there are also potential future studies to find out the most important skill that influences certain project outcome. This way, the construction industry can strategise when providing trainings for project managers to improve their performance.

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CURRENT U.S. DRUG TESTING PRACTICES

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ABSTRACT

A safe construction project requires all workers to be alert at all times. Workers must be able to recognize hazards and understand the appropriate measures to be taken to avoid injury. One practice that has been implemented by many U.S. construction firms to ensure all workers are alert is drug testing. In the U.S., the first construction firms to implement drug testing of their employees started the practice in the mid-1980s. Since then, the practice of drug testing has become more sophisticated and more widely adopted in the industry. A research study was conducted to investigate the current drug testing practices as implemented in the U.S. construction industry. The findings revealed that the basic practices of drug testing have remained relatively consistent for the past 15 years. A few modifications to the traditional testing procedures have been implemented by many firms. While urine analysis continues to be the most popular type of drug test, firms are beginning to explore and/or use such other techniques as breathalizer tests, hair analysis, blood tests, and saliva testing to detect drugs, with very few being interested in exploring the viability of sweat tests. When urine analysis is performed, many firms also measure the temperature of the specimen and they will also test the specimen for adulterants to identify potential attempts at cheating on these tests. The study results showed that the drugs most commonly abused by construction workers continue to be marijuana and cocaine, but the extent of this drug use has declined in recent years.

Key words: Drug abuse in construction, Drug testing practices, Types of drug testing, Adulterants

INTRODUCTION

Since the mid 1980s drug testing has been an effective method for decreasing the rate of substance abuse in the workplace. The benefits of creating a drug-free workplace include: better safety performance (such as lower injury rates), fewer absences, decreased rate of workers' compensation claims, increased productivity and increased profitability. On the other hand, drug abuse increases company expenses and creates a risk of increased injuries for all employees. If an employee has the positive test results, the employer either terminates the employment or may request the rehabilitation.

Of all industry sectors, the construction industry has the highest proportion of fatal occupational injuries and one of the highest rates of substance abuse. However, the construction industry has the lowest rate of implementing drug testing.

This study was conducted to investigate the current drug testing practices as implemented in the U.S. construction industry. The objectives of this study were to determine the following:

1. The extent of the implementation of drug testing programs.
2. The drug testing practices implemented: pre-employment, random, post-accident, etc.
3. The testing methods used: urine, hair, saliva, and sweat analysis.
4. The most frequently abused substances.
5. The frequency of “cheating” on drug tests and types of adulterants used.

LITERATURE REVIEW

Approximately 9.0% adults in the U.S. had some type of substance abuse in the past year. A majority of these American adults reported illegal drug use (90%) and heavy drinking (75%) in the past month. Seventy-five percent of the current illegal drug users were employed (SAMSHA 2008).

Construction is one of the industries with the highest rate of substance abuse, even though the rates of the substance abuse have decreased over time (Korman 1996, Pollack et al. 1998, Minchin et al. 2006). In 1988, 20% of construction workers had heavy alcohol use and 23% abused illicit drugs (NIDA 1990). In the period 2002-2004, 13.7% of the construction workers had used drugs in the past month and 15.9% had heavy alcohol use in the past month (Larson et al. 2007). Pollack et al. (1998) investigated the injury rates among construction labourers with substance abuse diagnosis. Findings showed that 5.3% of the workers had a diagnosis of substance abuse. Approximately 84% of these workers were dependant on alcohol while 5.3% had drug dependence. The workers that had substance abuse had a 93% higher risk of serious injury compared to workers without substance abuse diagnosis (Pollack et al. 1998). In 1997, the construction industry ranked the lowest among the industries that conducted drug testing (SAMSHA 1999). However, construction firms that do implement drug testing have lower incident rates (Altayeb 1992).

The most common drug testing practices in the workplace include pre-employment, random and post-accident testing. Pre-employment testing is required for all new hires. A prospective employee will not be considered for a job if the test is positive. Post-accident testing is administered immediately after an accident to determine if drug abuse was an underlying reason for an accident. Random testing is typically administered on a monthly basis with employees that are randomly selected for drug testing (Maloney 1988, Rhodes 1998, Altayeb 1992, Kerns and Stopperan 2000, SAMSHA 2005, Minchin et al. 2006, Hinze 2006, Bush 2008). Approximately 26% of the construction workers stated that their employers conducted pre-employment testing, 27% reported post-accident testing, while 26 % reported random testing (SAMSHA 1999). Ten years later, nearly 35% of the construction workers reported that their employers conducted pre-employment drug testing. Pre-employment testing is more common among the large companies. Over 70% of the employees who worked for the larger companies (more than 500 employees) reported pre-employment drug testing vs. 19 % of the employees who worked for a small company (fewer than 10 employees) (Larson et al. 2007).

The most common methods for drug testing in the workplace include analysis of urine, hair, and saliva (Moeller et al. 2008). The most prevalent method has been lab-based urine analysis (Callaghan and Tydings 1998, Kerns and Stopperan 2000, Reynolds, 2001, Lappe 2002, Moeller et al. 2008). Despite this popularity, urine analysis has the following disadvantages: 1) Its detection window is only 2-3 days so it cannot detect long-term drug use (Kintz 1996, Caplan and Goldberger 2001, Kintz and Samyn 2002, Bush 2008), 2) it is time consuming (Lappe 2002) and expensive (Reynolds 2001), and 3) urine samples can be adulterated (Kintz 1996, Cholakis and Bruce 2007, Reynolds 2001, Caplan and Goldberger 2001).

Hair testing has several advantages when compared to urine analysis. It has longer detection window (Hoffman 1997, Kerns and Stopperan 2000, Caplan and Goldberger 2001, Lappe 2002, Laws 2004, Kintz et al. 2006, Bush 2008) and provides the distinction between chronic and single drug use (Kintz 1996, Kintz and Samyn 2002). Specimen collection is noninvasive, easy to perform, less embarrassing and less susceptible to adulteration (Kintz 1996, Kintz et al. 2006). Hair testing can complement urine testing because of the different detection windows (Kintz 1996, Kintz and Samyn 2002, Kintz et al. 2006, Bush 2008). Since hair testing does not provide information about recent drug use, it should not be used for post-accident testing (Hoffman 1997, Kerns and Stopperan 2000).

Saliva testing has the following advantages when compared to urine analysis. It is more convenient and does not compromise accuracy and reliability. Specimen collection is noninvasive, user-friendly, less embarrassing, and can be performed at anytime and anyplace. Saliva testing is affordable, and less susceptible to adulteration (Wilson and Kunsman 1997, Kunsman, 2000, Reynolds 2001). The detection window ranges from few minutes to 2-3 days (Caplan and Goldberger 2001, Lappe 2002, Bush 2008), thus saliva testing is an appropriate method for post-accident testing (Reynolds 2001, Cholakis and Bruce 2007, Bush 2008).

Sweat testing is not frequently used in the workplace (Caplan and Goldberger 2001, Laws 2004). Its detection window ranges from days to weeks but it cannot detect the prior exposure. Sweat testing can be a used as complement to urine analysis since it provides a cumulative measure of drug use and (Kintz 1996, Bush 2008). Specimen collection is noninvasive.

Adulterating samples is a common practice to beat drug tests (Moeller et al. 2008, Jaffee 2007). Market offers over 400 products used to adulterate specimens (Bush 2008). These products include: 1) dilution products, cleansing products, adulteration additives and substitute urine products to adulterate urine samples (Jaffee 2007, Cholakis and Bruce 2007, Moeller et al. 2008, Bush 2008, Dasgupta 2008), 2) shampoos and spritzes to adulterate hair specimens, 3) mouthwashes and cleaners to adulterate saliva specimens (Dasgupta 2008, Bush 2008), and 4) whole body cleaners to adulterate blood specimens (Bush 2008). The validity tests on collected specimens must be performed to prevent adulteration of the specimens (Jaffee 2007, Bush 2008).

A company with the employee drug abuse record faces higher insurance premiums (Altayeb 1992, Gillian 2002, Minchin et al. 2006). Implementation of drug testing programs decreases drug abuse in the workplace and as a result decreases claims (Cholakis and Bruce 2007). The lower the rate of accidents (Gillian 2002) and employee absences, the lower workers' compensation insurance premiums (Callaghan and Tydings 1998, Gerber and Yacoubian 2001). For example, a construction company reported having 50% lower insurance premiums after drug testing was implemented (Minchin et al. 2006). Also, in many states insurance companies have to provide workers' compensation insurance premium discounts for companies that implement drug testing (Wilson and Kunsman 1997, Callaghan and Tydings 1998, Gerber and Yacoubian 2001, ENR 2002, Minchin et al. 2006).

RESEARCH METHODOLOGY

A survey questionnaire was used to investigate the current drug testing practices in the U.S. construction industry. The survey was developed in collaboration with several construction contractors and the Construction Industry Institute (CII) Safety Community of Practice. The survey was distributed either by: 1) the email (the companies were contacted by phone, asked to participate in the survey and then emailed the survey) or 2) standard U.S. mail (to the companies listed in the Blue Book of Building Construction).
The survey instrument requested the following information:

- Demographics (annual volume, number of field workers)
- Drug testing practices (pre-employment, random, post-accident)
- Testing methods (hair, saliva, sweat)
- Substances abused
- Workers' compensation
- Use of adulterants
- Consequences of positive tests
- OSHA recordable injury rate (RIR)

Sixty-three responses to the survey were received. The data were analyzed with the Statistical Package for the Social Sciences (SPSS), version 16.

RESULTS

There were 63 responses to the survey. While most of the respondents answered all of the questions, there were exceptions. The results of this study are based on the replies that were provided to the various questions. While a large number of questions were asked, the results being presented pertain to those findings that are of particular interest.

Respondent were asked about the use of various types of drug testing practices. All respondents (100%) reported that they conducted post-accident testing immediately after the accident occurs. About 80% of respondents stated that all of their employees must pass pre-employment testing in order to be hired. Approximately 67% of respondents reported that they conducted random testing (see Figure 1).

There are several different methods of tests that can be administered to detect substance abuse. The most widely used (over 90% of the respondents) test continues to be urine analysis. For alcohol abuse, nearly a fourth of the respondents stated that they employed the saliva test for alcohol. Some respondents indicated that they used either saliva tests to detect the use of illicit drugs or hair analysis, oftentimes in conjunction with urine analysis. Although sweat tests exist for drug use detection, none of the respondents had used the sweat test, primarily because there is a sense that the tests may not be reliable or that they simply do not know enough about these tests to implement their use (see Figure 2).

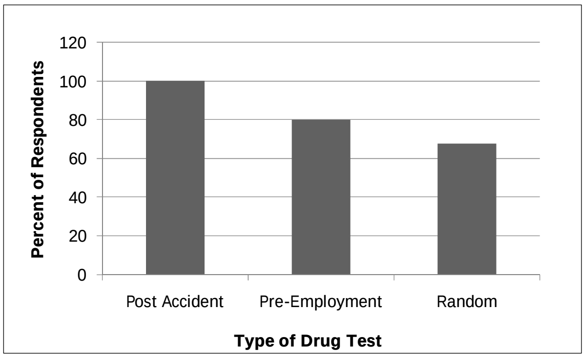

Figure 1. Frequency of Use of Drug Testing

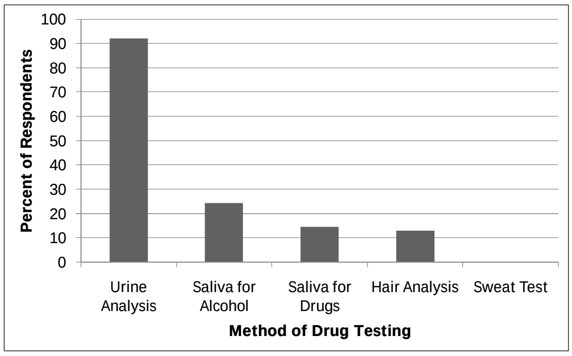

Figure 2. Drug Test for Detection

For the respondents using urine analysis, many respondents stated that they used a "field drug test" that would provide test results within a few minutes. These respondents were asked about the number of panels that were used in the tests. The typical response was that five panels were used, namely to test for marijuana, cocaine, amphetamines, barbiturates and opiates. Other respondents indicated that they used tests that had up to ten panels (see Figure 3). The ten-panel test will test for five additional substances, commonly including some combination of either phencyclidine, methamphetamine, methadone, methaqualone, propoxyphene, benzodiazepines, tricyclic antidepressants, oxycodone, and methylenedioxymethamphetamine (also known as ecstasy). Twelve-panel tests are also available. Regardless of the number of panels, companies have a standard practice of having positive results on "field drug tests" verified by an independent drug testing laboratory.

Respondents were asked which drugs were most commonly detected when identifying the presence of substance abuse. The most common drug that was detected was marijuana, followed by cocaine as a distant second. Only a few indicated that alcohol, amphetamines or barbiturates were most commonly abused. Respondents were also asked about the most common drugs five years ago. The results show that there has been little change in the types of drugs that are abused (see Figure 4).

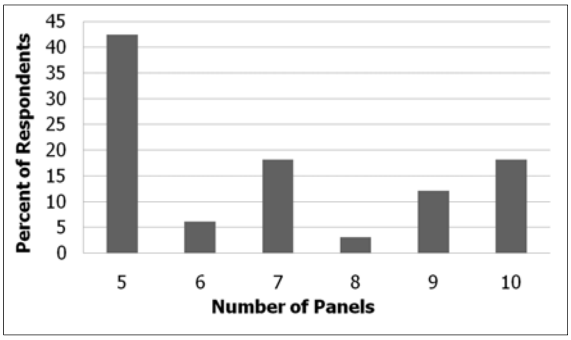

Figure 3. Number of Panels Used for Random Tests

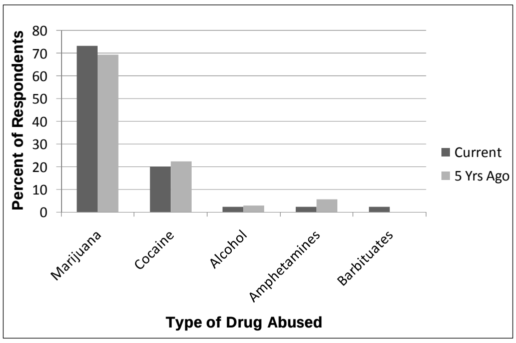

Figure 4. Types of Drugs Commonly Abused

Respondents were asked about the percentage of the tests that were positive, both as a current experience and five years ago. The results show that the percent positive tests on pre-employment and random tests range from zero to more than ten percent. It was noted that the current percent of positive tests tends to be lower than it was five years ago. This is especially true for the pre-employment drug tests. For the pre-employment and random tests, the results show that there are now more tests that show zero positive results and that five years ago there were more tests that showed more than ten percent positive results. In essence, the results indicate that drug use among construction workers has declined (see Figures 5 and 6).

The percent positive test results (those failing the drug test) on post-accident tests follows the general pattern for the pre-employment tests and the random drug tests. That is, approximately a third of the respondents reported observing no positive results on the post-accident drug tests.

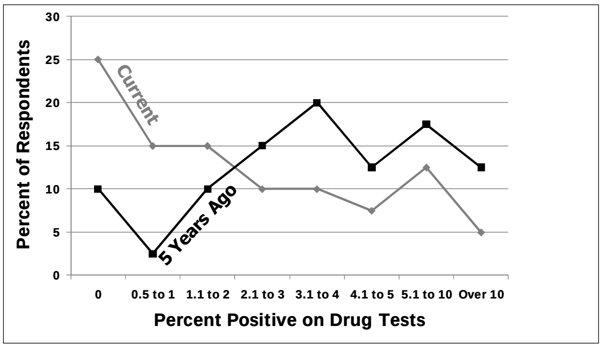

Figure 5. Number of Positive Results on Pre-Employment Drug Tests

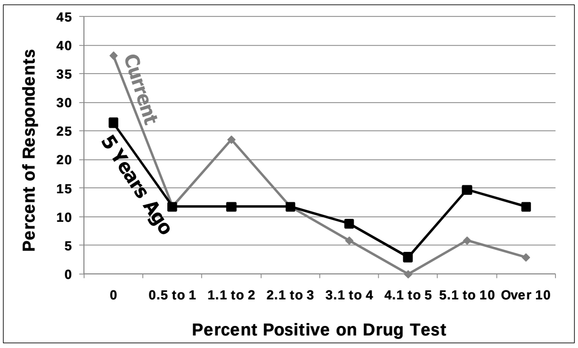

Figure 6. Number of Positive Results on Random Drug Tests

About twelve percent of the respondents reported that over ten percent of the post-accident test results were positive (see Figure 7).

The recordable injury rate of the respondents was obtained in this study. Recordable injuries can be broadly categorized as being those that are sufficiently severe that warrant treatment by a physician. The rate is based on 200,000 hours of worker exposure which is essentially equivalent to 100 workers working full-time for one year. The recordable injury rate (RIR) for the U.S. construction industry is approximately 5.4 injuries per 200,000 hours. For the survey respondents, the average RIR was 1.8, indicating that the sample of respondents had safety performance records that were considerably better than the average. It has been noted in other safety studies that firms that respond to safety surveys tend to be those with better safety records. In addition, it was observed that the respondents consisted of many firms from the industrial construction sector which is noted as having a considerably better safety performance record than the construction industry as a whole. Some analysis was conducted to determine the extent that drug use might be associated with the injury rate. The correlation was found to be statistically significant. The results show that there is a strong relationship between the RIR and the percent positive drug test results. This would suggest that higher drug use is associated with a higher injury rate (see Figure 8).

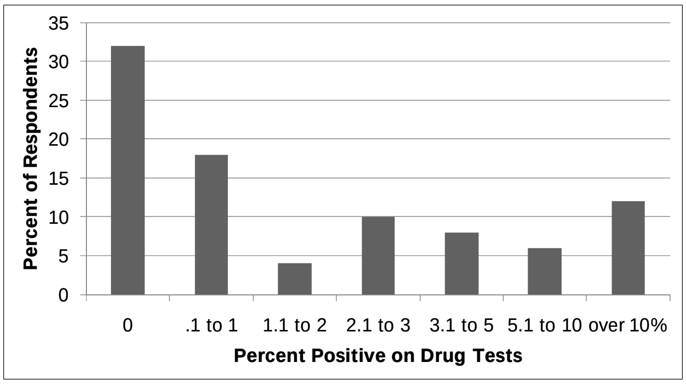

Figure 7. Percent Positive Results on Post-Accident Tests

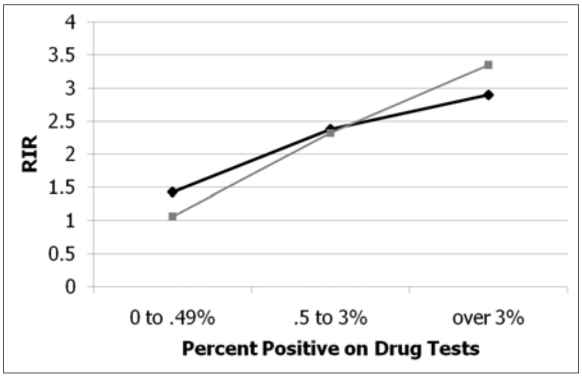

Figure 8. RIR as Influenced by Positive Test Results

The results of a positive drug test invariably result in the termination of employment of the worker who tests positive. The construction firms differ in their posture about subsequent rehiring of these workers. Some companies terminate workers who test positive for drug use and do not offer the possibility for the workers to be rehired, while others will consider rehiring workers if they can successfully pass a drug test after they have been terminated for a specified amount of time, typically 60 days to 3 months. The data were examined to determine if this possibility of being rehired after testing positive for drugs was associated with and differences in the resultant RIR. The results show that the RIR values are considerably higher in those companies that have a more relaxed policy about rehiring workers that have tested positive on drug tests. This was evident for both the random drug tests and the post-accident drug tests (see Figure 9). The differences in the RIR values in the figure are statistically different.

In recent years, there has been an increased awareness of the possibility of cheating on drug tests. In fact, many companies now advertise on the Internet about products that they sell that can effectively mask illicit drug use. Many of these substances can be detected with more sophisticated drug testing procedures. In fact, many laboratories have a standard policy of testing for the presence of adulterants in the specimens they test.

The respondents were asked about the prevalence of cheating on drug tests. To this, 15% of the respondents stated that there was no cheating on drug tests, 54% stated cheating occurred on an occasional basis, and 31% stated that cheating was common. This experience with or the perception of the extent of cheating was examined in terms of the RIR. It was noted that the RIR was particularly elevated in those firms in which cheating on drug tests was assumed to occur as a common frequency (see Figure 10). This correlation between the frequency of suspected cheating on drug tests and the RIR is statistically significant.

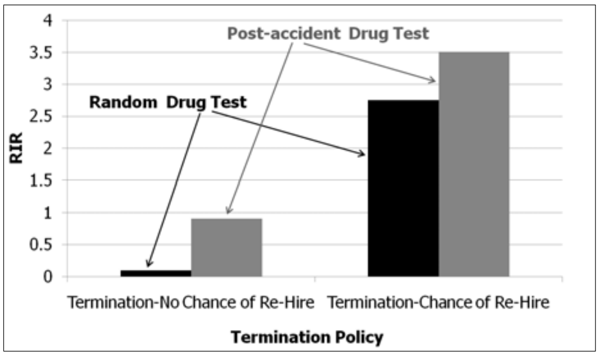

Figure 9. RIR by Consequence for Positive Test Results

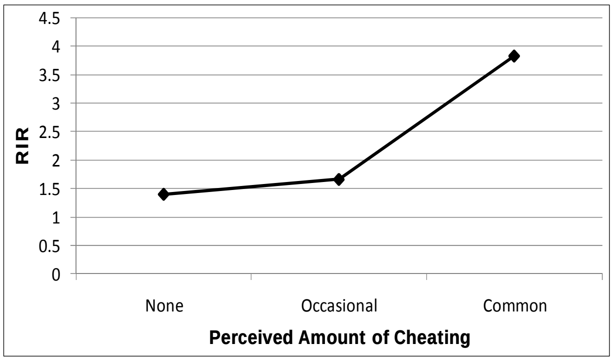

Figure 10. RIR as a Function of the Perceived Amount of Cheating

CONCLUSIONS AND RECOMMENDATIONS

This study shows that substance abuse continues to be a problem in the U.S. construction industry. It seems that the rate of substance abuse has decreased in recent years. The most frequently abused substances are marijuana and cocaine.

Urine analysis continues to be the most prevalent drug test used by the construction firms. Hair testing and saliva tests for alcohol have been used by some firms, however there is a great reluctance to use sweat tests and saliva tests for drug use. Cheating on drug tests seems to be a significant problem. As the amount of cheating increases, the injury rate increases, too.

There is a statistically significant relationship between drug usage and safety performance. The injury rates were higher on the projects where the drug use was higher. The drug use on these projects was detected through random tests or through post-accident drug tests. The percent positives on post-accident drug tests were considerably higher than the percent positives on random tests, showing that more accidents are associated with increased drug use.

Strict drug testing programs have positive effect on safety performance. In addition, severe consequences for positive drug test results appear to favourably influence safety performance. Thus, firms should implement stringent policies to create a strong disincentive for workers to utilize drugs. For example, refusal to rehire workers who have tested positive on drug tests was found to be associated with better safety performances.

Therefore, construction companies are encouraged to implement drug testing. Construction firms are encouraged to consider the use of new testing methods (other than urine analysis), but only after they evaluated the accuracy of the test results. The construction firms should be aware of the potential for the cheating on drug tests and take the necessary actions to decrease the cheating. Cheating on a drug test should be regarded the same as a positive drug test result.

While this study was conducted in the United States, there is a strong possibility that similar results might be found in other countries. Drug use is a serious social issue that has existed for decades but it has not been a general concern among the U.S. employers until the past thirty years. Any society that has a high incidence of drug use will undoubtedly have similar types of associated problems in the workforce, including lower productivity, higher absenteeism, higher turnover, increased illnesses, and higher injury rates. While there were initially concerns in the U.S. about the invasion of personal freedoms whenever drug tests were conducted, those arguments have largely abated with time. If drug use is viewed as an illness, there might be a more positive approach to addressing substance abuse in the workforce. Construction firms should devote time and effort to educating workers about the health impacts and job consequences of substance abuse. Companies should also be proactive in assisting in the rehabilitation of workers who test positive on drug tests.

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APPRAISAL OF WORKPLACE DRUG TESTING BY UK CONSTRUCTION CONTRACTORS

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ABSTRACT
Illegal drug use in the general population of society varies widely. Research evidence suggests that although the level of drug use is higher among the unemployed compared to those in employment, this gap may be narrowing. Substance misuse can damage health. It can also cost employers through increased absenteeism, reduced productivity and increased risk of accidents. Indeed, there is a well documented linkage between drug use and impairment of cognition and perception skills. Before someone starts performing safety-critical tasks, it is good practice for the employer to agree what health checks and/or medical examination will be required and record agreement. Some employers have indeed decided to adopt workplace drug testing as part of their overall drugs policy. Previous research undertaken into the influence of drug testing on occupational safety is reviewed in this paper. Results of a survey to evaluate the extent to which workplace drug testing programmes have been implemented by UK civil engineering construction contractors are evaluated. The reasons that have led UK construction firms to introduce or not to implement workplace drug testing programmes are discussed. Some countries, such as Ireland and Finland, have legislated for workplace drug testing. The future of workplace drug testing in UK construction is discussed, including an assessment of whether the UK government should intervene and legislate. This work is part of an ongoing research programme that aims to establish the prevalence of illegal drug use in UK construction. The work also aims to investigate the effects of illegal drug use on worker performance and to analyse whether there is an association between illegal drug use and workplace accidents and injuries in construction.

Keywords: Workplace drug testing, Accident prevention, Legislation

INTRODUCTION
Drug testing involves the analysis of biological material to detect the presence or absence of drugs and their metabolites. Metabolites are those substances into which drugs and alcohol are converted by the human body. The most common form of testing for drugs involves analysis of urine samples. Breath tests are more common for alcohol testing followed by blood testing for confirmatory tests. In addition, other materials such as hair, oral fluid, and sweat can be tested. Drug testing in the workplace has grown significantly over the last 25 years in the United States of America to become a multi-billion dollar business. The development of drug testing in the workplace in the United Kingdom has been at a relatively slower rate. Drug testing is a complex issue and involves scientific, legal ethical, social and economic dimensions. In a recent UK study (George, 2005), a significant number of workplace specimens (19 percent of those analysed) were positive for illicit drug use. The most common drug detected from workplace drug testing was cannabis, followed by opiates and benzodiazepines. Other samples were found positive for cocaine, amphetamines and heroin. In addition, morphine, codeine and dihydrocodeine were also confirmed in a few of the workplace samples analysed. It is suggested that the actual rate of illicit drug use may be much higher than the positive test rate and that random drug testing will only detect regular (near daily) users. More frequent testing of employees may therefore be required to develop a true picture of the extent of illegal drug use in the work place. In this paper, previous research undertaken into the influence of drug testing on occupational safety is evaluated. The

results of a survey to evaluate the extent to which workplace drug testing programmes have been implemented by UK civil engineering construction contractors are given. The effectiveness of these programmes is evaluated. The reasons that have led UK firms to adopt or not to implement workplace drug testing programmes are discussed. Some countries such as Ireland and Finland have legislated for workplace drug testing. The future of workplace drug testing in UK construction is assessed.

INFLUENCE OF DRUG TESTING ON OCCCUPATIONAL SAFETY

One of the justifications for introducing workplace drug testing is the view that drug intoxication increases the probability of an accident taking place at work. That would seem to be common sense. However, the relationship between drug use and workplace accidents is more complex and not as straight forward as is often assumed. In this section, a review of relevant published research on the connection between drug use and occupational accidents is provided.

The relationship between illicit drug use and workplace accidents among young adults in the USA was examined in Kaestner and Grossman (1998). The study examined whether individuals who use drugs are more likely than their non-using counterparts to experience an accident on the job. The data used in the analysis came from a national longitudinal survey of labour market experiences of young adults between the ages of 14 and 21. The data contained detailed information on a respondent's labour market experience, family and personal background, involvement in workplace accidents and illicit drug use. The data was drawn from a large scale sample. The results of the investigation are mixed. For young adult males, there is some evidence that drug use is significantly and positively related to workplace accidents. More specifically among males, the study found that drug use raises the probability of having an accident by 25 percent. For young adult females, the evidence suggests that there is no systematic relationship between drug use and workplace accidents. These conclusions may not be surprising. Male occupations generally tend to be in higher risk sectors than female occupations and men generally have higher rates of drug use than women (Kaestner and Grossman, 1998).

The effects of introducing a post-accident drug testing programme in a large retail chain in the United States on occupational injury claims was examined in a study by Morantz and Mas (2008). The study found that accident related claims fell significantly within the first fifteen months of introducing the programme. The observed drop in claims was driven mainly by the behaviour of male, high tenure and full time employees. Conditional on being tested, it was found that full time, high tenure and female employees were least likely to test for illegal drugs. Overall, the results lend considerable credence to the view that post-accident drug testing programmes can reduce workers compensation claims even in workplaces that already utilise other forms of drug testing. There are two possible explanations for the decline. The first is that employees may forgo using drugs or take great care on the job. However, this may also be due to a fall in employees' willingness to report accidents. Thus, although post-accident drug testing may improve occupational safety, its raises special policy concerns as it may encourage some employees to hide their injuries, (Morantz and Mas, 2004). It should be clarified that this study only shows that post accident drug testing reduces claims. Reductions in claims do not necessarily equate to an improvement in safety for a whole lot of reasons.

In the UK, the Health and Safety Executive published a research report in 2004 that examined the relationship between drug use and occupational accidents. The research was conducted in Wales and involved a community based questionnaire sent to 30,000 individuals. Of these, 7,979 individuals completed the survey of which 4,620 (58 per cent were employed). Data was also collected from accident and emergency units in hospitals and a survey of college students. A group of 54 people participated in a study involving cognitive performance tasks and of these, 44 participants had used drugs in the week of the study and ten had not done so. The principal conclusions of the study are as follows (Smith, et al 2004):

- Thirteen percent of the working respondents reported drug used in the previous year. The rate varied considerably with age from 3 percent of those over 50 years old to 29 percent of those under 30.
- Drug use is associated with a number of behavioral factors including firstly smoking and then heavy drinking.
- Drug use has an impact on cognitive performance, which varies with the type of drug(s) used.

- There is an association between drug use and minor injuries among those who are also experiencing other minor injury risk factors.
- There was no association between drug use and workplace accidents, though associations did exist between (a) cannabis only use and work-related road traffic accidents among those also reporting higher levels of other associated risk factors, and (b) drug use and non-work accidents among those also experiencing higher levels of other risk factors.
- The lack of association with work accidents may be because: no association exists; the number of accidents was too small for a significant association to be detected; accidents were not restricted to those resulting from the individual's own error; at work, individuals are in familiar situations, doing familiar tasks from which as much risk as possible has been eliminated and are less likely to be experiencing the acute effects of drug use.
- The study concludes that overall, drug use may reduce performance efficiency and safety.

This study answers some questions but equally raises the need for further research. For example, further research is needed on the impact of drugs other than cannabis on workplace performance and safety. In addition, objective assays of drug use e.g. urine and hair samples are needed to confirm the pattern of usage, assess dose response and determine associations between different metabolites and measures of safety and performance. Furthermore, other approaches to safety and performance measurement could also be used. This could involve simulations of real-life activities and cover functions such as risk perception that are known to be influenced by drug use. The association between drug use and accidents clearly requires further research to provide specific guidance for the construction industry. This research could also identify the type of work most likely to be influenced by drug use, e.g. safety critical jobs. Performance testing could also be extended to determine whether the effects of drug use are compounded by other risk factors such as noise, working at night, a high workload, etc.

Although there is a growing body of knowledge on the effects of drug use and workplace performance and safety, very little comprehensive research has been conducted in the construction industry. A survey was conducted in the USA on contractors, designers, labour union officials and owners to gather data on the extent and cost of substance abuse in the engineering and construction industry, (Maloney, 1988). This was a large scale sample. For contractors a sample size of 2000 was employed but the number of contractor respondents totalled only 250. The study found alcohol to be the primary problem followed by marijuana and cocaine. Labour leaders reported similar increases as a result of substance abuse in the following areas: absenteeism, late starts at work, early quits, reduced productivity and labour turnover. However, in relation to safety incidents, accidents and injuries, labour leaders reported increases approximately one-half of those reported by contractors. This raised an interesting question. Were the labour leaders understating the effects of substance abuse on safety or were contractors overstating the effects? Labour leaders argued that contractors had inadequate safety programmes resulting in more accidents. The question then was whether the increase in safety incidents, accidents and injuries was due to substance abuse or inadequate safety programmes. This important question was never resolved in the study.

A study by Altayeb (1992) investigated the technical aspects of drug testing in the construction industry and whether it is effective in reducing injury incident rates. The term substance in the survey included alcohol, illicit drugs, and unauthorised prescription drugs. Tobacco was not included. The sample size was large and involved 1,144 companies which included a number of company sizes, specialities, organisational types and geographic locations. A total of 203 companies responded to the survey and of these, 61 had a drug testing policy at the time of the survey. Of these 61, only 31 companies had sufficient quantitative data to justify being included in the analysis. The results show that drug testing helped the overall sample (31 companies) to reduce the incident rate by 19.1 percent. Statistically, the null hypothesis that incident rates before and after implementation of drug testing were the same was rejected for the whole sample. Other key findings from the study were as follows:

- Size of the company did not have a significant difference on the magnitude of change in incidence rates;

- The type of company (union, non-union or both) was not a proven factor in affecting change in incidence rates;
- The higher the incidence rate before implementing the drug testing policy, the better the likelihood of accident reduction;
- The number of drug test types in the company's policy was not proven to be a factor affecting the change in incidence rates, although companies that had four or five types of tests got large change values in incidence rates than companies with three or fewer types;
- Finally, a significant size increase through for example a merger or a take-over tends to adversely affect the incident rates for some time after it occurs. Unlike companies that had such an increase, companies that did not have a recent increase in size reduced their incidence rates significantly after implementing a drug testing policy.

Thus, although this study makes a useful contribution towards our understanding of the effectiveness of drug testing programmes on construction safety, the results must also be interpreted with caution because of the small sample size.

The work by Gerber and Yacoubian Jr (2001) analysed the impact of a drug-free workplace programme on the reduction of injury incident rates and related workers' compensation ratings. Data was collected through a survey sent to a randomly selected national sample of officials at construction companies in the USA. The data examined included injury incident rates and workers' compensation experience-rating modification factors compiled over a five year period. The key findings of this study are as follows:

- Implementation of a drug free work-place programme directly influences a reduction in injury incident rates and workers' compensation experience-rating modification factors, reducing the amount of workers' compensation premiums.
- The average company that drug tests in the study sample experienced a 51 per cent reduction in its injury rate within two years of implementing a drug testing programme. The difference was proved to be statistically significant when compared to the 14 percent decline in the average construction firm during the same period.
- As a result of fewer job site accidents and injuries, the average company that drug tests in the study sample experienced an 11.41 percent reduction in its workers' compensation experience-rating modification factor. Firms that did not drug test experienced no decline. This means that companies that drug test could save substantially on their workers' compensation premiums.
- Drug testing was most effective in reducing workers' compensation experience-rating modification factors in the first three years immediately following implementation of a programme.

The above study suffers from two important limitations. Firstly, a total of 405 construction companies were solicited to participate in this study. A total of 69 companies (17 per cent) responded. Of these 69, 49 (71 percent) had a drug testing programme at the time of the survey. Therefore, since the only companies included the study were those that were willing to participate, the sample of included firms may exhibit selection bias. Secondly, the study did not distinguish among different types of drug testing programmes, simply treating all firms with at least one programme of any type as part of the treatment group.

The survey by Minchin Jr et al, (2005) involved only 34 construction companies in the State of Florida in the USA. Of these, 29 companies had drug testing programmes and 5 did not. Of the companies surveyed, a high percentage had realised benefits such as reduction in accident rates and reduction in insurance premiums; additional savings from increased productivity, increased work quality, and lower employee turnover. In addition to these tangible benefits, companies indicated their recognition that their image and public perception were almost as important as their quality of work. This public perception translates into "good will" regarding the companies' reputations. Most companies surveyed interpreted this as a significant marketing advantage resulting directly from their drug testing programme. The sample size in this study is also very small in relation to the number of construction companies in the USA and is not representative of the entire industry as such. The results of this study must also therefore also be interpreted with caution.

RESEARCH AIMS AND METHODOLOGY

This paper reports preliminary results on a piece of ongoing research. The aims of the research project are to investigate the extent to which workplace drug testing has been adopted in UK construction. The work will also evaluate the extent to which the information generated by the testing systems is useful to organisations or to employees. The work also aims to investigate the effects of illegal drug use on worker performance and to analyse whether there is an association between illegal drug use and workplace accidents and injuries in construction. The first part of the research involved an extensive review of the literature. There is a growing body of knowledge on this subject. However, most of the publications relate to all workplaces in general. There has been very limited research into this area with specific reference to the UK construction industry. Primary data was collected through self-completion questionnaires sent to 119 civil engineering contractors. Details of these firms were obtained from the contractors file that is published annually in March by the New Civil Engineer. The questionnaires together with a covering letter were addressed to Health and Safety Directors in these firms and sent out in June 2009. A self-addressed postage paid return envelope was also enclosed in each case. A total of 32 completed questionnaires were returned giving a response rate of 27 percent. This was a reasonable response rate considering that no further action was taken to try to improve the response rate.

ANALYSIS OF RESULTS AND DISCUSSION

The 32 respondents in the sample were all senior level managers in UK civil engineering construction firms. Job titles of the respondents included designations such as Managing Director, Divisional Health Safety Quality and Environment Director/ Manager, General Manager, Health and Safety Officer/Manager/Director, Operations Manager, Company Safety Officer, Health Safety and Training Manager, Contracts Director, Head of Health and Safety Department, Senior Health and Safety Manager, General Manager Systems and Training, etc. It is clear that all the respondents in the sample had a clear understanding of the issues in the questionnaire and had relevant experience of construction health and safety. Indeed 94 percent of the respondents were over 40 years old and 84 percent had over 15 years experience in the construction industry.

Sixty-six percent of the firms in the sample were small and medium sized enterprises (i.e. have less than 250 employees) and the rest are classified as large firms. The smallest firm in the sample had an approximate annual turnover of £2.7 million and employs 10 full time staff. The largest firm in the sample has an approximate annual turnover of £5 billion and employs 20,000 full time staff. Thus our sample is a cross-section of UK civil engineering contractors although it must be accepted that the sample size is too small to be representative of the whole UK construction industry. Moreover, it should be noted that views of contractors involved in other sectors of the industry such as building or process plant construction have not been sought. Neither have other stakeholders in the industry such as client organisations or consultants been included.

Factors that Influence the Decision to Introduce Workplace Drug Testing

Approximately half (47 percent) of the firms in the sample have a workplace drug testing programme. Eighty percent of these firms introduced their drug testing programme between the period 2004 – 2009; i.e. in the last five years. Most of the firms in the sample use a combination of drug testing types. The four most commonly used drug testing types include: pre-employment testing, reasonable suspicion testing, post-accident testing, and random testing. The two least widely used testing types were routine fitness for duty testing and testing as a follow up to rehabilitation (after returning to work from drug/alcohol treatment). The respondents were asked to rate the relative importance of 13 factors that influenced their firms' decision to implement a workplace drug testing programme. Based on the following scale (Very Unimportant = 1; Unimportant = 2; Neutral = 3; Important = 4; Very Important = 5) the mean rating of each of these factors calculated from the survey results is shown in table 1:

FACTOR	MEAN RATING
1. To promote the safety of our employees.	4.64
2. Testing is seen as an effective deterrent	4.00
3. Because of concerns about the company's legal liability for drug related incidents	3.92
4. Contractual requirements	3.54
5. Because of the belief that drug testing contributes positively to the company's image	3.50
6. Mandated by law.	3.43
7. In response to initiatives by the Health and Safety Executive	3.14
8. In response to industry or trade association initiatives	3.00
9. Evidence of drug abuse in the community	2.84
10. Evidence of drug abuse in the workplace	2.77
11. Reported success of some other company with drug testing	2.69
12. Evidence of high cost of drug abuse to company	2.62
13. Required by the trade Union	2.31

Table 1: Factors that Influence Introduction of Workplace Drug Testing Programmes.

No factors were rated by the respondents as being unimportant. However, it is evident from the above table that the top three reasons why UK civil engineering firms in the sample made the decision to introduce a workplace drug testing programme were found to be:

- To promote the safety of their employees;
- Workplace drug testing is seen as an effective deterrent;
- Because of concerns about the company's liability for drug related incidents.

Effectiveness of Workplace Drug Testing Programmes in Construction

Respondents were asked to rate their perception of the impact of implementing the drug testing programme on 10 key performance indicators for their organisation. Figure 2 shows the mean rating calculated from the responses based on the following scale: Adverse Impact = -1; No Impact = 0; Some Improvement = +1, Significant Improvement = +2. From figure 2, all the respondents report no adverse impact from implementation of their workplace drug testing programmes. They also generally report no impact in most areas. However, modest improvements are reported in two key business performance indicators these being a better overall safety of the work environment and better health for their employees. From table 2, it would appear that the jury is still out on the effectiveness of workplace drug testing in UK construction although caution must be exercised in that this conclusion is based on data from a limited sample.

FACTOR	MEAN RATING
1. Better overall safety of the work environment	0.85
2. Better health of employees	0.64
3. Better quality of job applicants	0.38
4. Increased business opportunities	0.31
5. Better employee morale	0.31
6. Reduction in employee absenteeism	0.31
7. Reduction in insurance premiums	0.21
8. Improved productivity	0.15
9. Reduction in workers' compensation costs	0.08
10. Reduction in thefts	0.08

Table 2: Effectiveness of Workplace Drug testing Programmes in UK Construction.

It should also be clarified that the results in the above table are based on responses from only those firms that have a drug testing programme in place. When all the respondents were asked for their opinion on whether drug testing programmes are highly effective in reducing construction site accidents, 45 percent agreed or strongly agreed and 34 percent were neutral. The effectiveness of drug testing programmes in reducing construction site accidents is not so clear cut and is a subject of debate. Indeed, when the respondents were asked whether construction firms that institute drug testing programmes realize significant tangible and intangible benefits from their programmes, almost half (47 percent) of the firms gave a neutral response. Only 19 percent agreed or strongly agreed and 15 percent disagreed or strongly disagreed.

There was overwhelming agreement (84 percent of the respondents) that a drug testing programme must not be perceived as a substitute for effective drug education and rehabilitation. For workplace drug testing programmes to be effective, they must be part of a comprehensive drug free workplace model. An effective drug free workplace model includes a company substance abuse policy, education and training for managers, supervisors and employees, drug testing, and employee assistance programmes including counseling and rehabilitation of those who test positive for illicit drugs.

Factors Influencing the Decision Not to Introduce Workplace Drug Testing Programmes

Firms that did not have a workplace drug testing programme were asked to rate eight factors that may have influenced their decision NOT to implement a drug testing programme. Based on the following scale (Very Unimportant = 1; Unimportant = 2; Neutral = 3; Important = 4; Very Important = 5) the mean rating of each of these factors calculated from the responses to the survey questions is shown in table 3:

The top three factors that influence the firms' decisions not to introduce workplace drug testing were found to be concerns for increased legal liability, the genuine perception that it is not needed and the costs of implementing such a programme. No factors were ruled out as being unimportant by the firms.

FACTOR	MEAN RATING
1. Concern for increased legal liability	3.44
2. It is not needed	3.19
3. It is too costly	2.88
4. It is believed to be ineffective	2.80
5. It is prohibited by legislation	2.75
6. Employee opposition to drug testing	2.69
7. Belief that drug testing is an invasion of privacy	2.67
8. Union opposition to drug testing	2.33

Table 3: Factors that Influence the decision NOT to Introduce of Workplace Drug Testing.

The Future of Workplace Drug Testing in UK Construction.

Opinion was divided as to whether the government should intervene and legislate to make drug testing a mandatory requirement for all employees on construction sites. Forty-one percent of the respondents were neutral on the role of government. Those who agree or strongly agree (thirty eight percent) that government should legislate to make drug testing mandatory on construction sites cite the following reasons:

- It would demonstrate seriousness to employees.
- It reduces perception of victimisation of some employees.
- Operations on construction sites are reliant on actions of others around any employee.

- Personnel need confidence that their colleagues are fit to undertake their duties safely.
- It takes away choice in the matter – it would have to be done
- It would ensure a level playing field for all construction companies to apply it to the same standards.
- Legislation would clearly define duties on the company and employees with government backing and commitment.
- If it is an option, its effectiveness will be sporadic and patchy.
- Recreational drugs are being taken by many more people today. Anything that can be done to reduce fatalities and major incidents on construction sites should be implemented. We should not be reactive, but pro-active.
- The situation is muddy at present particularly where client sites demand it as a condition of contract which can then lead to human relations issues.
- Construction sites are hazardous with heavy plant and machinery operating. There is no place for drugs or alcohol whatsoever.
- All employers would have the same costs to bear.

Those who were neutral or disagree (62 per cent) with government intervention to legislate for workplace drug testing offer the following reasons:

- Drug testing usually tests for metabolites which is not a measure of impairment but a record of drug use in the past.
- Construction alone should not be singled out for government action.
- Drug testing should be client driven. Some clients drive it very well but there are some others that talk the talk but do not walk it.
- Contract size, contractor size are factors that affect the workability of such a scheme.
- Consideration must also be given to persons who do not appear at work under drug or alcohol influence.
- If legislation is to be introduced, it should be for all industries, not just construction.
- Companies need to take responsibility for their employees and not hide behind legislation.
- The major contractors already have policies and procedures in place to monitor and control drug/alcohol abuse. The small contractors and sub-contractors will ignore the legislation anyway.
- It should be down to every company to implement its drug and alcohol policies.
- Testing of everyone would have a negative effect on the perception of the company. Testing on a reasoned or random basis is just as effective when comparing on our sites (some have contractual requirements to test all) with failure rates around 8 per cent.
- There is evidence of recreational drug use from our random samples. There is no evidence of addiction or abuse. Alcohol remains our real issue.
- There would be a huge cost of mandatory testing on sites.
- Legislation would create an administrative nightmare.
- There is not a drugs problem at the moment.
- Companies should be left to ensure that they implement satisfactory management processes in terms of health and safety.
- The requirement should be risk based i.e. is the job safety critical or is the work environment high risk?

Opinion was sought from the respondents on whether drug testing programmes on construction sites should only be applicable to employees who work on safety critical activities e.g. construction plant operators. This was opposed by the vast majority of respondents (75 percent). The vast majority of the respondents take the view that if testing is to be carried out, it should be applicable to all employees on construction sites for the following reasons:

- The responsibility of everyone working on site should be even. NO DRUGS. Simple.
- All construction sites are potentially dangerous with a great variety of tasks to perform. Each individual has a duty to himself and to others on site. Everybody on site must act in a proper manner. Drug intoxication will seriously impair judgement and performance.

- Drug testing must be applicable to everyone on site as safety is everyone's responsibility.
- All personnel on site can be a potential risk.
- Everybody is safety critical to some extent.
- Applying a drug testing regime to only part of the workforce would be divisive.
- Others can cause safety related problems not just plant operators.
- Drug testing must include all personnel to be a fair, reasonable and effective system.
- It should apply to all staff. Ninety-nine percent of jobs are safety critical.
- It should cover all employees including managers and operatives. Plant operators are normally highly trained anyway.
- Fairness and consistency are important.
- Everyone on site through direct and indirect actions is part of a high risk safety critical activity, i.e. a drunk Quantity Surveyor can walk in front of a dump truck.

It is difficult to postulate the future of workplace drug testing in UK construction as there are strong arguments for and against it. What is evident from the survey is that several construction companies have introduced it in recent years. In the study sample, 12 out of 15 construction companies that have workplace drug testing programmes implemented it after 2004, i.e. in the last five years. What is also clear is that it is a divisive issue in the industry. Opponents of workplace drug testing argue that drug testing does not measure impairment. They argue that whilst drug taking is illegal and should not be condoned; workplace drug testing is a gross infringement of civil liberties and serves no useful purpose on a construction site. Furthermore, although workplace drug testing is widely used in some industries such as maintenance of railway infrastructure, power stations and oil refineries, the ability to instigate 'for cause' testing can lead to many malicious/confidential reports of drug use which nevertheless have to be followed up. They also assert that the level of drug testing that would be required to make random testing effective would be prohibitively expensive for the industry.

Supporters of workplace drug testing in construction argue that on balance, it is a good thing and essential for the health, safety and well being of all employees. They go further to advocate for a national register of persons dismissed or refused employment for failing a drug test to be maintained by an organisation such the Construction Industry Training Board. They go on to assert that Employers must however accept responsibility through employee assistance programmes to help and rehabilitate workers who disclose drug abuse problems and need support.

CONCLUSIONS

There are strong arguments for and against workplace drug testing. There is research evidence that impairment through drug use may have an effect on occupational safety. Workplace drug testing is on the increase in UK construction. The main reasons why UK constructions firms have implemented workplace drug testing programmes are to promote safety of their employees. Drug testing is seen as an effective deterrent and companies are also concerned about their legal liabilities for drug related incidents. No adverse impacts have been reported by construction firms that have introduced workplace drug testing programmes. On the contrary, they report benefits of a safer work environment and improvements in the health of their employees. Construction firms that have decided not to implement workplace drug testing programmes have done so because of concerns about increased legal liability, costs and also doubts about its need or usefulness. Some countries such as Ireland (Hogan et al, 2006) and Finland (Lamberg et al, 2008) have legislated for workplace drug testing. If the UK government is to legislate for workplace drug testing, it should be applicable to all workplaces and not just construction. If it is implemented by a construction company, workplace drug testing should be applicable to all employees in the interests of fairness, consistency and effectiveness as all workers on construction sites can be safety critical. Drug testing in the workplace has been criticised on the grounds that drug tests only detect earlier drug use and do not measure impairment at the time of testing. The presence of metabolites in the body from past drug use may not adversely affect job performance and safety now. It is suggested that impairment testing could provide an alternative to drug testing.

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THE APPLICATION OF Q-SORT METHODOLOGY TO IDENTIFY AND RANK STRATEGIES TO PROMOTE WORK-LIFE BALANCE, HEALTH AND WELLBEING IN CONSTRUCTION PROJECTS.

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ABSTRACT

Employees of the Australian construction industry experience high levels of work-life conflict which negatively impacts on their health and wellbeing. Research is underway to identify, implement and evaluate strategies designed to promote work-life balance, health and wellbeing in the Australian construction industry. An innovative Q-sort method was used in participative workshops with construction industry employees. This method enabled: (i) the identification of strategies that workers occupying different demographic and occupational groups would find beneficial; and (ii) the ranking of those strategies that workers believed would have the most impact upon their work-life balance, health and wellbeing. The result is a list of strategies recommended for implementation. A description of the Q-sort method and the workshop results are presented. The potential for Q-sort techniques to be used by organizations to identify opportunities to improve the health and wellbeing of their workforce and prioritise the implementation of work-life strategies is discussed.

Keywords: Q-Sort methodology, Construction, Work-family conflict, Work-life balance, Employee health and wellbeing.

THE RELEVANCE OF EMPLOYEE 'WELLNESS'

Hillier, Fewell, Cann and Shepherd (2005) write of an 'endemic un-wellness' that is affecting employees' behaviour within organizations, suggesting that a large number of employees and, by logical inference, organizational cultures are unwell. This is a concern because the health of a workforce is essential to productivity, performance and efficiency (Miller and Haslam, 2009). While it has long been recognized that workplaces expose workers to physical and chemical hazards, researchers have only recently begun to expose the health impact of long hours and psycho-social stressors. Another recent development has been the blurring of the distinction between occupational and non-occupational health effects (Drennan, Ramsay and Richey, 2006). There is a growing recognition that employee health and wellbeing are influenced by a complex interaction of factors in the work and non-work domains.

WORK-LIFE BALANCE, HEALTH AND WELLBEING

The link between work-life balance and health and wellbeing is very clear. Work-life balance is negatively impacted by conflict, in particular, work-life conflict. Work-life conflict occurs when "role pressures from the work and non-work domains are mutually incompatible in some respect" (Greenhaus and Beutell, 1985, p.77). People experiencing work-life conflict are known to experience negative health and wellbeing outcomes. In particular, work-life conflict has been linked to general wellbeing, psychological strain, psychiatric disorders, substance abuse, problem drinking and sleep disorders. Furthermore, a recent study revealed that employees' experience of conflict was adversely related to objective indicators of physical health, namely cholesterol level, body mass index and physical stamina (Van Steenbergen and Ellemers, 2009).

Research also reveals that work-to-family conflict acts as the mechanism by which adverse work conditions translate into depression (Franche, Williams, Ibrahim, Grace, Mustard, Minore and Stewart, 2006). According to Wang, Afifi, Cox and Sareen (2007) work-family conflict is significantly associated with mental disorders in the American working population. This association was found for both women and men, although the association was stronger in men aged between 26 and 45 years of age and among married or divorced men with children. Wang, et al. (2007) suggest this might be due to the fact that middle age is a period of high productivity in which many workers also start a family. The combination of pressures to provide financially and participate in family life at this busy time, the researchers suggest, takes its toll on men's health.

Work-life conflict also impacts upon health and well-being indirectly, via employees' health-related behaviours. For example, Allen and Armstrong (2006) and Roos, Salio-Lahteenkorva, Lallukka and Lahelma (2007) report that family interference with work is associated with the consumption of more fatty foods and less physical activity, while work interference with family is associated with lower consumption of healthy foods. Research has linked work-to-family conflict and role overload with unhealthy food choice coping strategies, for example eating take-away or fast food rather than home-cooked food, suggesting that this has serious implications for the nutrition and health of working parents and their children (Devine, Jastran, Jabs, Wethington, Farrell and Bisogni, 2006).

STATE OF HEALTH OF THE AUSTRALIAN WORKFORCE

In Australia, comprehensive workforce health statistics are not routinely collected. However, a national telephone survey of 16,304 Australian workers conducted between 1998-2001 revealed that a large proportion of Australian workers rate their health to be sub-optimal (Korda, Strazdins, Broom, Lim, 2002). In the Australian sample, male, blue-collar workers rated their health particularly poorly compared to other groups. These differences persisted after controlling for confounding variables including age, smoking and employment intensity (Korda, et al. 2002). Almost two thirds of the workers sampled reported a current long term health condition, such as asthma, arthritis, hayfever, back pain, cardiovascular disease or other long term health conditions.

THE AUSTRALIAN CONSTRUCTION INDUSTRY

One recurrent issue believed to impact upon the health of construction workers in Australia is the requirement to work long hours and participate in regular weekend work. In their study of work practices in the Australian construction industry, Lingard and Francis (2004) reported that the average number of hours worked each week was 62.5 among site-based construction workers. Perhaps unsurprisingly, recent evidence suggests that construction industry employees are particularly at-risk for negative work-life outcomes. For example, studies have linked long hours of work to burnout among Australian civil engineers (Lingard, 2004).

HEALTH PROMOTION INTERVENTIONS

An increasing number of organizations have initiated programmes designed to improve the physical and mental health of their employees (DeGroot and Kiker, 2003; Sorensen, Sembajwe, Harley and Quintiliani, 2009). DeGroot and Kiker (2003) distinguish between *reactive* employee health management programmes and those focused on more *positive health promotion*. Reactive programmes are those in which assistance is only provided once a particular health problem, for example alcoholism, is identified and help is sought. In contrast, occupational health promotion programmes focus on changing behaviours, both at work and outside work before adverse health outcomes occur. These programmes are designed to promote behaviours that will improve employees' fitness, health and general wellness. To date, little is known about the preferences of people in different demographic groups for health and wellbeing work-life initiatives, however it would be expected that preferences will vary by age, family status and occupational group (Roehling, Roehling and Moen, 2001).

Q-SORT TECHNIQUE

The Q-sort technique is useful for exploring attitudes, perceptions and beliefs about a phenomenon (Anandarajan, Paravastu and Simmers, 2006; Brown, 1986). This is of particular significance given that individuals' work-life balance, health and wellbeing is considered a subjective cognitive appraisal (Moen, Kelly and Huang, 2008). Furthermore, the Q-sort technique is considered a sound method for conducting exploratory research and investigating underlying perceptions (Anandarajan, et al. 2006). Q-sort methodology typically focuses on a small sample (referred to as the P-set), using many questions or statements (referred to as the Q-sample), instead of seeking responses to a smaller number of questions or statements from a large number of people. The P-set is typically asked to sort the Q-sample into seven graduated piles. The forced choice format of the Q-sort technique results in a normal distribution which identifies respondents' relative evaluation of the Q-sample. As far as the authors are aware, this is the first time the Q-sort technique has been used to identify and evaluate work-life balance, health and wellbeing strategies in a practical setting.

AIM OF THIS PAPER

This paper describes an innovative Q-sort method that was used in participative workshops with construction workers to: (i) identify strategies that demographic and occupational groups would find beneficial; and (ii) rank those strategies that would have the most impact upon workers work-life balance, health and wellbeing. The result is a list of strategies recommended for implementation. A description of the Q-sort method and the workshop results are presented.

RESEARCH CONTEXT

Participative workshops were conducted at the 'West Gate Freeway Alliance'. The Alliance is engaged in the upgrade of the Monash and West Gate freeways in Melbourne, Victoria.

Prior to conducting the workshops, a Health and Wellbeing Committee had been operating at the Alliance. The Committee comprised of workers from the project who represented various subsets of the workforce. The Committee's role was to coordinate the development and implementation of work-life initiatives for the project. This Committee had overseen the implementation of a number health and wellbeing initiatives in the twelve months prior to the workshops. Some of these included flu vaccinations, stress management information sessions, blood pressure testing, and sporting activities. Thus, the Alliance is characterised by a proactive culture that is generally supportive of workers' work-life balance, health and wellbeing (Turner, Lingard and Francis, 2009).

METHODS

Two Q-sort workshops were conducted with workers at the West Gate Freeway Alliance project. The Q-sort technique was initially tested with members of the Health and Wellbeing Committee at the first workshop. Due to the success of this workshop, an opportunity was provided to repeat the process with waged workers. It was considered important to investigate the preferences of work-life supports for waged workers, in addition to salaried workers, as their working arrangements differ significantly. In particular, waged workers are paid for hours worked which creates an incentive to work longer hours, while salaried workers are paid a set amount irrespective of the hours worked.

Workshop One

Eight workers of the West Gate Freeway Alliance project participated in the first workshop. All participants were classified as salaried workers. Seven of the participants were male, and one was female. Two participants had dependent aged children.

Q-sample
The Q-sample employed in this research originated from a set of 31 initiatives developed by the Alliance's Health and Wellbeing Committee. Examples of the initiatives included: blood pressure, cholesterol, blood sugar level testing; flu vaccinations; stress management presentation; and limiting weekend work.

Given that one of the aims of the research was to identify work-life balance, health and wellbeing initiatives that were relevant to workers occupying different demographic and occupational groups, participants formed groups and were asked to take the perspective of; salaried (office-based) workers; waged workers (direct construction activity); workers with dependent children; or workers without dependent aged children.

In the first instance each group was provided with a full set of (31) cards. All groups were asked to consider the initiative and answer the question: "will this initiative support my work-life balance, health and wellbeing?" with a yes or no response. At the end of this activity, each group had two piles of cards: (1) initiatives which they perceived as supporting work-life balance, health and wellbeing; and (2) initiatives which they perceived did not support work-life balance, health and wellbeing.

Participants were then asked to create a new card for other initiatives which would assist them to achieve work-life balance, health and wellbeing. Additional initiatives included suicide prevention information; alcohol at social events at work with a limit of two servings per person (the project has a no-alcohol onsite policy); conflict management process; charity/fundraisers; dental check-up; childcare facility; e-tags (free access to toll roads); lunchtime sporting activities; and an independent help line (similar to an employee assistance program which includes access to help and support via the telephone).

Using only those initiatives identified as supporting work-life balance, health and well-being (the 'yes' pile of cards), each group ranked the initiatives along a continuum ranging from least supportive (1) to most supportive (7) in response to the question: "to what extent will this initiative support your work group to attain work-life balance, health and wellbeing?". Participants were asked to form a 'bell' shape when ranking the cards, so that there were fewer cards at the extremes of the continuum (ie, least supportive (1) and most supportive (7)) and more cards in the midpoint of the continuum.

Workshop Two
Six workers participated in the second workshop. All participants were engaged in direct construction activity, and classified as waged workers. Five of the participants were male, and one was female. Two of the participants had dependent aged children, and one participant was a single parent.

The research method applied in workshop one was repeated in workshop two, with the exception that all participants completed Q-sorts. Additional initiatives suggested by participants included job security (many of the waged staff were employed as contractors on the project, and stated that the lack of job security and continuity of employment caused stress and anxiety and impacted on their health and wellbeing); and location of work (ideally the location of work would be closer to home so as to decrease travel time).

RESULTS

Initiatives defined as supporting work-life balance, health and wellbeing
Prior to the Q-sort exercise, participants were provided with a full set of initiatives and asked to consider whether the initiative would support their work-life balance, health and wellbeing. All of the initiatives presented to participants of workshop one were defined as supportive of work-life balance, health and wellbeing, while participants of workshop two considered the life insurance presentation, onsite childcare and superannuation information as not supporting work-life balance, health and wellbeing.

Q-sorts

Ten Q-sorts were completed, with four Q-sorts arising from workshop one (outlined in Table 1) and six Q-sorts arising from workshop two (outlined in Table 2).

Initiatives supporting all workers

Some initiatives were rated by all participants as supporting work-life balance, health and wellbeing irrespective of demographic or occupational group. These included stress management information; fatigue, quit smoking, and prostrate cancer information; skin cancer checks; blood pressure, cholesterol, blood sugar level testing; general practitioner consultation; and flu vaccination. Furthermore, limiting weekend work and time management information were also rated by all participants as supportive.

Health initiatives

Health-related initiatives such as prostate cancer information and skin cancer checks were rated very highly by salaried workers and to a lesser extent by waged workers as supporting work-life balance, health and wellbeing. Waged workers rated quit smoking information, fatigue and stress management information as more supportive in comparison to salaried participants.

Schedule revisions

Limiting weekend work was perceived by all participants as supporting their work-life balance, health and wellbeing. However, waged workers were concerned that limiting weekend work would impact on their income as they are paid for the number of hours they work in contrast to salaried workers who receive a set income irrespective of the hours they work.

Initiatives supporting subsets of the workforce

Job security

Four of the waged workers rated job security as the initiative most supportive of work-life balance, health and wellbeing. These participants explained that the lack of job security and continuity of employment causes stress and anxiety and impacts on their work-life balance, health and wellbeing.

Home and family

Salaried workers with dependent children ranked onsite childcare facilities as highly supportive of work-life balance, health and wellbeing. In contrast, waged workers rejected onsite childcare as supporting their work-life balance, health and wellbeing. For one waged worker, working close to home and reducing commuting time was rated as the initiative most supportive of work-life balance, health and wellbeing. Initiatives which provided important information that was directly relevant to participants' home and family life were considered supportive, such superannuation and financial/home budget information.

Fitness

Providing opportunities for exercise, such as bike riding and lunch time sporting activities were rated by salaried participants as supporting work-life balance, health and wellbeing. In contrast, fitness-based initiatives were either rated least supportive or discounted all together by waged workers.

DISCUSSION

This paper aims to describe an innovative Q-sort method that was used in participative workshops with construction industry employees to: (i) identify strategies that workers occupying different demographic and occupational groups would find beneficial; and (ii) the ranking of those strategies that workers believed would have the most impact upon their work-life balance, health and wellbeing. Ten Q-sorts were completed by workers of the West Gate Freeway Alliance project, and results indicated marked differences between waged and salaried workers, and well as by parental status. Furthermore, Q-sorts revealed that initiatives supporting work-life balance are fundamentally linked to employee's health and wellbeing.

Preferences of the workforce

Job insecurity was raised by waged workers as a critical issue impacting on work-life balance, health and wellbeing. Job insecurity is the perceived likelihood of involuntary job loss, and is associated with lack of control, uncertainty and ambiguity which in turn increases levels of work-life conflict (Voydanoff, 2007). Furthermore, job insecurity has been linked to heightened health risk (Strazdins, D'Souza, Lim, Broom amd Rodgers, 2004), psychological distress (Barnett and Brennan,1997), and poor self-rated health (Ferrie, Shipley, Newman, Stansfeld and Marmot, 2005). Given the probable impacts of job insecurity, it may be unsurprising that waged workers experiencing job insecurity identified health-related initiatives such as quit smoking information, alcohol abuse, fatigue and stress management presentations as supportive, as these initiatives essentially assisted to counter the impacts of job insecurity.

Salaried workers' preferences for initiatives supporting work-life balance, health and wellbeing differed across demographic and occupational groups. The 'child free' group identified health-related initiatives, such as flu vaccinations, as supporting their work-life balance, health and wellbeing while in contrast, workers with children identified family focussed initiatives, such as child care facilities, as providing a high level of support. The salaried group identified health- and fitness-based initiatives as supporting work-life balance, health and wellbeing, while the waged workers placed far less emphasis on fitness-related initiatives. Regular physical activity has been found to lower the risk of heath-related disease such as cancer (American Institute for Cancer Research, 2007) and positively impact on work-life balance, health and wellbeing. Studies have indicated that construction–based blue-collar workers are less likely to engage in leisure-time physical activity (Burton and Turrell, 2000) and this may be due to levels of physical labour associated with work (Sorenson, et al. 2009).

Supporting a diverse workforce

The present study highlighted that some work-life balance, health and wellbeing initiatives are supportive for all workers, irrespective of occupational or demographic group, while other initiatives support a subset only of the workforce. This finding is consistent with other findings (Behson, 2002; Blair-Loy and Wharton, 2002; Kirby and Krone, 2002), and suggests that organisations should give consideration to the differing needs of its workforce in supporting work-life balance, health and wellbeing, and that programs should cater for a diverse workforce rather than a 'one size fits all' approach. Similarly Casper, Weltman and Kwesiga (2007) suggest that organisations can enhance positive outcomes by providing work-life, health and wellbeing programs that appeal to a wider array of employees.

Equity

Catering for a diverse workforce in attaining work-life balance, health and wellbeing also supports the notion of equity and organisational justice, whereby procedures are perceived by workers to be consistent, unbiased, accurate and representative of worker concerns and perceptions (Judge and Colquitt, 2004). Research examining work-to-family conflict and organisational justice has suggested that the presence of justice allowed employees to better manage the interface of their work and family lives, which was associated with lower stress levels (Judge and Colquitt, 2004).

Designing effective health promotion programs

Sorensen, et al. (2009) propose that central to designing and implementing an effective health promotion program is broad representation from all occupational and demographic subsets of the workforce. As such, the Q-sort methodology is a tool which can be used to consult with subsets of the workforce to determine what initiatives they perceive as supporting their work-life balance, health and wellbeing. In addition to the Q-sort itself, the Q-sort exercise is a useful tool which provides an opportunity for the workforce to offer perspectives of why an initiative may or may not support their work-life balance, health and wellbeing. Such context can provide organisations with information about why an initiative may or may not be working, and how it can be changed or adapted to support a range of workers.

CONCLUSIONS

Participants engaged in the process with enthusiasm, and the Q-sort technique proved to be an effective way of eliciting information from various subsets of the workforce. There is great potential for the Q-sort technique to be used both in a practical and research setting to identify opportunities to improve the work-life balance, health and wellbeing of workers and prioritise the implementation of work-life strategies. This is of particular benefit based on the notion that the health of a workforce is essential to productivity, performance and efficiency (Miller and Haslam, 2009).

LIMITATIONS

The results are based on the experiences of a small number of employees at one case study construction project and no claims to generalisability of the findings are therefore being made. Although the Q-sort methodology typically focuses on a small sample (P-set), larger samples are preferred so that results may be generalised. Furthermore, each Q-sort completed in workshop one was undertaken by a group rather than an individual, based on the premise that no further Q-sort workshops would be conducted at the project. Based on the notion that Q-sort methodology reveals subjective structures, attitudes and perceptions, completion of Q-sorts by individuals is the preferred approach. Finally, the Health and Wellbeing Committee essentially evaluated its own efforts through ranking the nominated initiatives in workshop one. However, the process was piloted with the Committee prior to replicating with other workers of the project.

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Table 1: Workshop One - Health and wellbeing committee members' perceptions of the usefulness of initiatives supporting work-life balance, health and wellbeing

Level of support	Waged workers	Salaried workers	Dependant children	Child free
Most supportive **7**	• Quit smoking presentation	• Ride to work breakfast • Shoulder and neck massage	• Limit weekend work	• Limit weekend work
6	• Prostate cancer information session • Skin cancer checks	• Blood pressure, cholesterol, blood sugar level testing • Child care facilities • Dietician presentation • Flu vaccinations	• Blood pressure, cholesterol, blood sugar level testing • Child care facilities • Financial / home budget planner presentation • General practitioner visit site for general consultation • Provide blood pressure self testing equipment • Prostate cancer information session • Superannuation information	• Flu vaccinations • General practitioner visit site for general consultation
5	• Blood pressure, cholesterol, blood sugar level testing • Flu vaccinations • Hearing tests	• Dental check-up • Gym membership discount / Gym vouchers • Lunchtime sporting activities presentation • Personal trainer / exercise • Physical activities and competitions • Sports and activities equipment • Touch rugby team	• Conflict management and resolution process • e-tags • Flu vaccinations • Independent help line • Skin cancer checks • Quit smoking campaign	• Blood pressure, cholesterol, blood sugar level testing • Dentist • Hearing tests • Provide blood pressure self testing equipment • Skin cancer checks
4	• Alcohol abuse presentation • Alcohol at social events at work • Ergonomic assessment • Limit weekend work	• Alcohol abuse presentation • Alcohol at social events at work • Bicycle Victoria presentation • Charity / fundraisers • Conflict management and resolution process • Financial / home budget planner presentation • General practitioner visit site for general consultation • Prostate cancer information session • Sleep disorder presentation • Stress management presentation • Time management presentation	• Computers located at all lunch room locations for construction worker access • Fruit truck visit the site each day • Personal trainer / exercise presentation • Stress management presentation	• Fatigue presentation • Financial / home budget planner presentation • Sports and activities equipment • Stress management presentation • Prostate cancer information session • Time management presentation
3	• Fatigue presentation • Sleep disorder presentation • Sleep pods for power nap access during night shift	• Fatigue presentation • Hearing tests • Provide blood pressure self testing equipment • Quit smoking presentation	• Gym membership discount / Gym vouchers • Physical activities and competitions • Ride to work breakfast • Shoulder and neck massage	• Gym membership discount / Gym vouchers • Physical activities and competitions • Shoulder and neck massage • Superannuation information

Level of support	Waged workers	Salaried workers	Dependant children	Child free
		• Skin cancer checks • Superannuation information		
2	• Stress management presentation • Time management presentation	• Life insurance presentation • Limit weekend work • Parks Victoria presentation • Sleep pods for power nap access during night shift • Suicide prevention	• Fatigue presentation • Sleep pods for power nap access during night shift • Sports and activities equipment	• Charity / fundraisers • Dietician presentation • Personal trainer / exercise presentation
least supportive **1**	• Computers located in lunch rooms for construction worker access	• Computers located in lunch rooms for construction worker access • Fruit truck visit the site each day	• Time management presentation	• Alcohol abuse presentation • Quit smoking campaign

Table 2: Workshop Two - Waged workers' perceptions of the usefulness of initiatives supporting work-life balance, health and wellbeing

Level of support	Participant One	Participant Two	Participant Three	Participant Four	Participant Five	Participant Six
Most supportive **7**	• Location of work closer to home (to decrease travel time)	• Direct employee (permanent position)	• Job security	• Job security	• Dietician presentation	• Job security
6	• General practitioner visit site for general consultation • Limit weekend work	• General practitioner visit site for general consultation • Limit weekend work	• Stress management presentation	• Quit smoking presentation	• Fruit truck visit the site each day • Personal trainer / exercise presentation	• Fatigue presentation • Financial / home budget planner presentation
5	• Ergonomic assessment • Time management presentation	• Dietician presentation • Physical activities and competitions • Sports and activities equipment • Stress management presentation	• Fatigue presentation • General practitioner visit site for general consultation	• Financial / home budget planner presentation	• Gym membership discount / gym vouchers • Limit weekend work • Skin cancer check	• Ergonomic assessment • Limit weekend work • Stress management presentation
4	• Blood pressure, cholesterol, blood sugar level testing • Fatigue presentation • Financial / home budget planner presentation • Skin cancer check	• Activities (such as go-cart day) on a non rostered day off • Blood pressure, cholesterol, blood sugar level testing • Computers located in lunch rooms • Fatigue presentation • Financial / home budget planner presentation • Fruit truck visit the site	• Blood pressure, cholesterol, blood sugar level testing • Flu vaccination • Provide blood pressure self testing equipment	• Fatigue presentation • Flu vaccination	• Computers located in lunch room • Fatigue presentation • Flu vaccination • General practitioner visit site for general consultation • Sports and activities equipment	• Blood pressure, cholesterol, blood sugar level testing • Flu vaccination • General practitioner visit site for general consultation • Prostate cancer information • Skin cancer check

Level of support	Participant One	Participant Two	Participant Three	Participant Four	Participant Five	Participant Six
		each day • Skin cancer check				
3	• Bicycle Victoria presentation • Flu vaccination • Prostate cancer information session • Sleep disorder presentation • Stress management presentation	• Ergonomic assessment • Flu vaccinations • Personal trainer / exercise presentation • Quit smoking presentation	• Sleep disorder presentation • Time management presentation	• Alcohol abuse presentation • Fruit truck visit the site each day	• Employed directly (permanent position) • Ergonomic assessment • Stress management presentation	• Computers located in lunch room • Quit smoking presentation • Time management presentation
2	• Sports and activities equipment	• Gym membership discount / gym vouchers • Prostate cancer information session	• Computers located in lunch room • Prostrate cancer information session	• Sleep disorder presentation	• Provide blood pressure self testing equipment	• Gym membership discount / gym vouchers • Sleep disorder presentation
Least supportive **1**	• Activities / social functions during work hours	• Sleep disorder presentation	• Night shift sleep pods for power nap access	• Limit weekend work	• Financial / home budget planner presentation	• Fruit truck visit the site each day

RAISING AWARENESS OF THE OCCUPATIONAL HEALTH OF OLDER CONSTRUCTION WORKERS

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ABSTRACT

Due to demographic, political and economic pressures, there are now real benefits to be gained from retaining older workers within the construction industry. However the health of such workers, and its consequences for continued working, needs to be more widely appreciated.

The aim of the research project being undertaken by the Innovative Manufacturing and Construction Research Centre (IMCRC) at Loughborough University, UK, is to identify the key health issues affecting older construction workers and, from there, develop wearable devices which will simulate these health effects and their consequential impacts on both working and home life. When worn, such devices will enable other industry members (managers, architects, equipment designers, etc) to better appreciate the challenges faced by older workers and, through this improved awareness, contribute to an attitude-shift within the industry. This paper discusses: (i) the need to raise awareness of older construction worker health; (ii) the rationale for an approach using simulation; (iii) and the research undertaken to date as well as presenting analogous case studies.

A triangulated approach combining a review of current knowledge in this area, worker interviews and health professional consultations is proposed. From the resultant data a specification will be developed which will detail which health conditions, and what aspects of them, are to be developed into simulation devices. The devices are being developed to meet the specification as closely as is possible, within technological, ethical, cost and other constraints. The intention is to then pilot the devices with key groups within the industry to confirm proof-of-concept.

Whilst there are no results to date, a case study demonstrating the benefits to be obtained from changing attitudes through increased awareness, which is brought about by enabling third parties to directly experience a heath condition for themselves, is presented.

Keywords: Awareness raising, Dermatitis, Hand-arm vibration syndrome, Musculo-skeletal disorders, Noise-induced hearing loss, Older construction workers, Occupational health, Respiratory disorders, Simulation

Background

Due to demographic, political and economic pressures, there are now real benefits to be gained from retaining older workers within the construction industry. However the health of such workers, and its consequences for continued working, needs to be more widely appreciated.

Aims
The aim of the research project being undertaken by the Innovative Manufacturing and Construction Research Centre (IMCRC) at Loughborough University, UK, is to identify the key health issues affecting older construction workers and, from there, develop wearable devices which will simulate these health effects and their consequential impacts on both working and home life. When worn, such devices will enable other industry members (managers, architects, equipment designers, etc) to better appreciate the challenges faced by older workers and, through this improved awareness, contribute to an attitude-shift within the industry. This paper discusses the need to raise awareness of older construction worker health; the rationale for an approach using simulation and the research undertaken to date as well as presenting analogous case studies.

Methods
A triangulated approach combining: a review of current knowledge in this area, worker interviews and health professional consultations is proposed. From the resultant data a specification will be developed which will detail which health conditions, and what aspects of them, are to be developed into simulation devices. The devices will developed to meet the specification as closely as is possible within technological, ethical, cost and other constraints. The intention is to then pilot the devices with key groups within the industry to confirm proof-of-concept.

Results/conclusions
Whilst there are no results to date, a case study demonstrating the benefits to be obtained from changing attitudes through increased awareness, which is brought about by enabling third parties to directly experience a heath condition for themselves, will be presented.

Keywords
Awareness raising, Dermatitis, Hand-arm vibration syndrome, Musculo-skeletal disorders, Noise-induced hearing loss, Older construction workers, Occupational health, Respiratory disorders, Simulation.

INTRODUCTION

By 2050, one in every five people globally will be aged 60 years or over, rising to one in three by 2150; this compares to just one in nine in 2006 (United Nations, 2006). Although the developed countries tend to have greater proportions of older inhabitants, the rate of ageing in developing countries is greater which means that they will more quickly change from young to an old population structure. These facts therefore suggest that the effects of population ageing will have worldwide impacts.

One implication of ageing populations is changes to the Potential Support Ratio which measures the number of people aged 15-64 years per person aged 65 years and over and so indicates the dependency burden on the potential workforce. Globally, the PSR was 12 (1950) falling to 9 (2006) and is projected to fall to 4 (2050) suggesting that there is increasing pressure on the comparatively smaller working population (United Nations, 2006). One mechanism for alleviating this pressure is to raise the retirement age thereby inflating the size of the workforce. Initial steps in this direction have been evidenced in instances such as the call by the Confederation of British Industry, in 2004, for the retirement age to be increased to 70 years by 2030 (BBC, 2004 c).

The impact of the ageing population structure is most prominent in the manual workforce and this is reflected in the construction sector which shows an annual average increase of 2% in the number of workers aged 40 years and above since 1990; a trend which is predicted to continue (Construction Skills, 2008). In addition to the demographic and economic forces discussed above, the construction industry has also experienced a recent, high demand for its output, not seen since the 1980s. This has resulted in skilled construction trades being amongst the five occupations with the highest proportion of skills shortage vacancies in the UK (Dainty et al., 2005). In recent years, an influx of migrant workers to the UK has gone some way to reducing the severity of impact of this combination of circumstances. However in the longer term this is not a viable solution as all countries will face a relative shortage of younger workers as their population structure progressively ages. Taken together, it may therefore be reasoned that a more reliable mechanism for bridging the skills gap is to support the retention of construction workers within the industry for longer.

Whilst these factors act to ‘pull’ the older worker resource into the industry, the culture within the industry itself may serve to ‘push’ them away. Older workers are not prevalent within the construction industry since, due to the physical demands their work entails, they either move to alternative roles within the industry or out of the industry completely (Bremmer and Ahern, 2000). If the effects of the ‘push’ factors outweigh those of the ‘pull’ factors then the industry will experience a net loss in its older workforce which is likely to contribute to a potential overall skills shortage.

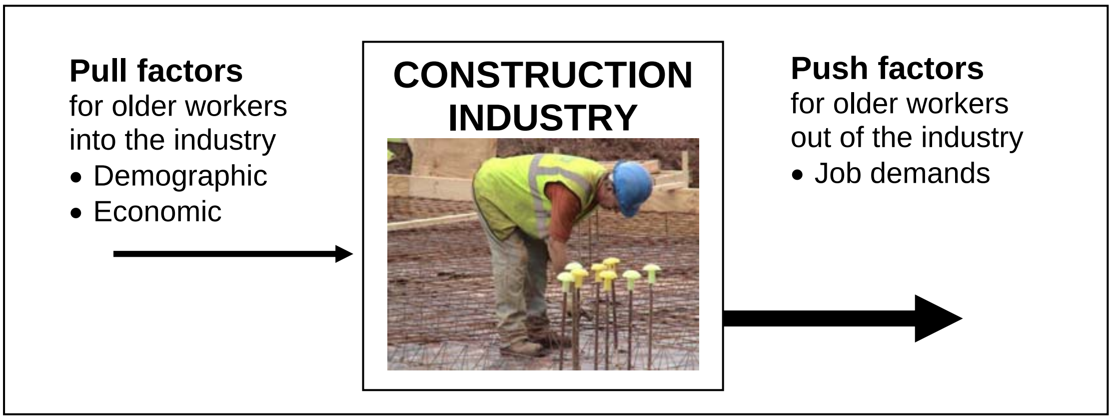

Figure 1: Factors affecting the older worker skill base within the construction industry

AIMS

One of the challenges for the future is therefore to develop mechanisms to facilitate the retention of older construction workers by addressing their occupational health issues within the industry and so contribute to reducing the skills gap. This is a particularly challenging area since, firstly, little research has been undertaken to date in the specific area of older construction workers and secondly, occupational health has not received the same level of attention and development as Occupational Safety evidenced by UK Government initiatives such as ‘Securing Health Together’ (The Health and Safety Executive, 2000). This comparative lack of attention to both older construction workers and occupational health indicates that as well as a need to improve the Occupation Health of older construction workers there may also be an additional need to first raise awareness of the importance of this within the industry.

In recognition of this, the aim of the research project being undertaken by the Innovative Manufacturing and Construction Research Centre (IMCRC) at Loughborough University, UK, is to identify the occupational health challenges of older construction workers and incorporate these into wearable simulations of their physical capabilities. In this way, those who wear them will be able to directly experience the effects and impacts of the identified occupational health conditions.

Following proof of concept, it is intended that the simulations can be employed to:

- Change the attitudes of younger workers to poor work practices, occupational health and ageing.
- Develop better work practices for all workers.
- Improve tools, equipment and workplace and work methods design (by demonstrating limitations from age-exacerbated ill-health conditions).

Using this approach, the identified real-world challenge of reducing the skills shortage by retaining the older construction worker within the industry for longer can start to be addressed.

The aim of this paper is to discuss the rationale for a simulation-based approach to awareness-raising, presenting illustrative, analogous case studies, as well as reporting upon the progress of the research to date.

OCCUPATIONAL HEALTH OF OLDER CONSTRUCTION WORKERS

Older workers and their health – Scope of the research project

Construction workers, like the rest of the population, are subject to the physiological, sensory, perceptual, cognitive and psychological effects associated with ageing. However this study centres on health problems which are caused or exacerbated by occupational factors arising directly from working within the construction industry. Those workers with the highest exposure to these factors are likely to be those workers who have laboured for longer and so are likely to be older members of the workforce. For the purposes of the study, older construction workers are defined as being aged 45 years or above.

Key occupational health conditions

Based on the following data sources: The Health and Occupation Reporting network (THOR) 2003-05 ill-health statistics (Constructing Better Health, 2008); The Health and Safety Executive (Health and Safety Executive, 2008 a) and Constructing Better Health (Constructing Better Health, undated a), the following have been identified as key ill-health conditions:

- Dermatitis – A reaction of the skin in response to chemicals, mechanical abrasion, biological agents or prolonged/frequent contact with water. The symptoms include: redness, swelling, blistering, flaking, cracking, itching, bleeding and pus formation. Irritant contact dermatitis is a local inflammation of the skin arising from acute (single, significant) exposure or chronic (repeated and prolonged) exposure. Allergic contact dermatitis develops as an allergic response once sensitisation to an irritant has occurred (Health and Safety Executive, 2008 b).
- Hand-Arm Vibration Syndrome – Over time vibration is transmitted from work equipment/materials into the workers hands and arms which can result in vascular, sensorineural or musculoskeletal damage. Symptoms may include: tingling/numbness/pins and needles in the fingers, blanching (whitening of the skin) in the fingers; red, throbbing and painful fingers following exposure to cold/wet conditions, reduced tactile sensitivity and reduced strength. (Health and Safety Executive, 2008 c; Constructing Better Health, undated b).
- Musculoskeletal disorders (MSDs) - MSDs include problems such as low back pain, joint injuries and repetitive strain injuries of various sorts (Health and Safety Executive, undated c). Symptoms include: aches, pains and reduced range of movement of varying severities. MSDs can be caused by: repetitive and heavy lifting; lifting awkwardly; bending and twisting repeating an action too frequently; uncomfortable working position; exerting too much force; working too long without breaks; poor posture (stooping, bending or crouching); stretching, twisting and reaching; and prolonged periods in one position (Health and Safety Executive undated a, b).
- Noise-Induced Hearing Loss (NIHL) – NIHL occurs as a result of regular, frequent exposure to loud noise which can be part of a person's job (Health and Safety Executive, 2008 d). This occurs over time and may not be noticeable until significant hearing loss has occurred which cannot be recovered. Initial symptoms include: difficulty in understanding speech in crowded environments, problems in hearing high frequencies, struggling to use the phone and confusion of words containing like 't', 'd' and 's' (Health and Safety Executive, 2009) As the condition progresses, hearing loss occurs within the middle, and sometimes, lower frequencies causing greater hearing difficulties.
- Respiratory disorders – The key work-related respiratory illnesses that are caused or made worse by breathing in hazardous substances that damage the lungs, are :
  - Chronic obstructive pulmonary disease (COPD) – Irreversible obstruction of the airways, in part caused by excess mucus and thickening airway walls. Symptoms include: chronic cough, sputum production and shortness of breath (Health and Safety Executive, 2008 e).
  - Occupational asthma - An allergic reaction that can occur on exposure to substances in the workplace which causes the airways to narrow. Initial exposure can sensitise people who, following a further exposure to the substance, can suffer an attack (Health and Safety Executive, 2008 e). The symptoms include: recurring sore and watery eyes; recurring

blocked or running nose, bouts of coughing, chest tightness and wheezing (Health and Safety Executive, 2006).

- Silicosis – An irreversible disease brought about by fine particles of respirable crystalline silica (RCS) embedding in the lungs causing scar tissue to develop over time. The symptoms include: breathing difficulties/breathlessness; rapid/shallow breathing; chronic cough; chest pain and fatigue (Health and Safety Executive, 2008 e; Wrong diagnosis, 2009).

Whilst all the sources also mentioned the growing importance of stress, it was decided to exclude this psychological condition from the study thus focussing on key physical conditions.

Data collection approach

A triangulated approach to data collection regarding the five health conditions was adopted comprising:

- Literature/research review.
- Health professional consultation – A range of professionals were consulted who either had specific knowledge of occupational health within the construction industry or were specialists in the health conditions identified.
- Workers/sufferer interviews – The intention was to interview construction workers regarding their experiences of the conditions. However accessing workers, identifying those aged 45 or over and establishing which workers had which conditions was extremely difficult and quickly revealed a preponderance to musculoskeletal disorders. As a means of ensuring that direct experiences concerning all of the conditions are collected, the sample base was widened to include sufferers from the general population who were accessed via support group meetings. Whilst the causes for their conditions were not linked to the construction industry, the consequential effects and impacts on their domestic and social activities would provide an insight into the lives of construction workers. Such activities were investigated to highlight the fact that whilst these are work-related health disorders their impact is not restricted to working hours.

For each of the five health conditions, data form the above sources was collated under the following headings:

- Description, symptoms, severity progression, frequency, impact and severity measures which would be used to inform the design of the simulations.
- Causes, risk, industry prevalence, aggravating factors, avoidance and treatment which would be used to provide context/rationale for the simulations.

SIMULATION DEVELOPMENT

Using this data, a specification was developed for each of the five health conditions to which the simulations would be designed. To reflect the variability in the severity within each condition, three levels were defined enabling each condition to be experienced in mild, moderate and severe forms. This 'idealised' specification (which will be tempered by ethical, technical, cost and time considerations during development) is currently being reviewed by relevant health professionals to confirm and prioritise attributes for inclusion.

Since simulation development and proof-of-concept activities are future phases in the project following specification approval, the impact of wearable simulations on awareness-raising within the construction industry cannot be reported at this stage. However through drawing upon Learning Theory and with reference to the role of wearable simulations in other sectors, the remainder of this paper will explore the rationale to using wearable simulations within the construction industry.

RAISING AWARENESS

Raising awareness is, in essence, an educational activity since it is designed to impart knowledge and encourage understanding concerning a specific topic. In the education field, there are a number of learning models such as those proposed by Kolb, Gregorc, VARK and Felder and

Silverman which are discussed by Hawk & Shah (2007). Analysis of such models indicates the value to learning of allowing for opportunities which support a 'hands-on' / learning 'by doing' approach. The VARK model is summarised in Table 1.

Table 1: VARK Learning Styles (Based on Drago & Wagner 2004)

Type of Learner	Preferred method of information communication
Visual Learners:	"maps, charts, graphs, diagrams, brochures, flow charts, highlighters, different colours, pictures, word pictures, and different spatial arrangements".
Aural Learners:	"explain new ideas to others, discuss topics with other students and their teachers, use a tape recorder, attend lectures and discussion groups, and use stories and jokes".
Read/write Learners:	"lists, essays, reports, textbooks, definitions, printed handouts, readings, manuals, Web pages, and taking notes".
Kinesthetic Learners:	"field trips, trial and error, doing things to understand them, laboratories, recipes and solutions to problems, hands-on approaches, using their senses, and collections of samples".

It can be seen that the traditional education/training resources of a speaker/course leader; written materials, such as handouts, and electronic presentations support the learning styles of the Aural, Read/write and Visual learners respectively but offer less benefit to kinaesthetic learners. However, wearable simulations which are used whilst engaging in simulated everyday activities would bridge this gap by providing the kinaesthetic learners with a hands-on approach and the opportunity to use their senses.

This suggests, theoretically at least, that there is benefit to using simulations to raise awareness in order to drive change within the industry as a means for extending the working life of construction workers and assisting the retention of skills. Using the simulations key staff, and young workers in particular, will be able to indirectly experience the daily challenges faced by older construction workers and, from this starting point, it is anticipated that more sympathetic design of tools, equipment, workplaces and work methods can be initiated.

WEARABLE SIMULATIONS AS A MECHANISM FOR CHANGE

Whilst theory suggests that wearable simulations will promote learning and so assist awareness-raising, their use in practice will now be discussed.

Existing simulation suits

The design and application of wearable simulations is still a novel field with fewer than a dozen organisations producing such simulations in the international arena and only a handful undertaking this in the form of Whole- Body suits. The Ergonomics and Safety Research Institute at Loughborough University, UK, has been active in this field for 15 years and has developed three whole body simulation suits, two of which are described in Figure 2 (the third remaining confidential).

The Third Age Suit ('Third Age' meaning older – typically 55+)		**Osteoarthritis Suit**	
The Third Age suit which simulates aspects of ageing was developed in 1994 for the Ford Motor Company as a mechanism for raising awareness within the design team of Older Driver characteristics and requirements.			The Osteoarthritis suit was developed in 2006 for Napp Pharmaceuticals Ltd for raising awareness within the health profession of the condition and its impacts on daily living.

Figure 2: Loughborough University Whole-Body Simulation suits

Case study – Transport sector
Using the Simulation Suit was the first step in developing 'trans-generational' vehicles (those which encompass the needs and aspirations of older as well as younger drivers) thus enabling Ford to develop vehicles more compatible with its future customer base. Use of the suit was judged to be successful on two accounts. Firstly, it was considered by Ford that greater awareness had been achieved within the design team and secondly, the impact of this improved awareness, influenced their designs. The Ford Focus has wide, high front doors; a raised "H-point" (the point at which the hips swivel) and higher seats which give better leverage when rising as you exit the car (Ford, 2000). Access/egress is further assisted by strap handles located on the inside doorframe, so drivers can grab and pull themselves into position (Ehrenman, 2003). In addition, it has the most headroom of any cars in its class and the dashboard controls are larger than those of its predecessor and have been designed to be easier to locate, grab and operate (Cambridge Engineering Design Centre, 2005).

"This is a key training and awareness tool for us. Through the suit, our engineers can understand what it's like to be in the shoes of this demographic. Our design decisions, therefore, become more in line with customer needs".
Eero Laansoo, Ergonomics Engineer[1]

The Third Age Suit "lets engineers slip into another generation, and feel for themselves what changes the body goes through that impact how a driver relates to a vehicle."
Fred Lupton, North American Program Ergonomics Supervisor[2]

"When you're young and fit enough to leap out of a car without effort, it's hard to appreciate why an older person may need to lever themselves out of the driver's seat by pushing on the seat back and the door frame. But, try leaping out while you are wearing this Suit and you really understand the challenges we face."
Mike Bradley, Ergonomics Specialist in the UK[3]

Ford Motor company (1998-2009). [2] Ehrenman (2003). [3] Gardin & Sheehan (1999).

Figure 3: Evidence of awareness-raising within The Ford Motor Company

Case study – Health sector
The Osteoarthritis suit was used by the NHS to enable staff to "have a real life experience to draw from when working with patients who suffer from a debilitating condition" (Calderdale and Huddersfield NHS Foundation Trust, 2009). By using the suit to undertake the daily activities of

their patients including – getting in and out of bed, moving from the bed to a chair, walking, feeding and dressing, staff members quickly came to realise the effort required by their patients to undertake these tasks and the difficulties which they encountered.

A variant of the Third Age suit was also used by Architects from Capita Symonds to assist in the redesign the Derby City General Hospital since the NHS Trust acknowledged that due to the ". . . increasing ageing population we need to understand more about mobility problems encountered by patients and how we can design more appropriate facilities”. As soon as the suit had been put on, the architects realised weaknesses in the design proposals, such as getting through doors, accessing patient wardrobes and reaching towels, which they were then able to change at no extra cost (BBC, 2004 c) because they were still at an early stage in the design.

Case study – Finance sector

The Third Age Suit was used by Nationwide Building Society to promote awareness and understanding of the needs of an ageing population both in terms of its employees and its members. A number of employees undertook the sort of routine activities that their colleagues and members might undertake, such as reaching for leaflets on display, getting in and out of chairs, reading promotional material, etc, whilst wearing the suit. This highlighted a number of areas worthy of further investigation including improved cash machine accessibility for members and revised workstation design for employees (Ergonomics and Safety Research Institute, 2009).

Cambridge Engineering Design Group

Independent research undertaken by the Cambridge Engineering Design Group supports the contribution of simulation to improved design. In a study of the design of domestic central heating control panels, designers were asked to assess the usability of three models, noting any problems encountered. It was observed that when using simulators of impaired physical capabilities, the number of problems identified increased substantially over the self-observation condition in which the designers directly on their own experience. Whilst use of the simulations did not identify all of the problems recorded in trials with older and disabled users nor prioritise them in the same way, it was proposed that “The physical limitations imposed by the simulators upon the designers allowed them to be more sensitive to the capability demands introduced by some actions” (Cardos et al., 2005).

SUMMARY

Since it is estimated by 2030 that: the average age of the workforce will be 43, the average retirement age will be 68, musculoskeletal disease will rise by 8% and rates of chronic obstructive pulmonary disorder (COPD) and asthma are likely to increase sharply (BBC, 2009 a); understanding and accommodating the older worker will undoubtedly become a real need within the construction industry in the future.

The benefits of wearable simulations as a mechanism for increasing awareness of the daily challenges encountered when suffering from various health conditions has been illustrated, within this paper, both theoretically and through case studies from the transport, health and finance sectors. It is therefore hypothesised that such simulations could provide a powerful means to tackle the significant challenge of integrating occupational health into some of the ‘upstream activities’ of building owners and design professionals – an activity identified as critical by this conference.

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MANAGEMENT AND PROTECTION OF HEARING AT CONSTRUCTION SITES

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ABSTRACT

The research for this project focuses on construction industry personnel and the high incidence of claims for compensation due to hearing loss from excessive noise levels on construction sites. The project aims to show the existing modes of noise management are not fully addressing the hearing impairment dilemma. Many people in the industry are still being subjected to excessive noise without being aware of the situation. A literature review was completed and demonstrated that many factors have an influence on the perception of excessive noise. The project has explored the question of whether the present management and protection of hearing at construction sites is adequate. A survey was conducted and carried out on eight (8) building sites in Sydney metropolitan area. The findings indicate that noise is affecting a wide range of workers, due to insufficient understanding of noise and inappropriate management techniques employed to ameliorate the potential damage.

Keywords: Occupational health and safety (OH & S), Hearing loss, Construction sites, Noise

INTRODUCTION

Occupational Health and Safety (OH&S) is a system of legislation which protects employees from injury at work. It is made up of rules and regulations in which employers put into place to provide a safe working environment for their employees. In Australia, OH&S applies across all Industries where people are employed to work. OH&S legislation in Australia originated from a 1956 building site, where employees were hoisting hot buckets of bitumen up to the roof of a five storey building (Safety Culture, 2006). The legislation currently in practice in NSW is the *Occupational Health and Safety Act 2000* (NSW) *(*the *"OH&S Act*"). It aims to protect the health, safety and welfare of people at work. This replaces the 1983 Act.

This research project is directed towards the on-site personnel of various building groups exposed to high levels of noise that contribute to the construction of many types of building structures throughout New South Wales and Australia, for example; in the areas of high rise, commercial, industrial, public utilities and private housing developments. These activities, from the economic perspective, contribute many millions of dollars to the economy. At a national level construction activity accounts for 6-7% of Gross Domestic Product (GDP).

A Study on "Workers' Views On Noise And Risk at Construction site" by Dineen (2001) reported that there is ample evidence that noise constitutes a significant risk to the hearing health of workers in the building and construction industry. Demographic studies have shown the incidence of noise induced hearing loss is as high as 60% in noisy workplaces (Dineen, 2001). Hearing conservation as currently practiced appears to be having little impact on the level of hearing injury to workers. Studies of the construction industry, in Australia have indicated that there is a low awareness of the risks posed by noise, with consequent minimal self-protective behaviours (Dineen , 2001)

Many people have been misinformed or lack the understanding and training to minimise the effects of high levels of noise introduced on building sites. A number of the on-site personnel have argued that high levels of noise do not affect them, and their hearing grows accustomed to the noise created in the immediate environment. Numerous personnel, itinerant and permanent employees employed in the construction industry, earn their income from the building industry. This diverse group of people are making claims for compensation due to noise induced hearing loss. "Deafness represented over 11% of all injury/disease cases reported in the construction industry. The majority of the reported cases were associated with the long-term sound exposure, as distinct from single, sudden sounds. Therefore, it would be seem advisable to consider ways in which long term exposure to sound might be reduced in this industry." (Foley, G 1996).

MEDIA AND SITE SAFETY MANUALS

In many industrial advertising brochures and the popular media, personnel are displayed using noisy apparatus and with personal protective equipment such as heavy clothing, gloves, hard hats, eye protection, leather aprons, but alas, no hearing protection. Various company site safety manuals and booklets give scant regard and direction for personnel working in excessively noisy environments. The use of hearing protection seems to be on a lower order of concerns for the authors of these manuals. Knowing that noise induced hearing loss is costing the industry $13.42 m (1994/5) in claims per year in New South Wales (Atsu, K, 1996), these manuals should focus more on the hazards of working in an excessively noisy environment.

INITIAL DATA COLLECTION

Initially sound levels were recorded on a construction site, to determine if instances of excessive noise were commonplace on construction sites.

This preliminary data was gathered using a Quest M-28 Noise Logging Dosimeter. A variety of hand-held electric tools were metered. These included: Makita 100mm Angle Grinder; Makita 170mm Power Saw; Makita 80mm Electric Planer; and Makita 13mm Electric Drill. The measurements taken were for peak levels and average dose levels. The results are given in Table 1 below:

Table 1: Typical Noise Levels

	Peak level	L_Aeq
Power saw	132.7dB	90.90dB
Angle grinder	132.0dB	94.4dB
Planer and electric drill	142.1dB	87.10dB
Planer	138.0 dB	88.60dB

These measurements are only approximate, however, they are indicative of how construction personnel can be subjected to excessive noise levels. The maximum sounds levels in New South Wales are set at 85dB (A) for an eight-hour period and peaks levels at 140dB (lin).

AIM OF THIS RESEARCH

The object of this report is to research real time data concerning the effects of noise on construction building personnel. The report will survey and gather data about the awareness of personnel to the safety and environmental conditions in which they work throughout their industrial experience. Many of the activities on site produce noise that can lead to hearing impairment. It is of paramount interest to identify and study the personnel who are exposed to the excessive noise. A personal interview survey questionnaire was carried out to establish real time data of situations experienced by on-site personnel.

LIMITATIONS OF THE STUDY

It is acknowledged that other situations can and do contribute to noise induced hearing loss, such as, shooting of guns, loud band concerts, noisy recreational vehicles, etc. However as Waugh (1991) reports: "Noise exposures outside the workplace can also cause hearing damage, but workplace noise is the predominant source of noise induced hearing loss in the Australian Community." (Waugh, 1991). Personnel who are subjected to excessive noise in their workplace need to be informed about the additional effects of noise from recreational activities. The survey questionnaire only addresses the workplace environment, and has no allowance factor or questions to adjust for contributions from recreational noise induced hearing loss.

This project is concerned with the on-site personnel who are actually engaged in the day to day activities of construction. Head office personnel in building companies will be excluded from the study, however, on-site project administration personnel who are perceived to be in noisy environments will be included. The working environment of construction building personnel in Australia will be examined especially companies in New South Wales and more specifically the metropolitan area of Sydney.

CONTEXT AND METHODOLOGY

This research project will employ the recognised scientific methods to discover data in the construction industry via the personal interview questionnaire. The personal interview technique does form a firm basis to obtain data form the personnel that are effected by noise. Conclusions will be drawn from the generated data and recommendations for new practises to reduce the impact of the noisy workplace environment.

In a study by Thomson, et al, (Thomson, 1993), into attitudes of noise as an occupational hazard, data supported that personnel:

- Accepted noise as an everyday part of the job
- Perceive noise as being different from and less serious than other health and safety hazards
- And viewed deafness as a normal, likely occurrence

A key problem in persuading personnel to protect themselves is that noise has no immediate effect, that damage is delayed and invisible. Less than 50% of those surveyed used hearing protectors when in noisy environments.

For management noise is often perceived as different to other health and safety issues:

- It is not life threatening
- There is no immediate evidence of damage
- There is no time lost off work
- No public relations problems of 'ambulance at the gate'

Some companies are trying to optimise performance on health and safety issues through the Occupational Health and Safety Act and Regulations, however, this was not at the time of the study reflected in hearing compensation claims.

WorkCover(NSW) has published a Code of Practise, Noise Management and Protection of Hearing at Work, "to assist employers, self-employed and employees to develop and implement practices for noise management" (WorkCover, 2004), in the identification of locations at which excessive levels may occur, and recommends ways to ameliorate the risk to personnel.

On sites where it is not economically possible for further reduce noise levels by technical means, steps must be taken to reduce exposure to noise that damages hearing, by encouraging personnel to continuously wear effective hearing protection. There are many types and brands of hearing protectors available through suppliers, such as, foam insert earplug type and ear muff type.

In a study of the effective use of hearing protectors reports by Ivarsson, et al (1992), showed that 28% of the participants using ear muff type, suffered discomfort in the form of heat and humidity and 29% using ear plugs complained of eczema and itching, pressure and headache were also considered as discomfort claims in the study. These devices have many drawbacks such as, comfort, inability to hear warning signals and length of use while in the hazardous zone.

The original proposal for this research project was to interview 50 site personnel and 20 site administration people. The numbers proposed were not achieved due in-part to the time constraints, costs of travel and in some cases in access to sites being declined.

The surveys were conducted over a period of three months, encompassing a variety of medium to large site in the Sydney metropolitan area. When access was gained the projects consisted of large factories, private hospitals, multi-unit dwellings, government infrastructure and multi-level hotels. A total of 76 site personnel and 16 site administration surveys were completed during the projects schedule, a high participation rate. The questions had a target audience of site personnel, supervisors, project managers working at building sites. A variety of tests related to the protection of hearing on construction site were directed through the questionnaire. The sample data accrued was extensive and will be analysed with appropriate statistical methods.

SURVEY RESULTS

The survey results with respect to the hypothesis that "the management and protection of hearing at construction sites is not adequate" are summarised in Tables 2 and 3 below.

Table 2: Respondent characteristics

	Site Personnel	Site Administration
Years in industry	Average 15.37 years, 53% between 5-25 years experience	Average 16 years experience, 44% between 5-25 years experience
Job classifications	31 classifications, from carpenters to construction worker	4 classifications, from site supervisors to leading hand
Experience on site	Average 7.2 months to experience on site with a range 1 month to 3 years	Average 8 years with a range 1 to 30 years
Wage/salary range (optional)	50% response, with 26% in $30,000 to $50,000 range	50% response, with 31% in $50,000 to $70,000 range
Have had training/induction on excessive noise	50% to 73% in different classifications answered 'yes'	Trade 13%, post trade 56%, diploma 6%, university degree 25%, range of 9 (post trade) to 4 (university degree)

Table 3: Survey response

	Site Personnel in different classifications	Site Administrators in different classifications
There has been an increase in noise producing equipment on site	49.88% to 50.11%	49.88% to 50.11%
Believe that hearing is important in their work	92% to 100%	100%
List problem noise sources	4.63 sources of noise per interview	6 sources of noise per interview
Work more than five hours a day in a noisy environment	43% to 66%	11% to 64%
Know the decibel limit prescribed by legislation	44% to 94%	78% to 94%
Believe that site administration do not measure sounds levels on site	60% to 100%	
Believe high impact, high impulse noise has some effect on hearing	84% to 97%	70% to 100%
Have never complained about high noise levels	66% to 88%	60% to 100%

Have never stopped work or had respite time due to high noise levels	75% to 91%	
Do not regularly test hearing		51% to 98%
Have never had a hearing test	52% to 74%	
Are aware of hearing protection issues	75% to 91%	60% to 100%
Think administration is aware of hearing protection	62% to 82%	
Have little or no understanding of the Code of practice	62% to 82%	35% to 88%
Are interested in training for the protection of hearing	62% to 82%	
Indicated the code was not implemented on their site		37% to 89%
Know the availability of hearing protection on the site	86% to 98%	
Do not have documentation of the Code of practice on their site		60% to 100%
Rate present hearing protectors as easy to wear	88% to 94%	81% to 100%
Have not received any information or training on hearing conservation		71% to 91%
Satisfied with the current design of hearing protectors	46% to 68%	
Have received information or training on hearing conservation		3% to 40%
Do not think noise effects them in any other way	46% to 68%	
Agree with training for site personnel's hearing protection		37% to 90%
Make hearing protection available on their sites	81% to 100%	
Do not think any change to the design of hearing protectors would encourage site personnel to wear them more regularly		30% to 84%
Do not consider low noise equipment		23% to 77%
Think that noise effects work performance, social behaviour		33% to 68%

SITE OBSERVATIONS

While conducting the survey, observations were made that indicated the level of non-compliance with the Code of practice. These include:

- Operators using concrete vibrators without any hearing protection
- Operators using large brick saws without any hearing protection
- Operators using electric planers without hearing protection
- Operators using electric rotary hammer drill without hearing protection
- Operators using electric screw gun fixing gypsum plaster board without hearing protection
- Personnel working adjacent to large rock excavators without hearing protection

CONCLUSIONS

The compensation claims of occupational noise induced hearing loss have increased throughout the early 1990's, going from 4,654 to 11,212 in 1995 and then decreasing to 10,684 in 1996/7. The reason for this decline was amendments to the Workers Compensation Act restricting the deafness claims to a minimum of 6% hearing loss for claims made on or after November 1995.

In this report the survey of construction personnel has inquired into the present state of noise management within the industry. The statistics of the site questionnaire survey have provided substantial evidence supporting the hypothesis.
The following data supports the position that:

- A simple majority of site personnel and site administration agree there has been an increase of noise producing equipment used on site in recent years
- Two thirds of site personnel and of site administration named 5 or more sources of noise of site
- Approximately half of site personnel work more than 5 hours in a noisy environment
- Two thirds of site personnel and of site administration are unaware of the 85 decibel limit set by regulation
- A large majority of site administrators do not measure sound levels on site
- A large majority of site personnel and of site administration agree that high impact and high impulse noise effects hearing
- Three quarters of site personnel have never complained about high noise levels
- A large majority of site administration have never asked personnel to stop work or have respite due to high noise levels
- Two thirds of site administration do not regularly test hearing
- Two thirds of site personnel have never had a hearing test
- Many site administrators have little or no understanding of the Code of Practice
- Most site personnel are interested in training for the protection of hearing
- Most site administrators indicated the code is not implemented on their site
- Most site administrators did not have documentation of the Code of Practice on site
- A large majority of site administrators have not received any information or training on hearing conservation
- Half of site administrators do not consider low noise equipment when purchasing machinery
- Most site administrators do think noise effects work performance, social behaviour and physical well being

The survey also indicates the site personnel and site administration responses are grouped within training areas, knowledge and understanding of the code. The data and information contained within this report, at the time of the survey, strengthen and corroborate the hypothesis: “That the management and protection of hearing at construction sites is not adequate.”

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SAFETY HAZARD IDENTIFICATION BY ADOPTING MULTI-DIMENSIONAL SIMULATION AT EARLY DESIGN STAGE FOR THE CONSTRUCTION INDUSTRY

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ABSTRACT

Researchers generally agree that the construction industry is one of the most hazardous industries in the world. In order to reduce the number of construction accidents, preventative control and precautionary control are adopted by construction safety management. However, it is understood that only very limited resource is allowed for the user to consider safety an issue as preventative control. Previous research efforts and weaknesses of preventative approaches are addressed. A new application of a multi-dimensional simulation tool which can integrate safety considerations is introduced. The user is allowed to conduct safety assessment in a virtual environment before the start of actual construction. The process of applying this technology and the viability of this application are also be discussed

BACKGROUND

Construction industry is one of the most hazardous industries in the world (Jannadi and Bu-Khamsin, 2002). In the USA and UK, construction workers are several times more likely to suffer from accidents than in other industries (Carter and Smith, 2006). The situation of Hong Kong construction industry is studied and presented as follow.

The number of industrial accidents in Hong Kong construction industry had obviously reduced from 19 588 to 3042 during the period of 1998 to 2007. At the same time, the number of construction workers reduced from 79 007 at 1998 to 50 185 at 2007. Despite the impressive improvement in safety performance of Hong Kong construction industry, the safety performance of construction industry is still unacceptably worse than that of any other industries in Hong Kong.

The accident rate per 1000 workers is reportedly the highest among different industries in Hong Kong. Comparing the data of 2007 with manufacturing industry, the construction industry has nearly 4 times higher accident rate and nearly 1.5 times higher than catering industry in Hong Kong while these three industries are reported to have the highest accident rates.

Table 1. Industrial Accidents in Major Industries in Hong Kong (1998-2007) (Occupational Safety and Health Council, 2007)

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
No. of Accidents										
Construction Industry	19588	14078	11925	9206	6239	4367	3833	3548	3400	3042
Catering Industry	13011	12549	12621	11914	10149	8527	9410	8902	9294	8876
Manufacturing Industry	6334	5499	5436	4385	3636	2719	2936	2912	2949	2735
Acc. Rate / 1000 Workers										
Construction Industry	247.9	198.4	149.8	114.6	85.2	68.1	60.3	59.9	64.3	60.6
Catering Industry	73.9	66.9	66.2	61.5	54.7	49.6	51.5	47.3	47.2	43.5
Manufacturing Industry	24	22.2	23.4	20.7	18.8	15.7	17.5	17.7	18.4	17.4

Not only the number of accidents, fatal accidents occurred in the Hong Kong construction industry is also far more than any other industries in Hong Kong. The number of fatal accidents in construction industry is about 76% of total fatal accidents occurred during 2007 in Hong Kong. Fatality rate for construction industry is about 20 times higher than manufacturing industry which is the second high fatal rate industry in Hong Kong during 2007.

Usage of advanced technologies and equipments in the construction industry has dramatically improved working conditions. As a result, construction accidents are now believed to be due mainly to human failures and organizational factors (Mitropoulos *et al* 2005). In this paper, it will be focus on the human failures at the early design stage, which is believed to be mostly neglected in Hong Kong construction project.

Table 2. Fatal Accidents in Major Industries in Hong Kong (1998-2007)
(Occupational Safety and Health Council, 2007)

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
No. of Fatalities										
In Construction Industry	56	47	29	28	24	25	17	25	16	19
In Catering Industry	0	0	2	0	0	0	0	0	0	0
In Manufacturing Industry	2	2	3	3	0	2	2	0	6	3
In all Industries	68	52	43	34	25	28	24	29	26	25
Fatality rate/1000 workers										
In Construction Industry	0.709	0.663	0.364	0.349	0.328	0.390	0.268	0.422	0.303	0.379
In Catering Industry	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000
In Manufacturing Industry	0.008	0.008	0.013	0.014	0.000	0.012	0.012	0.000	0.037	0.019
In all Industries	0.102	0.080	0.066	0.053	0.042	0.051	0.043	0.053	0.047	0.045

Existing Safety management Problems at Early design stage

During design stage, it is hard for construction team to identify hazardous activities before actual construction begins. There are two reasons which cause the difficulty. Construction planning, which is represented by critical path, and 2D drawings are usually adopted in construction industry for hazards identification, and yet, both practices are inadequate for safety management team to identify possible hazards. The use of these two traditional construction practices could undermine the probability for hazards identification in several ways.

The first problem associated with drawings was pointed out by Collier (1994), who believes that the drawings and method statements provided to the construction team are only texts and 2D drawings and thus, it is difficult for safety management team to understand all the information. If the safety management team cannot understand all the information, it is quite impossible for them to identify all dangers before start of construction. Similarly, Hartmann and Fischer (2007) believe that different parties perceive dissimilarly from the drawings, which leads to consentaneous problems.

Even if the safety management team can understand all construction information from drawings and texts, there is only limited information regarding the construction process. Construction of building elements would need more information then only drawings of the product, but resources and space employed by the construction process should also be considered. Young (1996) strengthens the same idea by stating that the 2D drawings may only represent construction components like wall, beams and columns but the construction process is not presented. Without information about construction process, it is difficult to predict the potential risks such as interaction between moving objects, which is found to be one of the most common causes of construction accidents in Hong Kong construction industry. Hadikusumo and Rowlinson (2002) vowed to agree the idea by stating that the traditional way to conduct construction site safety hazards identification, which is to use contract drawing issued by consultants or designer, is obviously difficult in translating these information into picture for planning purpose.

Without changing the whole construction practice in Hong Kong, the traditional construction practice undermines the safety management on site. It will require excessive time and efforts to establish a successful hazardous identification during early stage by introducing new technique to tackle the current difficulties encountered.

Construction Virtual Prototyping

In order to tackle the safety problem during early design stage, advanced technology is required to assist the planner and safety management team to verify their construction plan. Construction Virtual Prototyping (CVP) could be one of the best solutions to the situation. CVP aims to provide a simulation of construction process and its development has made remarkable progress in Hong Kong in the past few years. According to Li *et al* (2003), the implementation of CVP requires information such as site layouts, sketch drawings of building components and their assemblies. Equipments needed for construction are established and the associated building labours are defined. Knowledge base and resources database is updated and the resources planning is completed once information is collated. This is carried out by editing the PERT chart of the CVP. Motions and activities of site resources (e.g., product motion, grab, release and hyperlinks) are identified and building components within the CVP system is moved by these construction resources. Labour activities are also defined at this stage. When the above-mentioned processes are completed, the simulation of construction processes begins. Comparing with any other simulation tools available for the construction industry, the captioned tool shows a superior ability toward other simulation tools due to the ability to consider the temporary works design.

The benefits of CVP are well known. For example, design constructability, anticipated shortages and pitfalls before execution of the construction works can be checked and rectified (Huang *et al* 2007). Therefore, project planners are assisted by CVP in the modification of design and decisions making on constructability problems.

A case study has been conducted to specifically investigate the effect of CVP (Li *et al* 2008). The result shows that project team members are generally satisfied with the enhanced performance from the assistance of CVP. This tool has completed more than ten projects in Hong Kong so far and the categories of completed projects are found to be comprehensive. Although the tool is well adopted in the Hong Kong construction industry, there has not been any study carried out to explore the possibility and viability of integrating this tool with construction site safety.

While the value of CVP is proven in its ability to help improving project planning and management, it has never been used for construction safety considerations. In the following section, a case study interprets how CVP is used as a tool to identify hazardous activities in the early design stage.

The Proposed Multi-dimensional Simulation Method

<u>Background</u>

Its application begins with building 3D components. To achieve this objective, it involves consideration of the mechanics of the construction of elements. Different construction resources, such as tower cranes and temporary works are prepared and then the simulation of the construction process begins. The simulation relies on the construction program and method statement available. After the simulation is completed, a report that includes a video record of the simulation, together with any comments from the system, is passed to the construction team. The construction management team and safety management team will check for any problems. They could also comment on any necessary modifications to the CVP team. The process will be repeated until a successful outcome is obtained.

<u>Flow of Information</u>

The flow of application of CVP to simulation an atypical installation activities of a construction project is illustrated in the following figure.

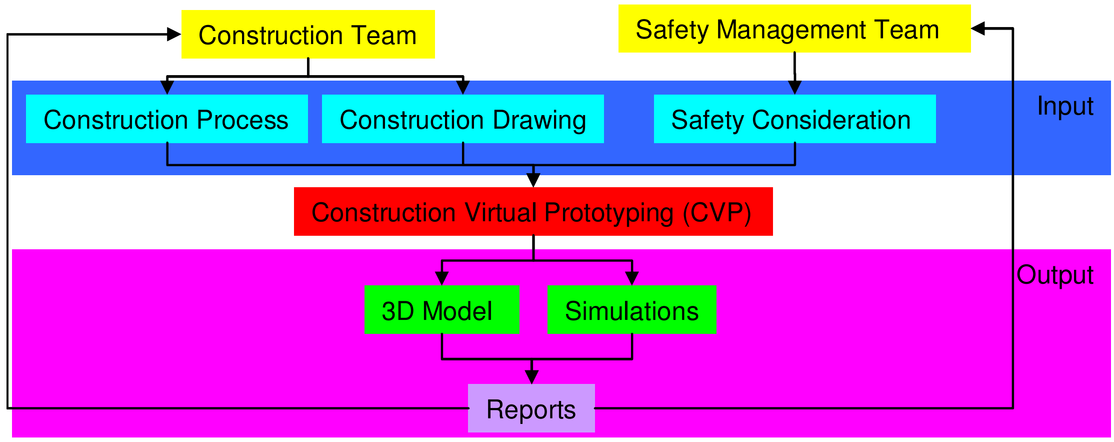

Figure 1. The flow of information

The application of CVP to the construction industry will act as a tool to assist the safety management team to consider safety issues in advance of schedule of construction. The tool can automatically detect collisions between different components for design improvements. However, it will not be contributing at the same area for safety management. All necessary information (input), if available, should be collected at early design stage. The considerations and concerns from the safety management team should also be collated. By integrating all collated information, CVP can generate two different kinds of information, which are 3D models and different simulations (output). The information will be converted to reports which could be easily read and understood by the construction team and safety management team. Both teams could amend the input to further modify the output so as to try the combination of different methodologies and resources in the virtual construction environment provided by CVP before actual construction begins. Once the 3D model is confirmed, changes in any other input information would require lesser time to conduct changes in the simulation. So, the cost for verifying different construction methods and programmes with different resources would be reasonably cheap and risk-free when comparing with conducting real life mock-up experiment.

Three-Dimensional Modelling

The Three-Dimensional (3D) model will be constructed according to the technical drawings available. All dimensions of the model should be built exactly the same as the available information. The 3D model will be useful for identification of available working space. The principle and benefits of constructing three-dimensional modelling for planning and management have been discussed by Li *et al* (2003) and Huang *et al (*2007), which the benefit for safety seems not to be involved however. It could be understood that the 3D model would consider all construction components, including the proposed building, temporary work and required resources. The combination of all these components will ensure that the safety management team can experience a “close to reality” environment for them to design a safety plan at early design stage.

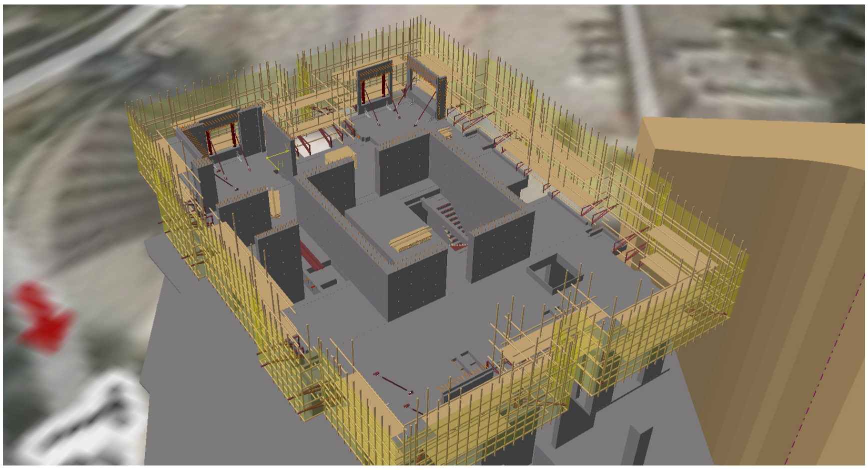

Figure 2. The 3D model as completed by CVP

<u>Simulation of Construction Activity</u>

After importing all construction components as mentioned above, the simulation of construction activities can be started. Unlike any other simulation tools, the simulation of construction activities does not only show and hide for particular construction components according to the construction sequence, but it will also simulate the manufacturing processes of all identified resources. For example, the system will simulates the manufacturing process of tower crane to transfer the construction material from initial location to assigned location. The simulation will also calculate the transfer path performed by the tower crane, thus the safety management team will be able to manage the interactions between different machineries.

<u>Human Ergonomics</u>

In contrast with project planning, the simulation for hazard visualisation and identification involves comprehensive human ergonomic simulation to simulate the construction acts of construction workers. Body structure of virtual humans was created very similar to real human, which contains information such as appropriate angles of movement for different joints. The virtual humans comprise a total of 46 adjustable different segments, with the limited degree of movement acquired from real human. Thus, the simulation of workers' postures could be carried out by the simulation.

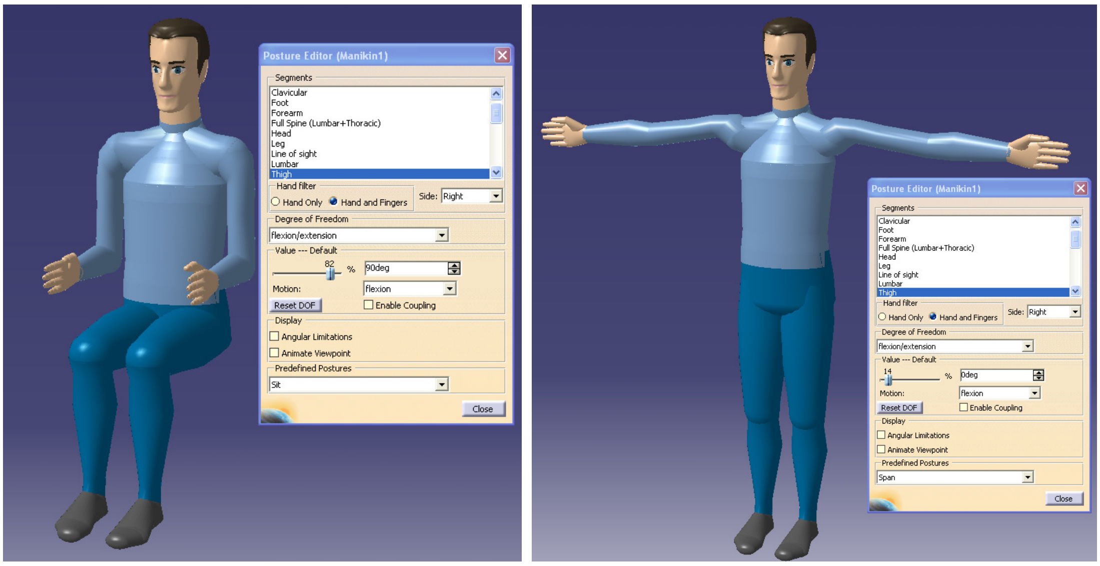

Figure 3 and 4. The simulation of human posturing

To simulate working posture of workers, the application will require you to set the initial posture and the final posture. Afterward, the system will automatically calculate the interim movement. The calculation will also depend on the database of a virtual human, which provide limitation on the space of movement of different joints, so that the move of joints will be closed to reality.

The simulation of the worker's postures can ensure that the environment will be adequate for the worker to conduct work safely. It would enable users to notice any clashes between the worker and the building component. If clashes are detected during the simulation, the working posture of the worker or the working environment should be amended at early stage to prevent any potential risk.

In addition to posture simulation, the system can also insert virtual human with different physiques. For some construction activities carried out in confined space or any other activities with extremely limited working space, this function could assist the planner to determine if physique could be one of the factors affecting the safety performance.

When Worker A and B in figure 5 is to perform the same working posture at the same working environment, the working space required would be different due to the differences in their physiques. Figure 6 and 7 indicate that the working space for worker B is found to be insufficient and could eventually hurt himself during the operation by hitting the wall or slab of the confined area.

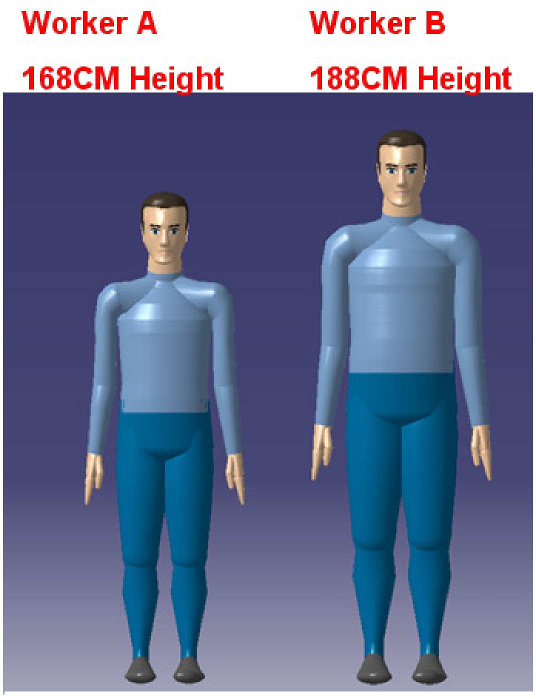

Figure 5. Different physiques of virtual human

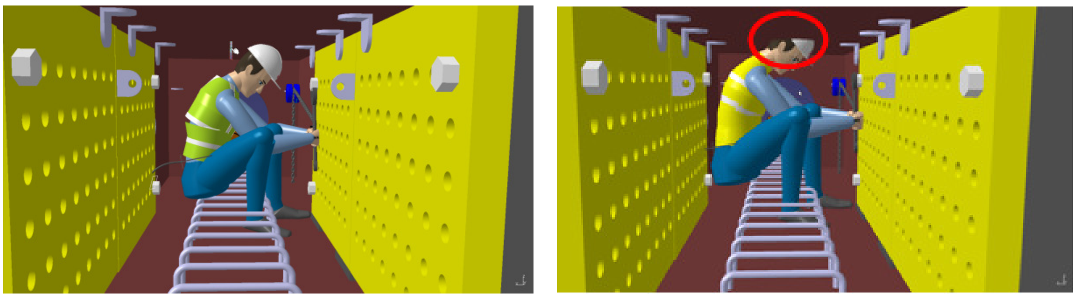

Figure 6 & 7. The comparison of worker in different physiques working at the same environment.

Eyesight

By inserting a virtual human into the simulation, another valuable function is to share eyesight from the inserted human. The eyesight could be recorded during the whole simulation period. So, the eyesight shows not only the situation of a particular construction stage, but also changes of the environment against the flow of the construction process.

The shared eyesight does not only identify hazardous activities, but also inform the planner if the worker could possibly identify potential hazards in the working condition. For example, the worker may not be able to keep sight of the interaction of two mechanisms at the same time. The early simulation of the eyesight could assist the planner to verify if more workers are needed to carry out the operation.

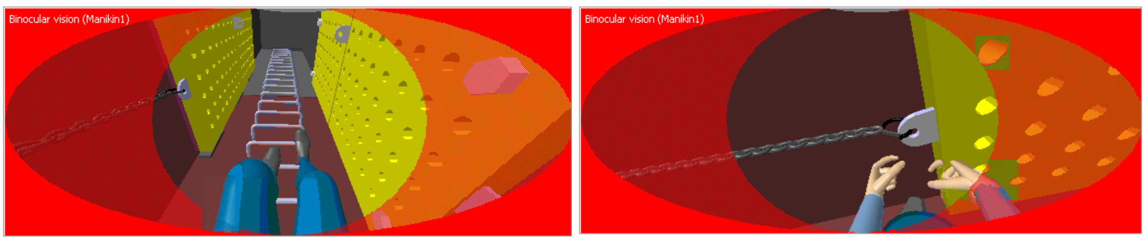

Figure 8 and 9. The eyesight shared by the virtual human

In figure 8 and 9, it shows that the eyesight shared by the virtual human within the virtual reality. The eyesight can indicate the focus of the vision and thus, the planner could easily notice that the workers would be in dangerous if their eyesight are blocked by other construction components. The planner may also wish to manage the construction activities on site if it is found that the workers may not be able to keep his sight on several important items while carrying out the installation work, which interactions between these items could lead to construction hazards.

CONCLUSION

In its standard form, the CVP is not a tool that can automatically identify construction hazards, however it does provide a proactive approach to assist the management team in planning very detailed aspects of particular construction activities at a very early stage. The simulation of worker's posture can substantially change the traditional hazard identification method of using only drawings and texts. This approach creates a new platform for the management team to discuss and consider the validity of construction planning in detail at the early design stage. By repeating the process, it is possible to identify the optimal construction methods for carrying out activities so as to fulfil both safety and scheduling requirements.

In addition to provide a platform for the management team to test and evaluate construction activities at an early stage, the system enables user to visualize construction information in a 3D or 4D format. The visualization do not only save the time of different team members in reading all the necessary information, but also ensures they will not misunderstand the 2D drawings and method statements. The visualization can also improve the construction safety management team's understanding of the project, which should enhance the safety performance of the project.

Finally, it should be noted that successful simulation can also be used as a means of training workers before construction begins. The provision of 4D formal training material should lead to improvement on workers understanding with complicated construction information.

LIMITATION AND FURTHER STUDY

Despite the discussed strengths of the approach, there are still some weaknesses in need of attention. Firstly, in order to build a detailed simulation, a great deal of information is needed. However, this information is often difficult to acquire at the early design stage as most of the information is only confirmed immediately prior to start of actual construction. Secondly, the simulation of human ergonomics is extremely time consuming and requires extensive manpower to conduct. Also, the simulation of human movement is more an issue for robotics than human ergonomics at present due to the calculation of the interim movement by computer.

Further study is needed to investigate the level of detail required to obtain optimal results with the least amount of information. This should lead to the acceleration of the simulation of human ergonomics.

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USING ENQUIRY-BASED LEARNING AND MULTIMEDIA INNOVATION TO ENHANCE CONSTRUCTION SITE HAZARD MANAGEMENT EDUCATION

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ABSTRACT
An inquiry-based learning project within an undergraduate occupational health and safety module has facilitated the development of an innovative learner-centred multimedia tool. The project was funded by the Higher Education Funding Council for England as a 'research-informed teaching project'. It involved students as enquiry-based learners participating in the researching, development and production of an innovative construction site 'hazard awareness' multimedia learning tool.

The development and production of the DVD teaching and learning tool was built upon cross-discipline student research, involving undergraduate students of construction–related and media production programmes of study. The project also involved collaboration with a main contracting construction organization so as to facilitate access to a construction site of significant size for the production of suitable supporting film footage and photographs.

This paper introduces the student-developed construction site hazard management multimedia learning resource and documents the research-led development process. Feedback regarding both the project and the resulting learning resource has been strongly positive. This is outlined along with the potential benefits of using enquiry-based learning approaches.

Keywords: Construction site hazards, Inquiry based learning, Multimedia

INTRODUCTION

The use of hypervideo within the curriculum of building technology modules at Hong Kong University is described by Haase et al (2005). Here hypervideo "allows the authentic visualisation of building design and the combination of video objects with other symbol systems (such as picture, texts and narrations) by the integration of hypervideo links". Here hypervideo is used to document real situations, such as a complex construction site environment, and then facilitate the teaching of design and technology of buildings. This paper documents how the use of hypervideo has been extended and applied to an occupational health and safety context.

A project within an undergraduate health and safety module tasked students with researching construction site safety hazards, preparing electronic presentations and contributing towards the development of a learning resource.

The underlying intention of the project was to facilitate pedagogical improvements within the undergraduate health and safety module. This was to be achieved through enriched engagement with a 'key aspect' of the health and safety curriculum in a student-centred, inquiry-based manner. The 'key aspect' for this 'enriched engagement' was hazard management.

THE RESEARCH-LED DEVELOPMENT PROCESS

Final year Construction undergraduate students were required to study and complete a Health and Safety Management module. As part of the module assessment, students had to identify commonly occurring construction site hazards and investigate documented case study examples of poor management practice. The researching of health and safety hazards and incidents occurring on construction sites involved students carrying out desk top studies, visiting sites and interviewing construction personnel. Further to this students researched good practice and relevant regulatory requirements and documented their research findings in the form of electronic presentations. Such electronic presentations commonly took the form of standalone ‘PowerPoint’ or ‘Flash’ files and were intended to contribute to a collectively-developed DVD learning resource.

The ‘hazard management presentation’ assignment was first delivered to built environment students on the H&S module in the 2006-07 academic year and the research exercise was repeated again in the 2007-08 academic year.

After the ‘first run’ of the assignment in 2006-07, a batch of over 30 hazard management presentations were submitted and assessed. With the permission of the student cohort a number of these presentations were complied into a ‘pilot’ CD learning resource. This resource was entitled ‘Hazard Management in Construction Projects’, contained nineteen presentations and sought to provide for the development of knowledge and practice regarding safety hazard management on construction projects.

Copies of this pilot learning resource were made available on CD for use by students studying on the Health and Safety module during the following 2007-08 academic year. Furthermore, the ‘hazard presentation’ exercise was also repeated for the academic year 2007-08.

By the end of January 2008 there was a sufficiency in both breadth of topic and number of student presentations submitted to enable the final production of the learning resource (combining ‘film with embedded presentations’ together to create the learning resource. Media Production students then had the job of taking the electronic presentation from the Construction students and combining them all into a single interactive resource. Visits were made to the construction site in order to plan film shots of work activities and aspects of the workplace of relevance to the site hazards identified by the construction students. After a number of ‘reckies’ footage was taken for production of the hypervideo. Panoramic photographs of the site were also taken in order to provide viewers with a virtual 360 degree view of various locations of the construction site. A script was prepared to accompany the film footage and a voice over recorder by a BBC news reader. The film footage, panoramic photographs and student presentations were then ‘knitted together’ to produce the student-developed DVD learning resource that users can watch and click within in order to be directed to embedded presentations.

Figure 1 illustrates students undertaking production activities - filming and documenting site activity.

Figure 2 presents a diagrammatic representation of the project process.

Figure 1 Students undertaking production activities - filming and documenting site activity

THE STUDENT-DEVELOPED SITE HAZARD DVD LEARNING RESOURCE

The developed learning resource is a DVD that takes the viewer on a journey around a construction project - the redevelopment of Newcastle upon Tyne's Royal Victoria Infirmary. The video journey is full of clickable objects which extend the opportunity to watch 27 embedded presentations, each highlighting a particular health and safety hazards and any associated good management practice.

The DVD contains some 5 sections:

- 'Introduction';
- 'Hypervideo';
- 'Panoramas';
- 'Hazard Types'; and
- 'Credits'.

Access to and between these sections is as simple as the click of a button. The 'introduction' section informs the viewer of how the resource came about. Following on from this, the 'hypervideo' section which informs the user of 'how to use the resource' and presents a film of a major construction site. The hypervideo is structured into 12 categories of hazard, each commonly encountered on construction sites. The twelve hazard categories are: asbestos, concreting, confined spaces, cranes, electricity, excavation, fire, movement around site, protecting the public, scaffolding, slips and trips and working at height. Within the twelve categories of hazard are some 27 student presentations and 5 hours of viewing. ***Figure 3*** provides some examples of screen shots extracted from the learning resource.

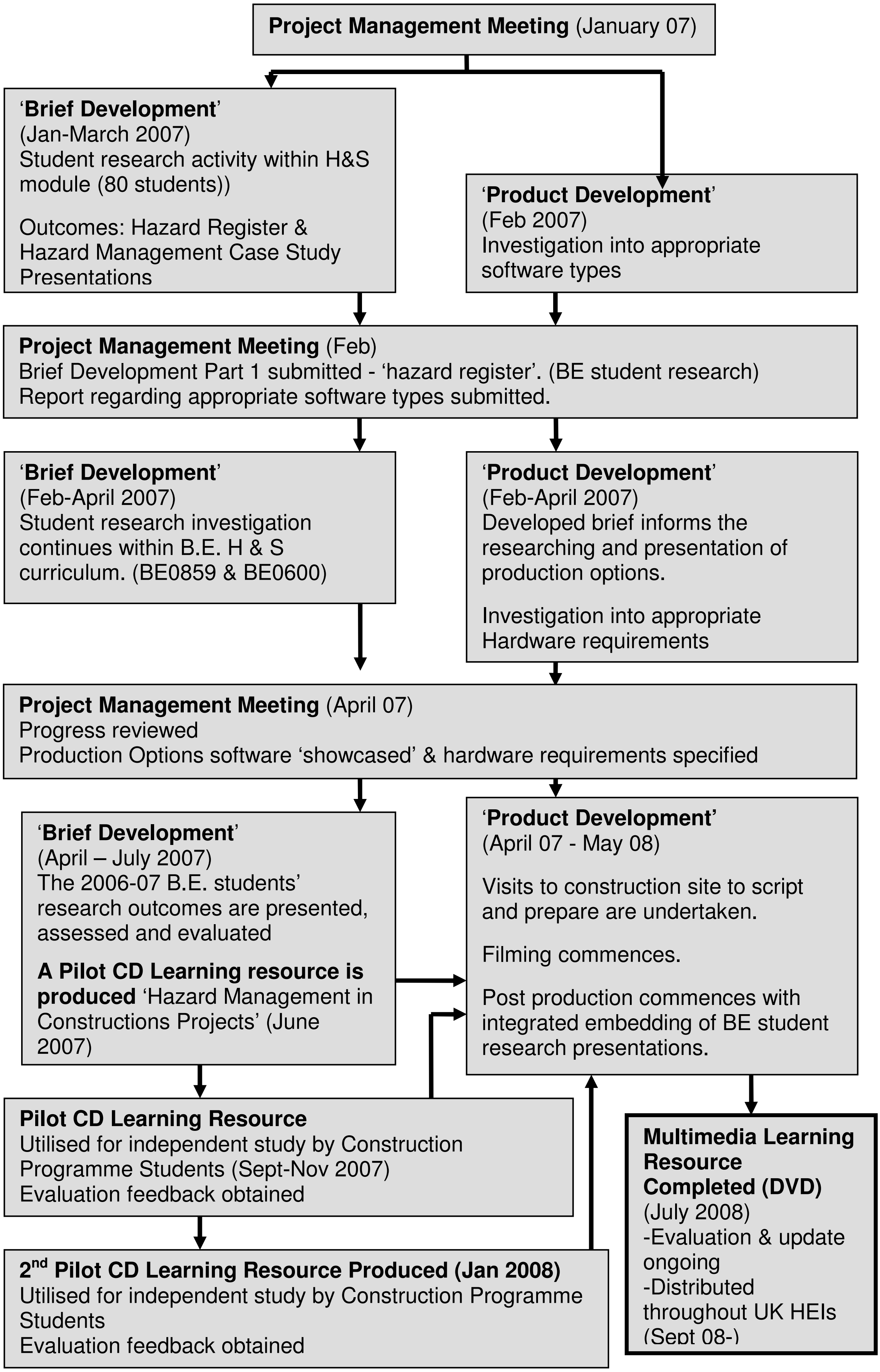

Figure 2 **Diagram of the Project Process**

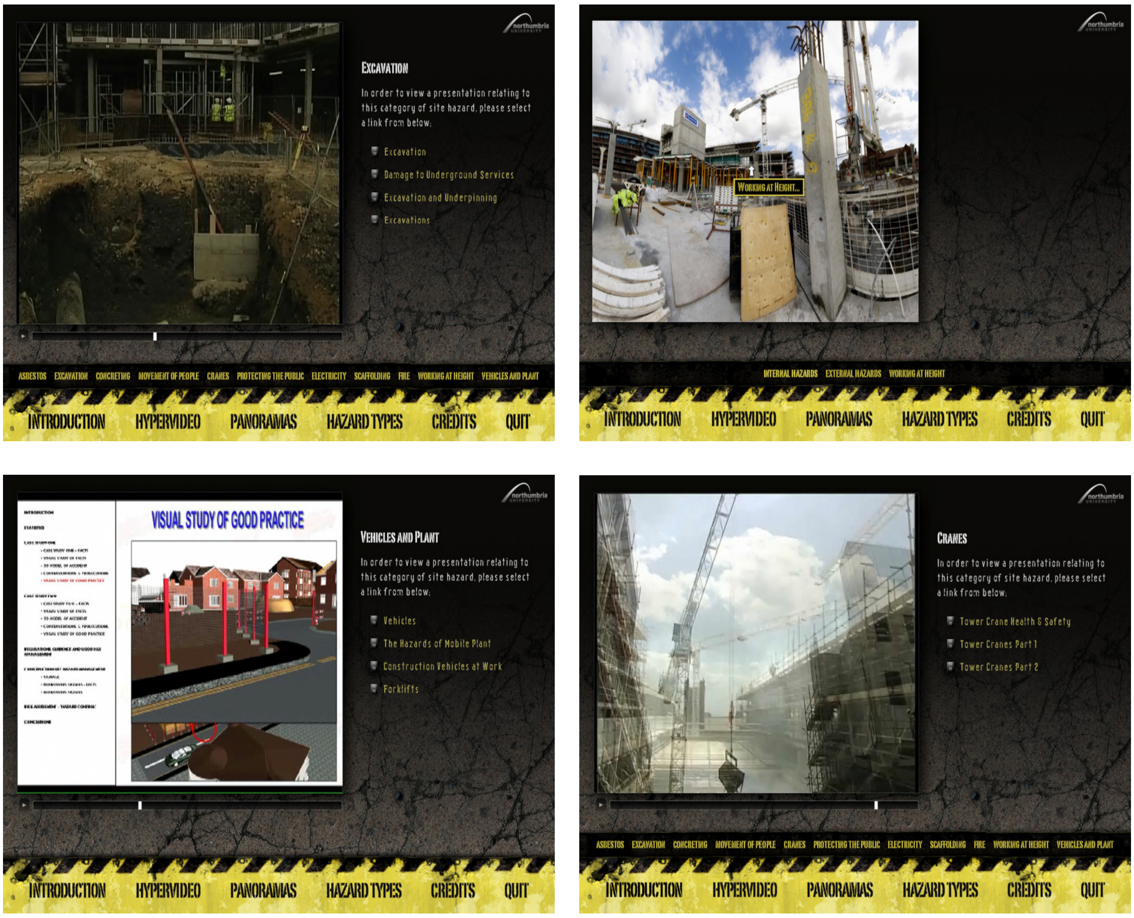

Figure 3 Screen shot pictures extracted from the learning resource

A SHIFT FROM THE TRADITIONAL MODEL OF THE RESEARCH AND TEACHING RELATIONSHIP

This project has engaged students as ‘inquiry-based learners’ and as such learners have undertaken research activity – to such an extent that the built environment and media production students can be said to have undertaken ‘research into practice’. This engagement is far removed from a ‘traditional model’ of teaching and research. Brew (2003) describes such a traditional model in figure 4.

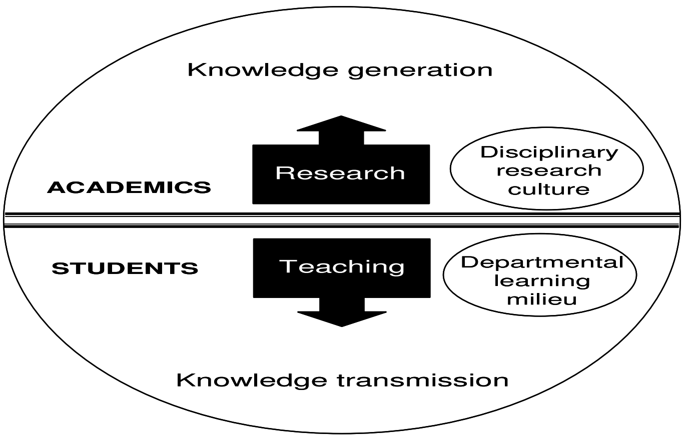

Figure 4 Brew’s Traditional Model of Research and Teaching

Unlike the traditional model, this project has facilitated an approach to the curriculum where students engage as participant researchers. This is an approach that is supported by Healey and Roberts (2004) who suggest that students are likely to gain most benefit from research, in terms of depth of learning and understanding, when they are also involved in research through various forms of active learning, such as inquiry-based learning.

Griffiths (2004) recognises a move away from the traditional Brew model of teaching and research links within university programmes. A typology that can be considered as useful for describing research-teaching links is presented by Griffith (2004), here four distinct dimensions of practice are described:

- Research-led – learning about others' research, focus on subject content;
- Research-oriented – learning to do research, inquiry skills;
- Research-based – learning in research mode, inquiry-based activities; and
- Research-informed - pedagogic research, enquiring and reflecting on learning.

Jenkins and Healey (2005) drawn upon Griffith's work to establish a diagrammatic representation of the Typologies of Research and Teaching. Figure 5 presents this diagram of typologies. The key dimensions of the site hazard project's teaching and research links are indicated and highlighted on this diagram.

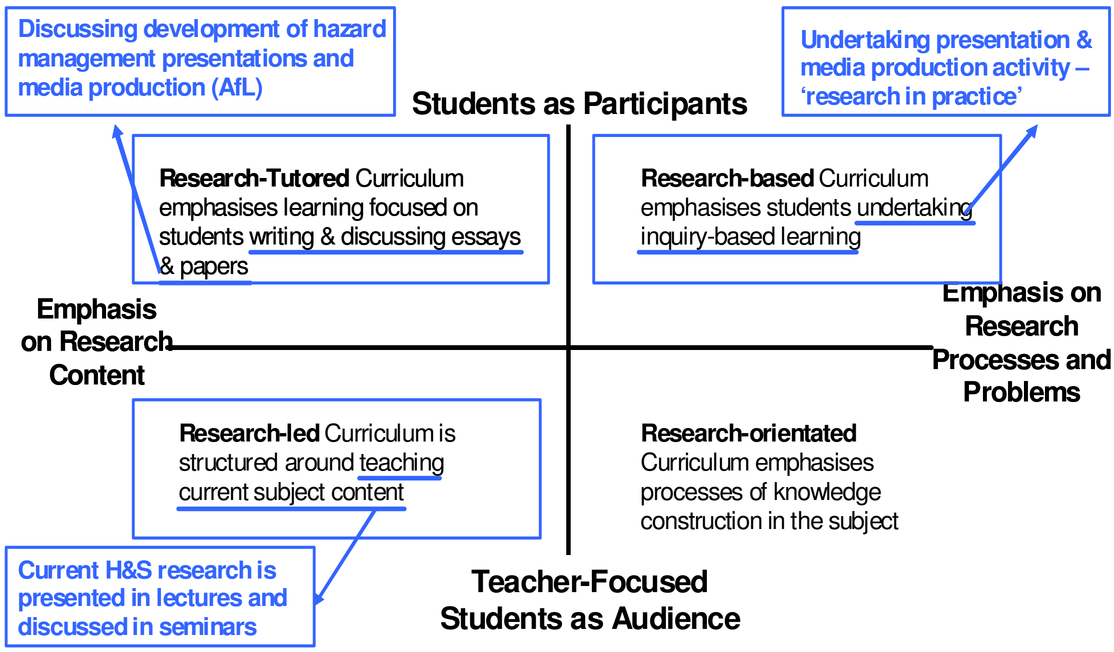

Figure 5 A Typology of the Project's Research-Teaching Links
(Developed from: Jenkins, A & Healey, M. (2005)

As well as improving the module's health and safety curriculum with regard to integrating and strengthening research and teaching links, the project also served to enrich the assessment of the module through close alignment with CETL's (200() principles of assessment for learning (Figure 6).

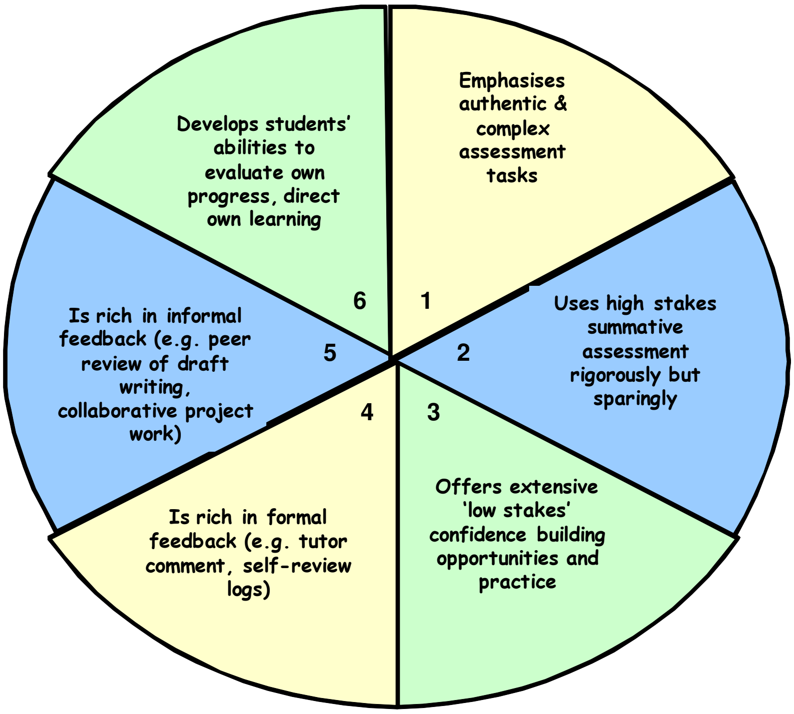

Figure 6 Principles of Assessment for Learning (CETL 2009)

DISSEMINATION OF THE RESULTANT LEARNING RESOURCE

The project engaged some 180 students in inquiry-based research during a period of 18 months. Since completion and production of the DVD learning resource, over 200 Built Environment students have viewed the resource at the author's H.E. Institution. The resource has also been publicised via two external websites. The first being 'Construction Knowledge Exchange' a government established in August 2004 with the aim of promoting links and collaboration between higher education and the construction industry. The second website was that of 'The Centre for Education in the Built Environment', a subject centre of established to provide 'discipline based support to enhance the quality of learning and teaching in the UK Higher Education Built Environment community' (CEBE 2009). Further to this publicity the resource has been requested by, and dispatched to some 50 Higher Education and Further Education institutions across the UK.

FEEDBACK

Feedback and evaluation of the learning experience and the resultant student-developed learning resource has been positive. With regard to the development process, 38 students returned an anonymous questionnaire. In answer to the question 'has the assessment been worth while? In what was it (not) worthwhile? The qualitative feedback was entirely positive and included the following comments:

- Expanding on my knowledge of H and S and developing my knowledge on how to complete risk assessment, very important for professional development
- Unconventional method meant more emphasis was placed on content and getting it right
- A good approach to the assignment using new techniques and presentation techniques. Also means ongoing learning for other students - by future use of the DVD
- Learned a lot of different cases, very topical which meant was enjoyable and interesting, very relevant for site work
- Interesting assessment format - rather than exams
- I had no idea of health and safety in any way before this module
- Made sure research is carried out and presented in an appropriate manner. Made project fun as well as educational

- Offered a chance to look at a variety of hazards, in others' assignments as well
- Very helpful ahead of going out on site after graduating
- Increased knowledge of health and safety legislation developing research skills and presentation skills
- The presentation enabled us to learn from what we presented rather than just forgetting what we'd done afterwards
- Interesting approach to help info sink in
- It has improved my knowledge and skills of risk management. I am more confident now
- I gained new knowledge, new skills, and found it enjoyable
- I can clearly identify importance of H and S in practice

Feedback and views have also been sought regarding the developed learning package from resource users, including the student-developers, other students and academics. Anonymous questionnaires facilitated the collation of feedback regarding the construction students' experience of the DVD resource. This feedback revealed that the learning package is perceived as easy to use and has a number of commonly reported strengths – it's easy to understand, enables self learning, provides an interesting approach to the topic and is portable, to list but a few. Importantly no significant limitations have been reported by users of the learning package. One student commended the package as being 'highly relevant to construction site management and also very useful for developing personal awareness of the many hazards potentially encountered on site'.

The positive feedback has not been limited to students engaged in the research process and to students who have subsequently used the developed DVD resource. Teaching staff who have provided feedback have commented favourably - one UK professor stated in a feedback email

> "This is an excellent and innovative construction health and safety learning resource that supports a good depth and breadth of relevant study. The resource is innovative in terms of its learning and teaching approach to construction health and safety and is a very user friendly. I am not aware of a similar tool within this particular domain and welcome this novel approach. [Our] University intends, with permission, to use this resource with our students and part-time professional practitioners to enhance the study of health and safety. This learning tool will no doubt effectively support our on and off-site delivery and will be particularly useful to students who are learning at a distance."

PERCEIVED BENEFITS

The project can be considered to have delivered a number of benefits. It has:

1. Refreshed the pedagogy of the health and safety curriculum through student-centred, inquiry-based research activities;
2. Delivered an innovative and interactive student-developed learning tool - a student research output for future use within the curriculum - the 'Construction Site Hazard Management' DVD learning resource;
3. Provided the opportunity to interact and work collaboratively across traditional university discipline 'boundaries';
4. Enhanced research-teaching links within the construction safety management and engaged Built Environment students with research activity that has informed and underpinned the H&S subject content of the hyper-video;
5. Engaged Media Production students with 'research as practice' (action research) – in a manner whereby they have been contracted by the built environment client to research, film, edit, produce and deliver the required hypervideo DVD;
6. Enabled Media Production students and staff to engage with the field of hyper-video production, - a new aspect of learning for both the staff and students;
7. Further ensured that students of the Construction Programme and Media Production Programme have attained learning outcomes pertinent to the knowledge economy. Each student has gain professionally–focused research experience that is relevant to their own

professional context, as well as carrying out and developing a range of research skills. Specifically, Construction Programme students have, through an inquiry-based approach, gained contemporary knowledge and awareness of construction site hazards and good health and safety management practice. Media Production students have participated in a 'real life' production project.

CONCLUDING SUMMARY

Engaging, relevant and challenging health and safety learning experiences are essential for the development of people with suitable knowledge, competence and excellence in practice. This paper has reviewed a case study example of an engaging, relevant and challenging health and safety (hazard management) learning project. The project's research-led development process has been outlined and the resultant student-developed DVD learning resource has been introduced. Feedback concerning this resource has been highly positive and the benefits of conducting the project are considered numerous.

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E-LEARNING FOR CONSTRUCTION SAFETY TRAINING IN THE AUSTRALIAN CONSTRUCTION INDUSTRY

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ABSTRACT

This paper investigates the current level of application of e-learning approaches for safety education and training in the Australian construction industry. The key issues discussed include the extent of uptake, its effectiveness, possible barriers and future implications of e-learning for construction safety training. Telephone interviews and case studies were used with regulatory bodies, teaching institutions and trade associations to collect relevant data. An action research methodology was adopted in which the authors trialed e-learning packages in order to draw comments. It was found that both face-to-face and e-learning are being used as training methods with an increasing trend towards e-learning. High initial cost and lack of IT skill are the main barriers for e-learning development. It is concluded that e-learning is feasible and valuable for most construction safety education and training, but further research is necessary into understanding its effectiveness and worker acceptance as well as learning outcomes.

Keywords: E-learning, Construction safety, Training

INTRODUCTION AND RESEARCH AIMS

E-learning for safety training and instruction has not been adopted widely in the construction industry. What factors influence the uptake of this technology?

E-learning has advantages such as flexibility to access the courses from remote locations at convenient times, ability for students to self pace and interrupt the course to suit individual attention spans, easy monitoring of course quality and ability to use the software as a screening and a refresher tool.

Conversely, high implementation cost and limited IT familiarity are issues for a large part of the construction industry. Availability of appropriate internet access, the need for computer literacy and a willingness to accept e-learning are issues for the learners. Teaching organisations require support to be able to make use of this technology. Regulatory authorities are concerned about probity. Opinions about quality of e-learning outcomes are divided among training providers and regulators.

The aim of this research is to understand the feasibility and current state of application of e-learning for construction safety training in the Australian construction industry and identify its potentials.

GOVERNMENT TRAINING REQUIREMENTS FOR OCCUPATIONAL HEALTH AND SAFETY (OH&S) IN AUSTRALIA

The “National Code of Practice for Induction for Construction Work” developed by the Australian Safety and Compensation Council (ASCC) sets a national standard for different types of induction required on construction sites. It specifies the following 3 modes of delivery:

- General induction: 6 hours face-to-face training delivered by Registered Training Organisations (RTOs). Assessment is required.
- Site induction: There is no nominal duration; training should be delivered by a competent person. No requirement for assessment.
- Task-specific induction: Same requirements as for site induction.

Currently most Australian States require construction workers to have completed a general construction induction course prior to commencing work on construction sites. The acceptable format is determined by the states. The courses are extensive and require knowledge tests.

Medium to large organisations use formal site induction processes to train their employees and subcontractors. These inductions often take the form of verbal instructions, video presentations and in more recent times may entail the use of custom-made computer packages. Small employers, who work on small residential construction sites of low complexity are not required to provide formal site inductions, however they must ensure that their workers are adequately instructed which often takes the form of verbal instructions and on-the-job training.

Additionally many task specific training procedures are carried out by employer representatives in various forms such as verbal instructions, hand-outs of Material Safety Data Sheets and Safe Work Method Statements.

DATA COLLECTION

Telephone interviews were undertaken with representatives from the regulatory bodies of WA, QLD, NSW, VIC and SA, registered training organisations and educational institutions in relation to their approved modes of delivery. Case studies were conducted with five organisations' e-learning packages. Action Research Methodology was applied to collect data where the first author trialed e-learning packages in order to obtain first hand information. The key issues investigated in the case studies included "literacy, prior learning, computer literacy, effectiveness of delivery, flexibility, engagement and competency test".

RESULTS

General induction training, e-learning versus face-to-face training:

Government Departments' Perspective and Practice

Both Western Australian and Queensland authorities have accepted online delivery as an accredited method for their general induction courses for the past three to four years. Other states insist on face-to-face training which is often combined with a video screening or power point presentation delivered by the trainer. Representatives from WorkSafe QLD and WA stated that the reason for the introduction of online delivery for the general induction safety course was the possibility to get workers through the certification process faster.

The main concern voiced by representatives from NSW, VIC and SA authorities with the online delivery of the general induction safety course is that of possible identity fraud by the applicant. In QLD it is a requirement for applicants to sign a statutory declaration stating that the applicant is in fact the person who took the course. Identification checks are also carried out.

Workplace Health and Safety QLD stated that there had been some questions about the online delivery of the general induction course in the past, resulting in a review being undertaken in 2006. The review concluded that the online delivery was acceptable.

Neither WorkSafe WA nor WorkSafe QLD is able to determine what percentage of general induction cards issued is obtained via e-learning.

RTO's E-learning Perspective and Practice

RTOs include training companies, TAFEs, industry associations and group training providers. Telephone interviews were conducted with 12 RTOs delivering general induction training in QLD and WA in relation to their mode of delivery (see table 1).

The three largest training companies interviewed offer online training courses. Their online packages are well received by their clients. Several small training providers reported a reduced demand for face-to-face training.

RTOs offering online courses believe that this type of training produces equal or better results than those achieved in face-to-face situations. Conversely, a group training provider and an industry association don't offer online training for general induction, as they believe face-to-face training is more appropriate and provides a better outcome. A blended approach is offered by another provider, which they see as very successful for applicants with poor English language skills or learning difficulties.

Table1 Interview Summary of RTOs providing General Induction Training

RTO	Type of Organisation	Size of Training Organisation	Course options offered			Applicants using online courses	Comments of Training Provider
			Online	face-to-face	blended		
RTO1	Training Company	large	x			100%	Online training is better than face-to-face because the learner can interrupt the online course according to attention span.
RTO2	Training Company	medium	x	x		75%	Online training was introduced 2 years ago and we are very happy with the results.
RTO3	Training Company	medium	x	x		70%	Online is just as good or better than face-to-face, online is more engaging. Face-to-face is better for people with learning or language difficulties.
RTO4	Training Company	medium			x		The blended approach (students use individual computer packages in the classroom) has the advantage of • Learner can progress at their own pace; • Teacher assistance is readily available; • Very suitable for people with English as second language, as they often have more difficulty following oral than written information. There is a plan to offer remote online courses in the future due to demand.
RTO5	Group Training Provider	small		x			Face-to-face is the better option because: • Learners can get better assistance if they have questions; • People with learning difficulties can get better help; • Better knowledge verification
RTO6	Training Company	small	x	x		70%	This company's online package consists of a scanned manual (author's observation).
RTO7	Training Company	small	x			100%	• Online courses are considered as good as face-to-face. • Face-to-face courses discontinued because of lack of demand
RTO8	Training Company	small		x			Not much demand for the courses any more
RTO9	Training Company	small		x			Don't know enough about online course to comment.
RTO10	Training Company	small		x			Face-to-face is best, dialogue with teacher can't be replaced by a computer package
RTO11	TAFE	Info not available	x	x			Mostly online training, face-to-face classes are offered on demand Online is as good as face-to-face.
RTO12	Industry Association	medium		x			• There is insufficient internet coverage, • People in remote communities are not ready to embrace the online technology, • Face-to-face provides a better result than online.

SITE AND TASK SPECIFIC INDUCTION, E-LEARNING VERSUS FACE-TO-FACE TRAINING:

Educational Institute's Perspective and Practice
In Australia, TAFE colleges play a major part in safety training of apprentices. They provide certified general induction as well as task specific induction. Information on the acceptance of e-learning for task specific safety training by TAFE teachers and students is difficult to determine as safety is integrated in the overall course.

Three TAFE colleges were contacted by phone to ascertain their uptake of e-learning for safety.

One TAFE teacher at TAFE-1 (carpentry) said that he was not using e-learning for safety, as that was inappropriate.

The head teacher of carpentry at TAFE-2 commented that all teaching is face-to- face because teachers are not familiar with the technology, a lack of staff development, and older teachers' resistance to the use of e-learning and a lack of resources. He further pointed out that he believes students would respond well to e-learning and teaching could be made more effective by using a blended approach.

A representative from TAFE-3 advised that several TAFEs who are teaching trades in their area are supported in their e-learning by a specialist IT group. The IT group provides the computer expertise while the teachers provide their subject knowledge. Safety training is incorporated in some of their e-learning programs. A blended approach of classroom teaching, e-learning and practical instructions is the preferred teaching method. This program has been in place for two years and is, after initial resistance, now well accepted by teachers.

The above responses suggest continued initial resistance by some TAFE teachers to incorporate e-learning into their courses. Thompson and Lamshed (2006) and Darby (2002) also reported teacher resistance towards the adoption of e-learning.

The example of TAFE-3 indicates that this resistance can be overcome through extensive support provided to teachers in the development and initial usage of the e-learning material.

Employer's Perspective
A number of construction companies were contacted to gain an understanding of the level of online safety training undertaken by this group. Their lack of response has resulted in a literature review together with use of statistical data.

To what extent e-learning is used for site and task specific induction is unclear. Publications by The Australian Bureau of Statistics (ABS) indicate that the construction industry has embraced the use of the internet to a similar extent as other industries. Large employers use online training to a larger extent than small employers; see details in Table 2.

It was not possible to ascertain what the online training was used for. It is conceivable that these figures include very little safety training.

A survey by Bloom (2003) on e-learning in Canada lists the use of e-learning for OH&S as the second lowest of 7 categories used in 570 organisations surveyed.

Table 2 Online safety training in the construction industry by employment size

No of Employees	Online training/learning
0-4 persons	14.2 %
5-19 persons	21.2 %
20-199 persons	30.5 %
200 or more persons	40.2%

Source: ABS 2007a, Table 10

Mack Consulting Group (2007, cited in Callan and Fergusson, 2009) investigated the uptake of e-learning in the small business. They found that on-the-job informal training is predominant in the small business sector. Key factors discouraging the uptake of e-learning by small business include the time, cost, concerns about effectiveness and a perceived lack of relevance to their business.

DISCUSSION 1 – FEASIBILITY OF E-LEARNING FOR CONSTRUCTION SAFETY

The results indicate that, where the learner has a choice, the online option is increasingly well accepted.

All RTOs providing interactive online training for construction induction said that their packages can be used on dial-up internet, but this would be very slow and non-dial-up was recommended. An examination of various reports by the ABS leads to the conclusion that a significant number of people do not have adequate internet connection at the moment. Groups likely to be affected are people in remote areas and indigenous people.

There are hurdles for small organisations to include high quality online safety training as part of their services as it is expensive to implement and maintain. It requires software expertise, which may have to be brought into the business.

DISCUSSION 2 – EFFECTIVENESS OF E-LEARNING FOR CONSTRUCTION SAFETY TRAINING

Effective e-learning depends largely on the quality of the package. A well designed e-learning package should:

1. Engage the learner, using a variety of media such as written information, the option of audio delivery, pictures, animations and possibly video clips;
2. Deliver the message effectively using straight forward language, clearly and suitably paced, avoiding complex sentence construction;
3. Acknowledge prior learning by allowing the learner to progress straight to test sections, skipping familiar content;
4. Allow the flexibility to stop and starting the program as required without the need to repeat large sections;
5. Keep the literacy requirement to a minimum;
6. Be easy to use for people with minimal computer knowledge. The navigation should be obvious;
7. Include a meaningful test system, which ensures all parts of the program have been understood and the learner can identify areas requiring revision easily.

The following e-learning packages have been trailed in respect of those aspects.

Table 3 E-learning packages trial results

Provider		A	B	C	D	E
Purpose of Package		**General Induction**	**General Induction**	**General Induction**	**Site Induction**	**Work Activity Training**
Type of Provider		Training Company	Training Company	Training Company	Construction Company	Industry Association
Attributes of Training Packages						
1.	**Level of Engagement**	high	very high	fair	very high	very high/low*
2.	**Effectiness of delivery**	very good	good	fair	very good	good
3.	**Acknowledgement of prior learning**	yes	yes	yes	yes	no
4.	**Flexibility to stop and start the course**	good	very good	fair	very good	good

5.	**Level of Literacy required**	little	basic	good	basic	good
6.	**Level of Computer Literacy required**	low	very low	fair	low	very low
7.	**Competency Testing**	good	good	good	good	fair

*This package includes an online video. The video is rated “very high”, the online training program is rated “low”

Three of the five packages trailed were of a high standard while the remaining two will benefit from further development.

There are situations where face-to-face delivery is preferable to e-learning, including

- Where the learner prefers face-to-face instructions;
- For students with learning or language difficulties;
- For students in areas with insufficient internet capability;
- Where companies are unable to afford e-learning induction packages;
- Where regulating authorities do not consider e-learning suitable for their general construction induction training.

Some of these issues may not exist in the future. The availability of fast internet connections is likely to improve. Testing procedures for general induction training can be improved by varying test questions from use to use or introducing testing at the RTO’s premises.

E-learning has many positive features which are not found in traditional face-to-face teaching, such as

- Flexibility for learners to access the course from remote locations and to be able to progress through the course at their own speed;
- The course is always available (outside work hours);
- Easy quality control of the course content;
- Once the course is in place, it can be used over and over and become a refresher tool
- Provide large construction companies with an economical way to deliver OH&S training.

Anon.(nd), *John Holland, e-Learning Engagement Project 2006,* states that John Holland identifies cost-effectiveness, flexibility and consistency in training as the main drivers for their decision to implement e-learning for site induction.

E-learning in its current state can further improve its effectiveness by incorporating various language options into the programs. The lack of interaction between student, teacher and other students for long courses can be mitigated by requiring students to attend a short class for the final revision and exam. Another option is the introduction of virtual classrooms which RTO’s could operate at set times.

FURTHER RESEARCH - WHERE TO FROM HERE?

Further research into understanding workers’ attitudes and perceptions towards safety e-learning programs is required as there may be a link between acceptance and effectiveness of the learning methods. Studies into the effectiveness of e-learning by Sankaran et al (2000 cited in Pan et al, 2003) suggest that students with a positive attitude towards web based learning perform better in an e-learning environment than in a face-to-face course.

With this in mind the logical next step from here would be to gather empirical evidence regarding the correlation between acceptance and effectiveness of e-learning for construction safety.

CONCLUSION

The paper has studied the current state of play of the Australian construction industry in relation to e-learning for construction safety training. It is clear that such ITbased e-learning is suitable for many aspects of safety training either as a stand alone tool or in a blended approach, but more effort is required to fully utilise its potential. E-learning can be used in most situations for most people successfully.

There is no doubt that e-learning can make a valuable contribution to construction safety. The effectiveness of e-learning courses depends largely on the quality of the courses.

If e-learning is to succeed across the construction industry, ways will need to be found to assist small and medium size companies to access generic software for site induction and task specific training. Regulating bodies need to look more closely at the possibilities of overcoming shortcomings of current e-learning approaches for general induction safety. TAFE teachers need continued support to assist them in the implementation and use of this technology.

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WEB-BASED SAFETY KNOWLEDGE MANAGEMENT SYSTEM FOR BUILDERS: A CONCEPTUAL FRAMEWORK

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ABSTRACT

Despite the fact that there are more than 144 laws, 200 standards and numerous codes of practice that cover occupational health and safety (OHS) in the construction industry throughout Australia, workplace fatalities in construction were 9.2 per 100,000 workers, compared with the national average of 3.1 fatalities per 100,000 workers. Moreover, the industry accounted for 9% of the workers' compensation claims when it employed only 5% of the Australian workforce. OHS appears to be difficult to manage as the construction activities, workforce and the site management team on a given site change frequently. This dynamic nature of construction entails constant safety inductions for workers and site staff, and the cultivation of safety climate on sites. Safety knowledge management has therefore become a key component for a sustained business development for builders as well as for safeguarding the interests of construction workers. The integration of safety knowledge management and information technology can provide an innovative means for improving safety in the Australian construction industry. This paper discusses the conceptual framework of a web-based safety knowledge management system that can be used by builders to improve their safety performance and thereby productivity. The implementation of the proposed system in the construction industry will help reduce workplace accidents and the social costs that stem from them.

Keywords: Construction, Occupational health and safety, Knowledge management, Intranet

INTRODUCTION

Construction is Australia's third most dangerous industry. The construction industry employed approximately 5% of the Australian workforce but accounted for 9% of the workers' compensation claims (Dingsdag, Biggs & Sheaham, 2006). The incidents of workplace fatalities were 9.2 per 100000 workers in construction, compared with the national average of 3.1 fatalities per 100000 workers (NOHSC, 2005). The fatality rate is three times higher than the all industries rate. On average, 49 construction workers have been killed at work each year (Fraser, 2007). The industry's incident rate for workplace injuries and diseases remains at 28 per 1000 workers, which is nearly double that of all other industries (16 incidents per 1000 workers) (MBAI, 2005). In addition to the social costs on the community, construction accidents inflict direct and indirect costs on a contractor's business. The direct costs include: increased workers' compensations insurance premiums, equipment repair and replacement costs, fines, fees and legal settlements, and damages to works and temporary structures. The indirect costs refer to the cost of production downtime and tarnished company image. Despite the currently available 144 laws, 200 standards and numerous codes of practice that cover occupational health and safety (OHS) in construction throughout Australia (Robinson, 2002) may have improved OHS performance, it still appears to be difficult to curtail accident rates due to the existence of the following peculiar dilemmas (Preston & Cruickshank, 2000; Trajkovski & Loosemore, 2005):

- Construction process is dynamic. Factors such as the working environment, activity, workforce mix, equipment and tools usage and site layout change rapidly and constantly over the period of construction. This makes safety on site volatile.
- Every construction project is unique. Parameters such as the scope of work, location and materials used are different between projects, and therefore every project faces new challenges in OHS management. Moreover, it is unlikely that a project team will possess all the expertise and knowledge to meet the challenges despite they may be experienced.

- Employee (both professionals and workforce) turnover in the construction industry is relatively higher. Thus, there is a need for a continual safety training system in place.
- Safety knowledge that resides in codes of practice, best practice manuals, databases and papers evolve overtime and it is abundant. The project management team is required to be abreast of the contents and changes. This is rather difficult for them to refer to written documents and attend workshops due to tight project schedules and work pressure.
- The Australian construction industry has migrant workers and professionals. They pose skill shortages that have become a significant contributor to accidents.

The strategy to overcome these dilemmas towards implementing better safety systems is to adopt a knowledge based safety strategy, in other words introducing a safety knowledge management system in contractor organisations. It can help capture a company's collective expertise wherever it resides—in databases, on paper, or in people's heads—and distribute it to wherever it can help produce the biggest payoff (Hadikusumo & Rowlinson, 2004). Lingard & Rowlinson (2005) also argued that the concept of organisational learning is critical to the construction industry's ability to improve its OHS performance, and suggested that, with regards to OHS, construction organisations need to develop the ability to learn. A construction company may have several professionals and team players. Each professional/team may have some knowledge and experience in OHS. Likewise, there are plenty of literatures on OHS best practices from many sources and they evolve from time to time in pace with the changes in construction technology. If these experiences and knowledge were collated and transformed into a rich OHS knowledgebase, it may help overcome the aforementioned OHS challenges.

This research aims at integrating knowledge management and web-based technologies to provide an innovative means for improving construction safety in the construction industry. The objectives of this research are:

1. Identifying and analysing the components of an effective and innovative safety knowledge management system for builders.
2. Formulating the conceptual model of a web-based safety knowledge management system.
3. Prototyping and validating the system.

However, the paper discusses only around the first two objectives. Firstly an introduction is provided to the paper to put the matter in context. Then a detailed literature review on knowledge-based OHS management is presented followed by the conceptual framework of the proposed safety knowledge management system. Finally, a conclusion is drawn.

KNOWLEDGE-BASED OHS MANAGEMENT IN CONSTRUCTION

Managing hazards on construction sites may be facilitated by the implementation of a dynamic occupational health and safety management system (OHSMS). On-site OHSMSs contain three essential components as seen in Figure 1.

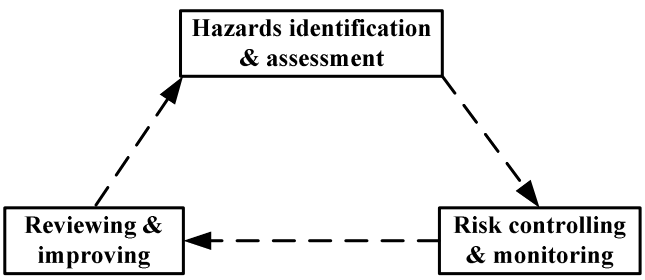

Figure 1: Basic elements of OHSMS (modified from Toohey, Borthwick & Archer, 2005).

Traditionally, OHSMSs are site independent. However, knowledge-based OHSMSs integrate information and knowledge from various sites, professionals and sources and thus making the traditional OHSMSs dynamic. The account below describes knowledge-based approaches for each of the components.

HAZARDS IDENTIFICATION AND ASSESSMENT

A hazard is simply a situation that has the potential to harm people physically or psychologically. Fatalities, injuries, health damages or ergonomic are the possible outcomes of a person being exposed to the hazard (Toohey et al, 2005). The project team is required to identify task-based hazards by analysing the: (1) nature of the task, sub-tasks, processes and procedures; (2) location of the work; (3) interface with other activities; (4) materials, equipment and tools used; and (5) nature of the work crew (alcohol addiction, language barrier, worker mix, and demography). Lingard & Rowlinson (2005), Toohey et al (2005), and Trait & Cox (1998) suggested that:

1. The prime source of OSH knowledge would be line managers, safety officers, professional safety consultants and OSH management. Their expertise, past experiences, intuitions and perceptions are vital.
2. Records of incidents may help learn: (a) the area of workplace/sub task of an activity where the incident occurred, (b) the nature of injury, (c) the occupation/trade of the victim, (d) the time of the day/month/year incidents occurred, and (e) the causes of the incident.
3. Workplace inspections, audits and walkthrough surveys and the use of checklists can assist in the risk identification process.
4. Suppliers of hazardous substances and suppliers of plant and equipment.
5. Compensation cases and insurance claims.

Hence, it is understandable that hazards should be identified in tasks based on the sub-processes involved, materials used, plant and tools used, interfaces with other tasks and zones and the nature of the work crew. Meticulous studies of these situational variables with the assistance of checklists, perceptions, experiences, past incident records, and the collective involvement of site management and supervisors, technical specialists, OHS advisors, and subcontractors are crucial for a productive hazards identification and assessment process.

RISK CONTROLLING AND MONITORING

Risk controlling and monitoring on site pursues a hierarchy of control, which offers a number of ways to approach the hazard control process. The project team has to work the below list down and implement the best measure possible for the situation: (1) eliminate the hazard, if not possible; (2) substitute the hazard with a lesser risk, if not possible, (3) isolate the hazard, if not possible, (4) use engineering controls, if not possible, (5) use administrative controls, if not possible, or (6) use personal protective equipment. The project team is required to be well-versed with the knowledge relating to certain aspects to better implement the hierarchy of controls, including: (1) Safe work practices; (2) Safe use of machinery and tools; (3) Regular safety inspections of activities and the work site; (4) Safety training and workers' involvement in safety; (5) Involving subcontractors in safety; and (6) Emergency management (Mohamed, 2002; Holt, 2005; Teo, Ling & Chong, 2005; Imriyas, 2007; Choudhry, Fang & Ahmed, 2008).

SAFE WORK PRACTICES

Having identified the hazards in an activity, the project team is required to implement controls through: (1) best construction practices; (2) personal protective equipment use; (3) permit-to-work systems; and (4) housekeeping systems. Choudhry et al (2008) suggested that it would be a good practice at construction sites to organise planning meetings with workers before they execute an activity to discuss about the abovementioned issues in relation to that activity and hazards. It is also encouraged that safety managers and safety advisors organise safety talks at project sites during lunch box meetings with workers to keep them constantly safety conscious. Successful implementation of this critical management task demands the project management team to be abreast of latest knowledge and information regarding the aspects above.

SAFE USE OF MACHINERY AND TOOLS

A particular project may have various machinery and tools and they may be used by various subcontractors. It is an inevitable role for the main contractor to ensure the safe use of machinery and tools on site. It is thus crucial to communicate information and share knowledge with supervisors of the main contractor and subcontractors regarding: (1) testing and inspection of the status of machinery and tools; (2) safe use of machinery and tools; and (3) maintenance systems for machinery.

REGULAR SAFETY INSPECTIONS OF ACTIVITIES AND THE WORKSITE

The site management team is suggested carrying out regular safety inspections on site and forward inspection reports to the sectional manager and subcontractors concerned. It is advised that safety inspectors use photographs of unsafe conditions and unsafe behaviours of workers on site to bring these to the attention of site staff and subcontractors for their immediate actions (Choudhry et al, 2008). There are two key needs to perform these tasks effectively by a site safety inspector: (1) thorough and latest knowledge about safe work practices for all the activities in the project; and (2) a medium for creating and communicating interactive reports and feedback in a timely fashion.

SAFETY TRAINING AND WORKERS' INVOLVEMENT IN SAFETY

Accidents may occur because of poor attitudes and unsafe behaviours of workers, which are difficult to monitor and control. There is a positive link between safety performance and workers' attitudes. In addition, negative behaviours and attitudes have prompted most workers not to wear their personal protective equipment whilst working on site. In this regard, workers need to possess the correct skills and knowledge for the nature of work and to be motivated to behave safely (Teo et al, 2005). This is therefore crucial to have an in-house/on-site safety training programme in place for workers on: (1) safe work practices and behaviours; (2) checking tools and equipment before use and their safe use; (3) housekeeping; (4) emergency responses; and (5) hazard communications with co-workers.

Berghaus (2007) compared the outcomes of instruction-based (standard) safety training and behaviour-based safety training and found that the behaviour-based safety training improved occupational safety significantly even among inexperienced young workers. Under the standard safety training programme, all new employees receive the same basic safety training which is entirely classroom based, and consists of reading materials and lectures supported by audio-visual aids such as video tapes and power point presentations.

The behaviour skills programme includes trainers modelling correct safety behaviours, practice of safety behaviour, praise for correct responses and corrective feedback for incorrect responses, in situ training (training in an actual situation), realistic training materials in multiple training situations to promote an active learning approach, positive reinforcement for correct responses, and generalisation of skills. Heck et al. (2001) demonstrated that structured and interactive training and individual rewards based on overall group performance decreased risk taking behaviours. Hence in construction projects, work supervisors and other site staff need to possess the knowledge, skills and resources for conducting behavioural training for workers continually on changing work trades or tasks in the project. There must also be an incentive system in place to reward group safe behaviours, which will motivate a group member to be careful about her behaviours as well as of co-workers.

INVOLVING SUBCONTRACTORS IN SAFETY

A chain of subcontractors (third/fourth party subcontractors) is commonly observed in construction. A major concern for managing safety is the effectiveness of control over the large numbers of subcontractors on construction sites due to diversification of activities. Thus, with higher numbers of subcontracting, the chances of accident occurrences will be more frequent (Debrah & Ofori, 2001). As such, the probability of the lack of communication, coordination and control will increase (Rowlinson, 1997). Furthermore, main contractors may shift all safety responsibilities to subcontractors and may not ensure that the subcontractors are capable of providing a safe working environment (Wilson & Kohen, 2000). But, safety is the responsibility of both because when a subcontractor's worker is killed at site, the WorkCover may fine the main contractor and often the main contractor's image is tarnished. Additionally, the subcontractor might be terminated and may have difficulties getting new jobs in the future. Smith (1998) thus suggested that the main contractor should ensure subcontractors have reasonable OHSMSs in place and needs to oversee their implementation on site. He further suggested that improving communication in general between all parties would improve safety. Daily meetings between site safety managers and subcontractors would help keep everyone informed about changing worksite conditions and provide an opportunity to share information and knowledge about safety and potential hazards. Subcontractors are often hired for specialised works that are beyond main contractor's scope/trade. Overseeing safety and having meaningful daily safety discussions may be a challenge for main contractor's team due to their experience and knowledge limitation. However, if a centralised safety knowledgebase can be maintained by the main contractor, the team members would be able to learn on demand.

EMERGENCY MANAGEMENT

Even with the best safety program and risk management strategies, a construction project is still vulnerable to incidents (Reid, 2000). It is essential that project managers give equal attention to both proactive and reactive managerial strategies (Rosenthal & Kouzmin, 1993). A construction company without an emergency management plan becomes a victim of the demands of the incident and cannot afford the luxury of being proactive (Reid, 2000). The importance of a well-conceived emergency management plan cannot be overemphasized since 80% of unprepared companies go out of business within two years of suffering a major crisis (Brown, 1993). Due to the narrow profit margin yielded in construction business, a mishandled incident can significantly impact on a company's bottom line. A single poorly handled job can affect the positive outcomes of twenty successful projects (Reid, 2000). A contractor relies heavily upon reputation and the public's perception of the company's ability to achieve the community's business goal. This reputation is built over the course of many years and many projects. A single incident has the potential to cause great harm to a company's reputation, particularly if the incident is mishandled. Hence, having a well developed and properly implemented emergency management sub system in place on each construction project, regardless of the size of the project, is essential in construction (Reid, 2000). The system could provide a first-hour response checklist with simulations to handle accidents of various natures.

REVIEWING AND IMPROVING

Chua & Goh (2004) argued that in order for the construction industry to improve its poor safety performance, it needs to learn from its mistakes and put the lessons learned to good use. This needs calls for effective feedback mechanisms that can transmit information derived from incident investigations to be utilized in safety planning. The feedback should be at two levels: first, feedback to the OHSMS that had failed; and second, feedback to the safety planning of future projects (see Figure 2).

Additionally, Rivers (2006) recommended capturing direct and indirect costs of accidents, analysing these data and producing various accident cost summaries for the project and for the company as a whole for the attention of site and upper management. This information can motivate safety professionals to set safety benchmarks and goals both at organisational and site levels. Tang, Ying, Chan & Chan (2004) analysed construction accidents and recognised the following costs for contractors due to accidents: (1) Increased premiums for workers' compensation insurance; (2) Legislative fines and legal expenses; (3) Adverse publicity; (4) Cost of administrative time for accident investigation and reporting by site management; (5) Cost of damaged machinery; (6) Cost of damaged materials, finished work and temporary structures; (7) Cost of idle machinery due to accidents; (8) Cost of idle workers due to accidents; (9) Cost of emergency supplies and management; (10) Cost of overtime necessitated by work disruptions due to accidents; (11) Cost of training to replacement personnel; (12) Cost of transportation of injured workers to medical facility; (13) Cost of clean-up; (14) Cost of productivity loss due to work stop and resume; and (15) Cost of productivity loss of the retuned worker due to a reduced capacity.

Error! Objects cannot be created from editing field codes.

Figure 2: Learning from accidents

Four types of summaries may be produced by processing these cost data from sites: (1) Annual profit loss for the company due to accidents; (2) Project specific profit loss due to accidents/ratio between accident costs and the tender price; (3) Safety investments versus accident costs; and (4) Accident costs comparisons for all the projects on hand. These summaries may be used by contractors to: (1) Set goals and benchmarks for the company and for individual projects; (2) Devise a bonus system for site staff to motivate them to work towards a "zero" accident project; and (3) Measure the performance of the safety management team in the organisation as well as in individual projects.

PROPOSED SAFETY KNOWLEDGE MANAGEMENT SYSTEM

Under the knowledge-based approach, the process needs to be: (1) site boundary independent; (2) actively involving site staff, subcontractors, workers and head office safety staff; (3) learning and improving from the experiences of site teams and incidents in other projects; and (4) continually incorporating innovations in safety. The successful implementation of this innovative approach of OHS management entails a strong synergy of KM strategies and ICT technologies as described below.

- The formation of a Community of Safety Practice (CoSP) that integrates the organisational safety staff, site safety staff and external entities such as subcontractors, suppliers, manufacturers and consultants is necessary.
- A systematically developed corporate safety memory is crucial to continually capture and store OHS knowledge. The corporate memory would constitute the following compartments:
    1. A knowledgebase that captures explicit and tacit OHS knowledge. The explicit OHS knowledge related to construction activities includes: (1) sub-steps, potential hazards associated with each sub-step and recommended precautionary measures (safe work practices); (2) safety inspection procedures; and (3) emergency procedures. It is preferred that the explicit knowledge to be stored in interactive media such as visual and audio records so that it will be easy for users to retrieve and use in a short time period. The activity-based tacit OHS knowledge refers to the experiences of site personnel and CoSP members in the form of stories, audio and video records, debriefings and images. This would include stories related to accidents and causes.
    2. A database to capture direct and indirect costs of accidents, analyse these data and produce various accident cost summaries for the project and the company in general for the attention of site and upper management. This information would motivate them to set safety benchmarks and goals both at organisational and site levels.
    3. An e-learning content catalogue that contains interactive training materials on safe work practices, emergency procedures and hazard communications as well as simulations and behavioural safety training assignments. This catalogue can be accessed by site personnel to train workers from time to time.

A well designed intranet is essential to host:

1. The corporate safety memory to enable the exploitation and refinement of stored knowledge by users on dispersed construction sites of a contractor.
2. A virtually interactive notice board facility to foster communications of daily events and news on construction sites to other remote sites and to keep the site staff informed of the updates to the knowledgebase. It can also help disseminate the accident cost summaries from the database in the corporate memory.
3. A homepage for the CoSP that recognises the existence of the CoSP in the organisation while encouraging safety experts to subscribe to the community. This can also function as a Safety Expert Yellow Pages in which experts are mapped on their professional and specific trades and experiences. Users can access this service to locate relevant experts to seek help from for problems in their projects.
4. A discussion portal that fosters interactive threaded discussions by CoSP members surrounding concerning OHS issues on sites. It may be done through audio conferencing, videoconferencing or text-based conferencing. The content of threaded discussions may be recorded and preserved in the knowledgebase for future use, which will avoid the possibilities of initiating discussions for already solved problems.
5. A virtual learning portal to facilitate on-demand safety training to workers on remote sites. Learning on-demand is more effective than having a standard training because the on-demand knowledge is activity/context specific, and applied immediately and thoroughly. The e-learning portal would facilitate the training of new workers on site, which is quite important in the Australian context where the workforce is dynamic and possessing skill shortages. It is important to introduce simulations of safe work practices, emergency procedures, etc. in designing the e-courses because they are easily and completely grasped and registered in the human minds. It is also faster as opposed to reading through written descriptions and regulations. Additionally, it removes the problem posed by language barrier for foreign workers.

- Because construction is fieldwork-based, involving scattered stakeholders and projects at a time, and team members get rare opportunities to sit in front of a computer, it is essential to implant mobile computing technologies into the safety knowledge management system to ensure a successful implementation of knowledge-based safety management. PDAs, smart phones, Bluetooths and/or tablet PCs could be used to facilitate mobile interfaces with the safety knowledge management system by users.

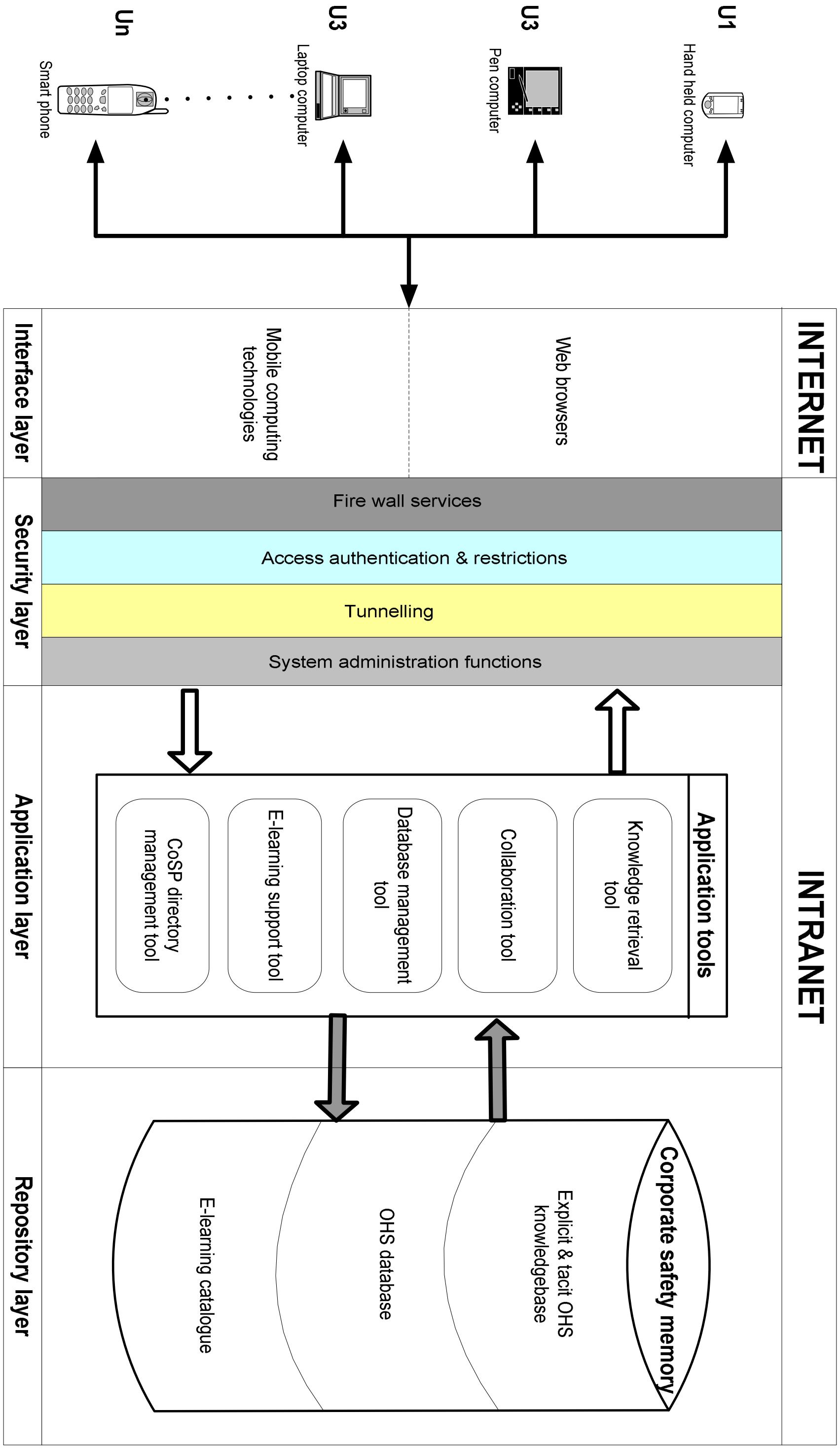

Figure 3: Top level system architecture – SKMS

The system architecture of the proposed safety knowledge management system, which addresses the functional requirements described above, is illustrated in
Figure 3. It constitutes the following four layers: (1) Repository layer; (2) Application layer; (3) Access and authentication layer; and (4) Interface layer. The repository layer houses the corporate safety memory, which contains an OHS knowledgebase, an OHS database, and an e-learning contents catalogue. The knowledge in the corporate memory may be retrieved, used and refined by users via the application layer. The application layer consists of various sub applications for managing the creation, storage, retrieval and dissemination of knowledge. These sub applications offer facilities for the retrieval of stored knowledge, online collaborations, database management,

e-learning support, and CoSP directory management. The access and authentication layer provides system security, access authentications and restrictions, firewall services, tunnelling and system administration functions. The interface layer defines the web browsers and mobile computing devices that users may use to access the intranet.

Figure **4** illustrates the semantic model that explains the objects and their relationship in the corporate safety memory. This was developed based on the finding of the literature review in the preceding sections, and comprises the information content needed for knowledge-based OHS management. The diagram is read by starting with object "work site". Arrowed lines show the relationships between objects. An arrowed line leading from an object shows the relationship the object has with another object.

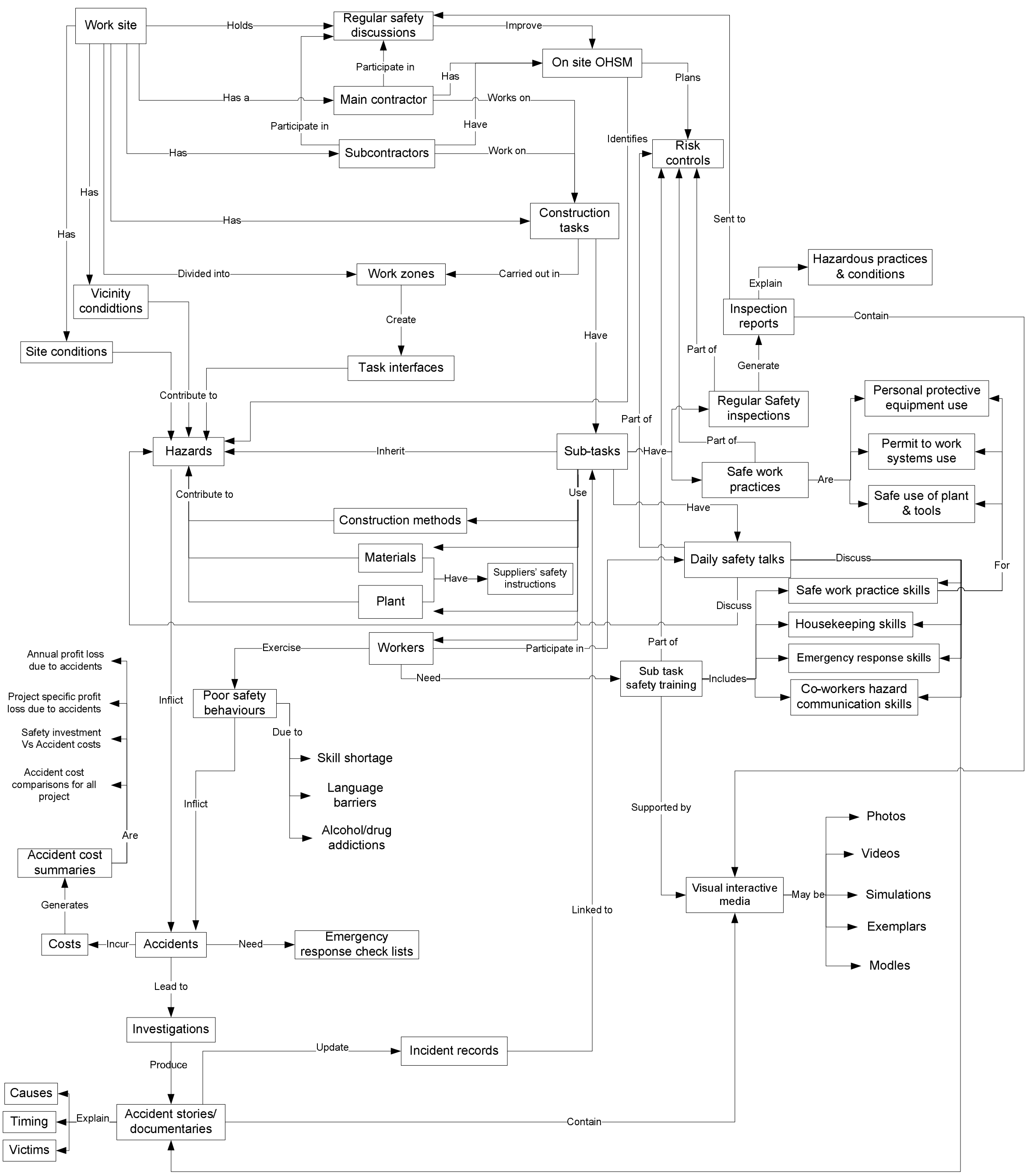

Figure 4: Semantic model for SKMS

CONCLUSIONS

The management of OHS in construction has been facing enormous challenges due to the dynamic nature of construction. The constantly changing nature of work activities, work environments, workforce and subcontractors necessitates the incorporation of knowledge management into OHS to keep the workforce and the site management team abreast of activity based OHS skills and knowledge. This would also enable explicit and tacit OHS knowledge to be captured from various sources and disseminated to wherever it is needed at a particular point in time. The synergy of IT, KM principles and OHS principles provided with an excellent platform for developing the conceptual framework of a web-based OHS management system for builders. The proposed system would pave the way to an innovative safety management approach in construction projects, departing from the traditional mode as exist in the Australian construction industry. This approach would also add value to the current knowledgebase of construction safety management. The author believes that, if implemented, the system would help: (1) Enhance safety and reduce accidents on sites; (2) Safeguard the interests of construction workers; (3) Improve productivity of the construction industry and thereby GDP growth; (4) Reduce social costs of construction accidents. Further research is underway to implement and test the system.

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DEVELOPING A STRATEGY FOR INTEGRATION OF DESIGNING FOR CONSTRUCTION WORKER SAFETY AND BUILDING INFORMATION MODELING

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ABSTRACT

Until recently, the responsibility for reducing construction injuries was placed solely on the contractors. At the same time, designers make many decisions about the facilities they design that directly impact worker safety. The implementation of designing for construction worker safety (DCWS) principles can have a positive impact on construction safety, cost, schedule, productivity and quality of construction, but the widespread implementation of DCWS (also referred to as construction hazard Prevention through Design (PtD)) by U.S. design firms has been lacking. The purpose of this research was to investigate how the use of Building Information Modeling (BIM) technology in conjunction with DCWS/PtD principles can reduce the potential for fatalities and injuries on construction projects. The objective was to develop a strategy that would help implement DCWS/PtD principles in the design phase of a project through the use of BIM. For example, the strategy can include: 1) a knowledgebase of the DCWS/PtD principles; 2) an interactive web site for adding suggestions; and 3) a BIM tool that checks for DCWS compliance. The ultimate beneficiaries of an integrated BIM and DCWS/PtD system include designers, contractors, facility owners, and construction workers. By integrating DCWS/PtD and BIM in a project, safety will no longer be an afterthought, but it is put on equal basis with the other design parameters. DCWS/PtD becomes an integral tool for use with BIM software, just like quality, cost, schedule information, structural analysis, HVAC load and building code compliance checking tools that are currently available for BIM. Introducing construction safety as a parameter at the design stage enhances its impact on construction workers in terms of human asset sustainability.

Key words: Design for construction safety, Building Information Modelling, Safety compliance checking.

INTRODUCTION

The U.S. Bureau of Labour Statistics reports that while over 6% of the nation's workforce is employed in the construction industry, nearly 20% of all worker fatalities occur in the construction industry. Until recent years, the responsibility for reducing construction injuries was placed solely on the employing contractors. At the same time, designers make many decisions about the facilities they design that will directly impact worker safety. Designing for construction worker safety (DCWS) (also referred to as construction hazard Prevention through Design (PtD)) has received considerable attention in recent years. The implementation of DCWS /PtD can have a positive impact on construction safety, cost, schedule, productivity and quality of construction; however the widespread implementation of DCWS/PtD by U.S. design firms has been lacking.

A Building Information Model (BIM) is a digital representation of the physical and functional characteristics of a facility. The information maintained and produced in the BIM approach includes both geometric (e.g. 2D drawings, 3D models, dimensional and spatial relationships and Virtual Reality) and non-geometric data (e.g. annotations, textual information, reports, tables, charts, freehand illustrations, graphs, images, audio-visual data). BIM is expected to enable improved interdisciplinary collaboration across distributed teams, intelligent documentation and information retrieval, greater consistency in building data, better conflict detection and enhanced facilities management. Hence, the purpose of this research is to explore the use of Building Information Modeling (BIM) technology in conjunction with DCWS/PtD principles to reduce the potential for fatalities and injuries on construction job projects.

LITERATURE REVIEW

Design for Construction Workers Safety (DCWS)

Design for Construction Worker Safety (DCWS) requires consideration of the safety of construction workers in the design of a project (Gambatese et al. 2005). Since the design determines the building components and configuration, the design also affects the construction process and the consequent safety hazards (Gambatese 2000). Previous research found that widespread implementation of design for construction worker safety by the United States design firms was lacking (Hinze and Wiegand 1992, Gambatese et al. 1997, 2005, Toole 2005). Some of the reasons for the designers' minimal knowledge of DCWS principles were identified by researchers as:

- Failure to offer construction safety courses in engineering programs at universities (Gambatese 2003, Toole, 2005).
- Narrow specialization of design (Gambatese et al. 2005).
- Designers' minimal to nonexistent construction experience and understanding of the construction process (Gambatese et al. 2005, Toole, 2005)

Early research on DCWS identified the need for a single source/repository compiling the various design concepts that had been successfully implemented on past construction projects (Hinze 1997, Gambatese et al. 1997). The proposed DCWS/PtD Wiki allows for this compilation of DCWS/PtD design concepts into a centrally maintained and available body of knowledge, while at the same time establishing a mechanism for adding and vetting new concepts to that body of knowledge.

A study by Gambatese (2005) showed that 47% of the interviewed designers used DCWS principles without giving an indication of how or when safety was addressed in their designs. Designers typically address safety during the value engineering phase of the project and 42% of the designers indicated that they made modifications in their designs to improve construction worker safety.

Several researchers have recommended a variety of approaches to implement DCWS in practice and these approaches include:

- Creating a motivational force to implement DCWS/PtD (Hinze 1997, Gambatese et al. 2005).
- Changing the mindset of designers about construction safety (Young 1996, Gambatese et al. 1997, 2005).
- Increasing the knowledge of designers about DCWS/PtD as well as about the construction process (Gambatese et al. 1997, 2005, Toole 2005).
- Integrating safety in the engineering curriculum (Toole 2005).
- Encouraging the use of the design-build project delivery method that involves close collaboration between designers and constructors (Gambatese et al. 2005).
- Creating construction documents that facilitate worker safety (for example, technical specifications that include safety standards) (Toole 2005).
- Developing the tools and guidelines for DCWS/PtD (Gambatese et al. 1997, 2005, Toole 2005, Hadikusumo and Rowlinson, 2004).
- Encouraging facility owners to insist that designers implement DCWS/PtD in their designs (Hinze, 1997, Gambatese et al. 1997, 2005).
- Revising current contract documents to include requirements for including DCWS/PtD (Gambatese et al. 1997, 2005, Toole 2005).
- Utilizing consultants for safety to mitigate the lack of knowledge of designers about construction safety (Gambatese et al. 2005, Toole 2005).

Designers can potentially be involved in a number of activities related to construction safety. These include the review of designs to ensure that safety is addressed, the creation of construction documents that implement DCWS/PtD principles, and the adaptation of practices to ensure safety is adequately addressed in procurement practices, submittal reviews, and site inspections (Toole 2005).

How does DCWS/PtD affect construction safety? The design of connection details, selection of the materials and the way building components are put together directly affect the way construction workers perform their work. If designers know about modified design approaches that can improve worker safety, they have an ethical responsibility and obligation to apply these approaches in practice (Hinze 1997). Previous research has shown that the implementation of DCWS/PtD had a positive impact on construction safety as well as on cost, schedule, productivity and quality of construction (Gambatese et al. 1997, 2005).

Building Information Modeling (BIM)

In 2004, the U.S. National Institute of Standards and Technology (NIST) published a report stating that poor interoperability and data management costs the construction industry approximately $15.8 billion a year (Gallaher et al. 2004). Since that report was publicized, many have dubbed Building Information Modeling (BIM) as an emerging technological information management process and product that holds the key to resolving this interoperability problem. The National BIM Standard (NBIMS) defines a BIM (e.g. a single Building Information Model) as "a digital representation of physical and functional characteristics of a facility" (Kennett 2005). Furthermore, a BIM represents a shared knowledge resource, or process for sharing information about a facility, forming a reliable basis for decisions during a facility's life-cycle from inception onward.

Building Information Modeling (BIM) is an Information Technology (IT) enabled approach that allows for improved inter-disciplinary collaboration across distributed teams, intelligent documentation and information retrieval, greater consistency in building data, better conflict detection and enhanced facilities management. BIM facilitates the storage, management, sharing, access, update and use of all the data relevant to a project throughout the project life-cycle in the form of a data repository. The information maintained and produced in the BIM approach includes both geometric as well as non-geometric data. Geometric data includes 2D drawings, 3D models, dimensional and spatial relationships and Virtual Reality (VR). Non-geometric data could mean annotations, textual data, reports, tables, charts, freehand illustrations, graphs, images, audio-visual data and any other forms of information generated during the project. BIM is expected to enable improved interdisciplinary collaboration across distributed teams, intelligent documentation and information retrieval, greater consistency in building data, better conflict detection and enhanced facilities management (Kunz and Fischer 2007; Haymaker et al. 2005).

Computer Programs for Safety in Construction

Computer tools have been developed to address construction worker safety in design. Gambatese et al. (1997) created the Design for Construction Safety ToolBox that offered a variety of project-specific design suggestions that would improve construction worker safety. The tool incorporated diverse approaches for reviewing a construction project, and had the ability to identify safety hazards and to document the results in reports. The tool allowed the user to follow one of three paths when selecting design for safety suggestions, namely 1) project components, 2) construction site hazards, and 3) project systems. The potential benefits of ToolBox included: utilization of the tool by a design team as well as by the entire project team; management and control of the review process; accurate and thorough record keeping on a project; improved safety through the life-cycle of the building; and a safety instructional tool for architectural and engineering curricula.

Hadikusumo and Rowlinson (2004) developed the Design-for-Safety-Process (DFSP) Tool that had the ability to identify safety hazards on a construction site and to suggest precautions to avoid the occurrence of accidents in the presence of those hazards. The DFSP Tool was developed based on three components: design for X-ability (DFX), virtual reality (VR) and construction site safety. The DFSP Tool had a safety database that consisted of: construction components, possible safety hazards, and accident precautions. The DFSP Tool enabled a user to walk-through and to observe a virtually real construction site. The user could select a virtually real construction component that might be considered a possible safety hazard and the Tool would list possible safety hazards from the safety database. The benefits of the DSFP Tool were: 1) VR could represent the virtually real project in a 3D model that is easier to understand than 2D drawings; and 2) the virtually real construction process is easier to understand than the conventional method of representing the process as text or diagram.

PROBLEM STATEMENT

There is a need to develop a strategy for the integration of DCWS and BIM. The lack of such strategy is an important problem because of the following reasons:

- Construction documents define the end result, but not the construction means, methods and process. Construction documents are presented in the format of 2D drawings and written specifications, and these are not easily understood when compared to the 3D, nD or virtual reality models that might be developed for construction projects.
- Commercially available BIM software does not incorporate DCWS/PtD tools to check for safety compliance.
- Existing computer programs that were developed for DCWS/PtD are not readily available and are therefore not extensively used.
- There is currently no widespread implementation of DCWS/PtD by U.S. design firms.
- The knowledge of designers about construction worker safety and the construction process is limited. Most designers do not have: 1) adequate university-level training related to construction safety and construction processes, and 2) construction experience.
- The DCWS/PtD tools and guidelines are inadequate. Currently available safety checklists, manuals and guidelines are not compiled and organized in a format that is useful for designers.
- Traditional Design-Bid-Build projects are created by architects and engineers with their collaboration being limited to ensuring building code compliance, without any regard for worker safety. On conventional projects, construction worker safety is considered for the first time when the contractor undertakes the construction of the facility.

RESEARCH OBJECTIVES

The purpose of this research is to explore the integration of construction worker safety into Building Information (BIM). The users include designers, contractors, and facility owners, while the ultimate beneficiaries are the construction workers. Ideally, during the design phase of a project architects and engineers could analyze projects in terms of the safety of the construction workers and implement design principles that would provide for the safety of the construction workers during the life cycle of the project (including construction, operation or occupancy, and maintenance phases). In turn, the contractors and facility owners develop their site specific safety plans for the execution of the projects by using the safety-related BIM information. Figures 1-3 show some examples of DCWS/PtD concepts which include simple, yet highly effective design features that have been shown to increase worker safety.

1. Design parapets to be 107 cm high (Figure 1). This accident precaution provides safety during the construction, operation and maintenance phases.

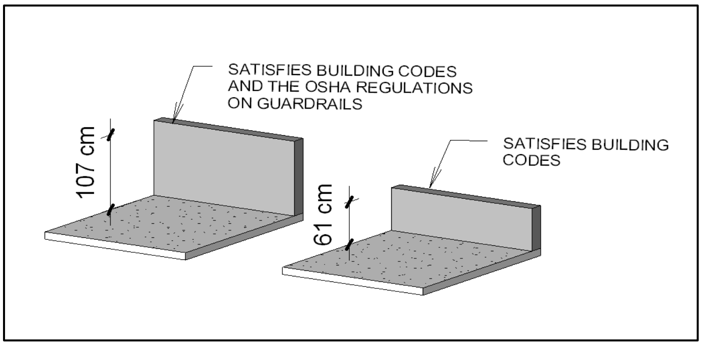

Figure 1 Parapet 107 cm high.

2. Install permanent roof anchors (Figure 2). This measure would provide for safety during the construction, operation and maintenance phases of the facility.

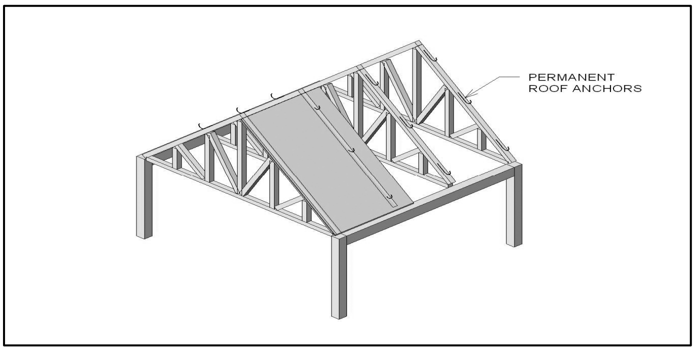

Figure 2 Permanent roof anchors attached to the trusses.

3. Use of #5 rebar at a 7.5 cm spacing instead of using #10 rebar at a 30 cm spacing provides a walking platform for construction workers (Figure 3). This precaution provides safety during the construction phase.

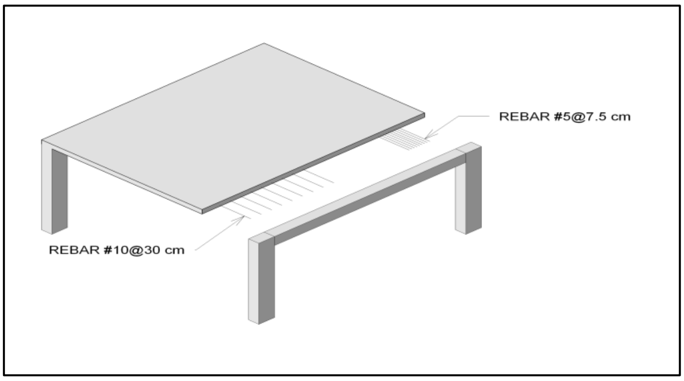

Figure 3 Rebar #5 @7.5 cm provides working platform.

The objective of this research is to develop a strategy that would help implement DCWS/PtD principles similar to those listed above in the design phase of a project. This strategy includes:

1. Creating a knowledgebase (checklist/guidelines) of the DCWS/PtD principles.
2. Establishing a multi-media DCWS/PtD website that will provide the opportunity for adding new suggestions for DCWS concepts/principles to the existing database.
3. Developing a framework for a DCWS/PtD checking tool for use in BIM that checks for compliance with DCWS principles and as is customary with other BIM tools:
   - Highlight and display graphically on the BIM the problem areas and the DCWS/PtD diagnostics.
   - Provide the ability to link each building component to related safety measures.
   - Provide the ability to link each construction activity of the project schedule to the required safety measures, that is, create a schedule of the implementation of the particular safety practices.

The tool can use the Model View Definition (MVD), Information Delivery Manual (IDM) and Industry Foundation Classes (IFC) approaches developed by the International Alliance for Interoperability, as espoused by the National BIM Standard (NBIMS) and the buildingSmart™ Alliance.

RESEARCH METHODOLOGY

The overall objective of this research is to devise a strategy for the incorporation of the principles of DCWS/PtD into BIM software. In order to develop a strategy for integration of DCWS/PtD and BIM, the following **tasks** are suggested:
Strategy 1: Create a knowledgebase of the DCWS/PtD principles.

- Develop and compile suggestions for design for construction worker safety. These basic safety principles are obtained from literature sources, DCWS/PtD Wiki, accident statistics, and other industry records.
- Convene a panel of safety professionals to help compile a knowledgebase with DCWS/PtD suggestions.
- Develop knowledge-base rules for DCWS.

Strategy 2: Establish a multi-media DCWS/PtD Wiki.

- Create and support a DCWS/PtD Wiki to augment the DCWS/PtD knowledge base.

Strategy 3: Develop a conceptual framework for a DCWS/PtD checking tool for use in BIM.

- Evaluate existing BIM software and select appropriate software for the DCWS/PtD application.
- Create a DCWS/PtD code checking prototype tool for use with BIM, based on MVD, IFD, IDM principles.

Strategy 4: Validate the DCWS/PtD checking tool by using the buildingSmart™ Alliance methodology.

- Perform a pilot case study to validate the DCWS/PtD code checking tool. Organize a focus group of construction safety experts that would walk through a specific project and identify potential safety problems, especially those which could be addressed by the modifications to the design. Subsequently, the safety hazard simulation of the same project would be conducted by using the developed DCWS/PtD code checking tool to evaluate the framework performance.

STRATEGY FOR INTEGRATION OF BIM AND DCWS

Table 1 shows the barriers to the implementation of DCWS/PtD by the designers that were identified in previous research and how they can be favourably impacted by the strategy for integration of DCWS/PtD and BIM developed by this research.

Table 1 Barriers to DCWS and the Impact of the BIM for DCWS Strategy on Those Barriers

Barriers to DCWS	Impact of the BIM for DCWS strategy on barriers
Designers have minimal knowledge of construction worker safety (Gambatese et al. 1997, 2005, Hadikusumo and Rowlinson, 2004, Toole 2005).	Development of a BIM system that can alert designers to safety issues through safety code checking enhances their knowledge and ability to take worker safety into consideration.

There is limited availability of the DCWS tools and guidelines (Gambatese et al. 2005).	Tools to check for compliance with DCWS guidelines (similar to tools currently available to check on Building Code compliance) can be incorporated in the BIM software system to check the completed model.
Traditional project delivery systems limit collaboration between the designers and constructors (Gambatese et al. 2005).	The shift towards BIM with a single model to be used by all parties has started to eliminate these barriers.
Construction documents define the end result, but not the construction means, methods and process (Hinze 1997).	By using the BIM features that allow the construction processes to be defined, safety, safety training, and coordination of the schedule with safety toolbox talks are taken into consideration.
Designers have the perception/concern that implementation of DCWS will require more time and increase the cost of design (Toole 2005, Gambatese et al. 2005).	With the tools to be developed the DCWS code compliance checking could be executed as a feature of the BIM software used, similar to the way tools are currently used to conduct Building Code and ADA compliance checking.
Regulatory mandates to implement DCWS are lacking (Hinze 1997, Gambatese et al. 2005, Toole, 2005).	With the availability of BIM-based tools which reduce the cost of DCWS implementation, regulatory bodies may consider mandating DCWS.
Motivation to implement DCWS is lacking (Gambatese et al. 2005).	Once the DCWS tools are developed, code compliance checking will aid in constructability and value engineering reviews.
Designers have traditionally not been asked to apply DCWS (Young 1996, Hinze 1997, Toole 2005).	The integration of DCWS and BIM will secure a footing for safety-minded design in the burgeoning world of BIM, which is rapidly becoming standard practice for large owners such at the GSA and U.S. Army Corps of Engineers.

RESEARCH CONTRIBUTIONS

This proposed research is innovative because it is the first study to address in depth the problem of the integration of BIM and DCWS/PtD. The strategy developed by this research makes a positive impact in the area of the application of BIM for safety in construction. Benefits of the integration of BIM with DCWS/PtD include:

- Enhancing communication, knowledge and collaboration.
- Providing more timely design acceptance and approval.
- Improving construction worker safety and performance.
- Reducing construction, administration, and design costs.
- Opportunity for the broad application of BIM with DCWS/PtD tools in the construction industry.

While some attempts have been made to develop computer programs that will address the issue of DCWS/PtD, they remain relatively unused in the industry. One reason is that these programs are not readily available for use. For those firms that have utilized these software programs, some have commented that they are too cumbersome to use. In addition, these design for construction worker safety software programs run independent of the design software, so it is not integrated into the design process, i.e., a specific effort must be expended to utilize the software to address DCWS/PtD.

The DCWS/PtD code checking tool for BIM can build on existing applications for building code compliance checking, structural analysis, and constructability analysis. Thus, DCWS/PtD becomes an integral component of the BIM software, just as quality, cost, schedule information, structural analysis, HVAC load and building code compliance checking tools are currently available for BIM. By integrating DCWS/PtD into the BIM for a project, safety is not an afterthought, but it is on equal basis with the other design parameters addressed by BIM. In light of the increased focus on software interoperability, economic and workforce globalization, and software vendor adoptability, a BIM-centric approach is required for having relevance to the future of the facility lifecycle.

CONCLUSIONS

Integration of DCWS/PtD and BIM enriches the education of future designers and construction managers and enhances human sustainability by reducing safety hazards encountered on construction projects. In addition, the strategy for the BIM integration can also be applied to other design and construction issues ranging from checking designs for compliance with building code requirements, including structural, life safety, and disability codes. Furthermore, the research establishes a global virtual community of professionals interested in DCWS/PtD issues and educators that can greatly facilitate knowledge sharing and dissemination.

The need for BIM-savvy employees in the design and construction industry seems to be endless. Integration of BIM and safety brings together a diverse group of researchers, engineers, architects and construction managers into a virtual community. The integration of Web 2.0 technology and DCWS/PtD provides an open, extensible infrastructure. The infrastructure implemented in this research can be applied to other research domains such as manufacturing and other general applications relying on semantic web technologies for consensus building. The advancement in the DCWS/PtD can be used synergistically with other information technologies to explore, develop and advance new integration strategies that are more practical and applicable, in order to better address the central issue information integration and knowledge management for sustainable human development in the design and construction areas. The results obtained from this research can potentially lead to major breakthroughs and open up new directions for research.

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SAFETY AND HEALTH RISKS IN INTERNATIONAL CONSTRUCTION

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ABSTRACT
The international construction market is a viable financial endeavor. According to the survey by Engineering News Record, the top 225 international contractors generated revenues of $310.25 billion in 2007 from projects outside their respective home countries. Despite this financial volume, the international construction market is more risky than its domestic counterpart. Numerous studies have examined many risk management aspects of international construction, including joint venture risks, bidding risks, financial risks and political risks. Despite this, few efforts have analyzed the safety and health risks for different international construction regions. Based on 13 safety and health risk factors identified in the literature and through interviews, a survey was conducted to collect information and make an assessment on the safety and health risk factors in three different geographic regions, namely developed regions, developing regions and the Middle East. Statistical analysis investigated the criticality of the 13 risk factors for the different regions. The risk factors were grouped into three categories, namely high risk, medium risk and low risk. Findings show that: 1) the developing regions have the riskiest situations with 8 high risks and 5 medium risks; 2) the developed regions have much less risky situations with 10 risk factors (76.92%) falling into the medium and low risk categories; 3) the Middle East has 6 risk factors categorized as high risk and low risk respectively; 4) the six risk factors were found to be critical risks for all the three regions.

Keywords: International construction, Safety and health risk, Survey

INTRODUCTION
The Engineering News Record (ENR) reported that the top 225 international contractors generated $310.25 billion in 2007 revenues from projects outside their respective home countries. This represents a dramatic increase of 38.3% over 2006's mark of $224.40 billion. The top 225 had total contracting revenues of $826.96 billion in 2007, a 27.1% increase over 2006's figure of $650.66 billion (Reina and Tulacz 2008). Although the international work increased at a higher rate than the domestic work, the international construction market presents greater risks than its domestic counterpart. After a thorough review of the literature on international construction from 1987 to 2004, Dikmen and Birgonul (2006) concluded that risk management was one of the most important factors for the success of international projects. There have been a considerable number of studies pertaining to risk management on many aspects of international construction, including joint venture risks (Bing et al 1999a; Bing et al 1999b), bidding risks (Han and Diekmann 2001a; Han and Diekmann 2001b), political risks (Wang et al 1999a; Wang et al 2000a) and financial risks (Wang et al 2000b; Wang et al 2000c). A few studies have focused on the safety and health risks in international construction, including safety and health issues in developing countries (Gibb 2006), the influence of the different laws and regulations on safety and health in international construction (Koehn et al 1995; Mahalingam and Levitt 2007), language barriers and cultural issues (Dong and Platner 2004; Escobar 2006; Kartam et al 2000; Mahalingam and Levitt 2007; Trajkovski and Loosemore 2006). It is recognized that the safety and health risk situation may vary between regions in international construction markets, but few efforts have addressed safety and health risks for different international construction regions over the world. This paper presents the

results of a questionnaire survey aimed at making an assessment on the safety and health risk factors for different international construction regions. This provides a better understanding on the safety and health risks in international construction.

SURVEY DESCRIPTION

A questionnaire survey was conducted to assess the safety and health construction risks in different international regions during April to June of 2009. The survey was based on 13 safety and health risk factors (Table 1) identified through a literature review on construction risk management. The 13 risk factors were categorized into 4 groups, namely political & economical risks, social risks, environmental risks, and project risks. Because the safety and health risk situation may vary from region to region, the international construction market was divided into six geographic regions, namely:

- Region 1 (West & North Europe, Australia and North America)
- Region 2 (Latin America/Caribbean)
- Region 3 (South Asia, Southeast Asia and East Asia)
- Region 4 (Central Asia, Russia and East Europe)
- Region 5 (Africa)
- Region 6 (Middle East)

The respondents were asked to assess the risk occurrence level and the risk impact level of the 13 risk factors for the international construction regions with which they were most familiar. Similar to previous studies (Zhu 2007, Sun et al 2008), the Likert scale ranging from 1 to 5 was assigned to both the risk occurrence level and the risk impact level (Table 2). The questionnaire survey was distributed via email to three groups of targeted respondents, consisting of 1) the top 225 international contractors listed by ENR in 2008; 2) the academic research networks (e.g. CIB W99, CIOB, GloNIC); and 3) the work partners of Tsinghua University and the University of Florida. More than 500 emails were sent for the questionnaire distribution and 58 valid responses were received by the end of June, 2009. The estimated response rate is about 10%, but the exact response rate cannot be computed as some email addresses were invalid.

Table 1. Safety and health risks identified for international construction

Category	Risk Factor	Code	Description or Example
Political & Economical Risk	War	WA	➢ Problems caused by the war at or near the project location.
	Civil Unrest	CU	➢ Problems caused by the civil unrest at or near the project location.
	Terror Attack	TA	➢ Such as terror attack targeting the project and project workforce or influence from attack not targeting the project and project workforce.
	Bad Economical Situation	BES	➢ Problems caused by the bad economical situation of project country, such as losing or weakening the financial support for safety and health of project workforce.
Social Risk	Crime	CR	➢ Such as theft, dacoity and kidnap.
	Language Barrier	LB	➢ Language barrier problems during the project daily running or safety program execution, such as language barrier in safety training and site safety management.
	Cultural Difference and Conflict	CDC	➢ Problems for project safety and health caused by cultural differences and conflicts, such as race discrimination, differences in ethics, conflicts between workers with different races or nationalities, and cultural differences resulting in difficult communications.
	Difference in Laws & Regulations	DLR	➢ Safety and health problems caused by unawareness of differences in laws & regulations between the contractor's home country and project country, such as different requirements on safety protection, safety training, insurance, compensations or misunderstanding on local law and regulations. Worker injuries might even result in fines.
Environmental	Natural	ND	➢ Safety and health problems caused by disasters happen

Category	Risk Factor	Code	Description or Example
	Disaster		at or near the project locations, such as earthquakes, hurricanes, typhoons, volcano activities, floods and mudflows.
Risk	Disease	DI	➢ Safety and health problems caused by disease happen at or near the project location, such flu, mad cow disease, malaria and impaludism.
	Extreme Natural Condition	ENC	➢ Safety and health hazards caused by extreme natural conditions, such as extremely hot conditions, extremely cold conditions and unsafe geologic conditions.
Project Risk	Lack of Infrastructure Facilities	LIF	➢ Safety and health problems caused by the lack of infrastructure, such as the lack of medical facilities for injury treatment or lack of transportation facilities to safely transport project workers.
	Labor Risk	LR	➢ Safety and health hazards or problems caused by the idocyncracies of workers, such as workers with poor safety attitudes or workers with poor knowledge

Table 2. Likert scale of risk occurrence and risk impact

Occurrence level	Value Assignment	Impact level	Value Assignment
Impossible	1	Almost None	1
Not Likely	2	Minor	2
Possible	3	Moderate	3
Very Possible	4	Severe	4
Almost Definite	5	Very Severe	5

Of the 58 valid responses, there were 6 from Region 2, 2 from Region 4 and 6 from Region 5. These low response rates were insufficient to conduct viable statistical analysis for the safety and health risk factors of the three regions. As a result, the six regions were re-categorized as three regions according to the regional level of social and economic development and the construction safety and health performance. Regions 2, 3, 4 and 5 were re-categorized as the developing region because most countries located in these regions were developing countries; the Region 1 was re-categorized as a developed region because all the countries in this region were developed countries with the best construction safety and health performance in the world; the Middle East was re-categorized as an independent region because of its distinct oil-motivated international construction. The amounts of responses for above re-categorized three regions are shown in Figure 1. The information on each respondent's experience, work region, and affiliation was obtained as part of the survey. The experience refers to how many years of experience each respondent had with international construction. Most respondents (77.59%) had more than 5 years experience on international construction (Figure 2). Work region refers to the number of regions (6 regions possible) where the respondent had worked. Most respondents (75.86%) had work experience in 1 or 2 international construction regions (Figure 3). Most of the respondents (79.31%) represented international contractors (Figure 3).

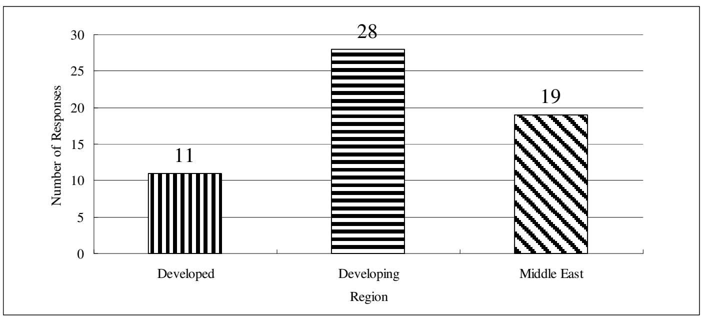

Figure 1. The amounts of responses for the three regions

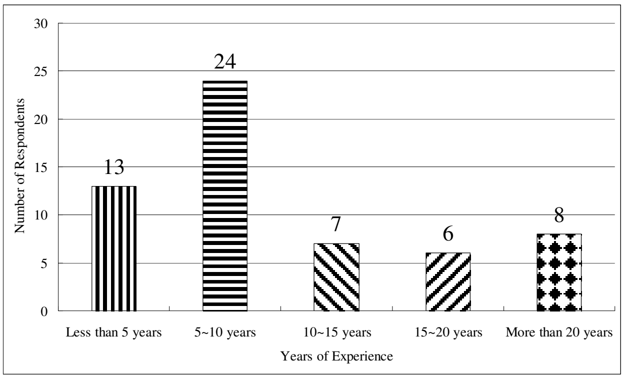

Figure 2. The experience of respondents in international construction

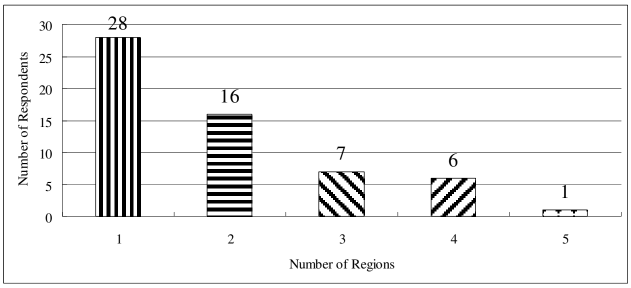

Figure 3. The work regions of respondents in international construction

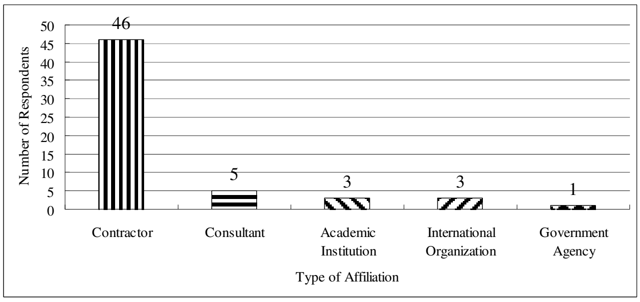

Figure 4. The affiliations of respondents in international construction

DATA ANALYSIS

In this research, the risk criticality index was used to prioritize the risk factors for the three international construction regions. The risk criticality index was intensively adopted by previous researchers to extract the critical risks from a risk checklist (Shen et al 2001; Fang et al 2004; Sun et al 2008; Zou and Zhang 2009). Formula (1) and (2) demonstrate how to calculate the risk criticality index according to the experts' assessment on the risk occurrence and the risk impact.

$$R_j^i = P_j^i I_j^i \tag{1}$$

$$R^i = \frac{\sum_{j=1}^{n} R_j^i}{n} \tag{2}$$

where n =number of people surveyed; R_j^i =evaluation of the criticality of the ith risk factor by the jth person surveyed; P_j^i =evaluation of risk occurrence level by the jth person surveyed; I_j^i =evaluation of risk impact level resulting from the ith risk factor by the jth person surveyed. R^i =criticality index of the ith risk factor.

Calculations were carried out according to formulas (1) and (2) with the data obtained in the survey. The statistical analysis was conducted to investigate the differences between the risk criticality indices of different risk factors. The major statistical methods employed were Paired-samples T test and Wilcoxon test (for comparison between two risk factors in a matched-pair set). It should be noted that for parametric methods such as Paired-samples T test the objective is to compare the mean of different groups; while for the non-parametric methods the objective is compare the median (or distribution) of the different groups. In this analysis, the comparisons were all conducted between two risk factors in the matched-pair set. As suggested in the literature (Huang and Hinze 2006), if the means and medians revealed the same prioritizations between the two compared risk factors, a one-tail test was conducted. Because this research was an exploratory study, a significance level of 0.1 was established to detect the differences between the criticality index values of different risk factors. Based on the results of statistical analysis, the 13 risk factors were categorized into three groups (high risk, medium risk and low risk) in accordance with the criteria as follow:

1. As the literature suggested (Zhu 2007; Sun et al 2008), if the risk criticality index of the ith risk factor was no less than "P(3)×I(3)＝9", it should be grouped into high risk category;
2. For the ith risk factor with the criticality index less than 9, if the statistical analysis showed that there was no statistically significant difference between the two criticality index values of the ith risk factor and the last risk factor with the criticality index no less than 9, it should be grouped into medium risk category;
3. For the ith risk factor with the criticality index less than 9, if the statistical analysis suggested that there was a statistically significant difference between two criticality index values of the ith risk factor and the last risk factor with the criticality index no less than 9, it should be grouped into low risk category;
4. If the parametric and non-parametric tests showed the opposite results, which meant one test showed there was a statistically significant difference while the other test showed none, the risk factor would be grouped into the medium risk category according the conservative point of view of "never underestimate the risk".

FINDINGS

For the three international construction regions, the risk criticality indices of 13 risk factors were computed. The risk criticality indices of 13 risk factors were also analyzed regardless of the three regions, which could provide a global view of the safety and health risks in international construction.

DEVELOPED REGIONS

Of the 58 valid responses, 11 respondents gave their assessments on the safety and health risks for developed regions. Risk criticality indices of the 13 risk factors were then computed and the results were listed in Table 3. Three risk factors (namely labor risk, extreme natural condition and natural disaster) were in the high risk category with criticality indices greater than 9. The risk factor "natural disaster" is the last risk factor with its criticality index value more than 9. Based on the statistical comparison of the criticality indices between "natural disaster" and the risk factors with the criticality values less than 9, seven risk factors were in the medium risk category (e.g. terror attack, language barrier, bad economical situation, crime, cultural difference and conflict, difference in laws & regulations and disease) and three risk factors were in the low risk category (e.g. lack of infrastructure facilities, war and civil unrest).

Table 3. Risk criticality indices for the developed regions

Risk Factor	Code	Mean	Median	Risk Category
Labor Risk	LR	9.55	9	High
Extreme Natural Condition	ENC	9.36	9	High
Natural Disaster	ND	9.00	9	High
Terror Attack	TA	8.27	8	Medium
Language Barrier	LB	8.18	8	Medium
Bad Economical Situation	BES	8.09	9	Medium
Crime	CR	7.91	6	Medium
Cultural Difference and Conflict	CDC	7.91	9	Medium
Difference in Laws & Regulations	DLR	7.82	9	Medium
Disease	DI	7.82	8	Medium
Lack of Infrastructure Facilities	LIF	6.27	6	Low
War	WA	6.00	5	Low
Civil Unrest	CU	6.00	8	Low

DEVELOPING REGIONS

There were 28 respondents that provided their assessments on the safety and health risks for developing regions. The risk criticality indices of the 13 risk factors for the developing regions were computed (Table 4). Eight risk factors, e.g. labor risk, lack of infrastructure facilities, cultural difference and conflict, crime, disease, language barrier, difference in laws & regulations and bad economical situation, had criticality indices greater than 9. The risk factor “bad economical situation” is the last risk factor with its criticality index value more than 9. The comparison of the criticality indices were conducted between the risk factor “bad economical situation” and the risk factors with the criticality values less than 9. The results indicate that all the 5 risk factors with less than 9 criticality values should be categorized as medium risks. It should be noted that for the comparison pair “bad economical situation and war”, the Wilcoxon test p-value was less than 0.1 while the Paired-samples t test p-value was more than 0.1. Complying with the conservative point of view, the risk factor “war” was grouped into the medium risk category.

Table 4. Risk criticality indices for the developing regions

Risk Factor	Code	Mean	Median	Risk Category
Labor Risk	LR	12.89	12	High
Lack of Infrastructure Facilities	LIF	11.54	9	High
Cultural Difference and Conflict	CDC	10.96	10.5	High
Crime	CR	10.93	11	High
Disease	DI	9.86	9	High
Language Barrier	LB	9.39	8.5	High
Difference in Laws & Regulations	DLR	9.39	9	High
Bad Economical Situation	BES	9.11	9	High
Civil Unrest	CU	8.50	9	Medium
Extreme Natural Condition	ENC	8.25	7.5	Medium
Natural Disaster	ND	8.18	9	Medium
Terror Attack	TA	7.79	8	Medium
War	WA	7.71	8	Medium

MIDDLE EAST

A total of 19 respondents provided assessments on the safety and health risks for the Middle East. The risk criticality indices were computed for the 13 risk factors for the Middle East (Table 5). There are 6 risk factors with criticality indices greater than 9 so that they are grouped into the high risk category, including bad economical situation, extreme natural condition, labor risk, language barrier, cultural difference and conflict, and difference in laws & regulations. The last risk factor in this group is the risk factor “difference in laws & regulations”. The comparison of the criticality indices were conducted between the risk factor “difference in laws & regulations” and the risk factors with the criticality values less than 9. The statistical analysis shows that only 1 risk factor (lack of infrastructure facilities) should be grouped as medium risk category and 6 risk factors would fall into the low risk category, including terror attack, war, natural disaster, disease, crime and civil unrest.

Table 5. Risk criticality indices for the Middle East

Risk Factor	Code	Mean	Median	Risk Category
Bad Economical Situation	BES	12.95	12	High
Extreme Natural Condition	ENC	12.11	12	High
Labor Risk	LR	10.42	9	High
Language Barrier	LB	9.74	9	High
Cultural Difference and Conflict	CDC	9.53	9	High
Difference in Laws & Regulations	DLR	9.47	9	High
Lack of Infrastructure Facilities	LIF	8.53	9	Medium
Terror Attack	TA	6.89	8	Low
War	WA	6.84	6	Low
Natural Disaster	ND	6.74	8	Low
Disease	DI	6.68	6	Low
Crime	CR	6.47	6	Low
Civil Unrest	CU	5.74	5	Low

ANALYSIS COMBINING THE THREE REGIONS

With the combined data of all 58 responses, the criticality indices of the 13 risk factors were computed by combining the regions (Table 6). Computations revealed 7 risk factors with criticality indices more than 9 (grouped into high risk), including labor risk, bad economical situation, cultural difference and conflict, extreme natural condition, lack of infrastructure facilities, language barrier, and difference in laws & regulations. The comparison of the criticality indices were conducted between the risk factor "difference in laws & regulations" (the last risk factor falling into high risk category) and the 6 risk factors with the criticality values less than 9. According to this analysis 2 risk factors (crime and disease) should be categorized as medium risk and 4 risk factors as low risk, including natural disaster, terror attack, civil unrest, and war.

Table 6. Risk criticality indices of consolidated data

Risk Factor	Code	Mean	Median	Risk Category
Labor Risk	LR	11.45	12	High
Bad Economical Situation	BES	10.17	10.5	High
Cultural Difference and Conflict	CDC	9.91	9	High
Extreme Natural Condition	ENC	9.72	9	High
Lack of Infrastructure Facilities	LIF	9.55	9	High
Language Barrier	LB	9.28	9	High
Difference in Laws & Regulations	DLR	9.12	9	High
Crime	CR	8.90	9	Medium
Disease	DI	8.43	8.5	Medium
Natural Disaster	ND	7.86	8.5	Low
Terror Attack	TA	7.59	8	Low
Civil Unrest	CU	7.12	8	Low
War	WA	7.10	8	Low

DISCUSSION

Risk profiles for the three regions

A radar chart was created to demonstrate the risk profiles on the safety and health issues for the different international construction regions (Figure 5). It shows that the developing regions have the greatest risk with safety and health issues. All the risk factors in the developing regions are high and medium risks. At the same time, developed regions have less risky situations with 10 risk factors (76.92%) falling into the medium and low risk categories. The Middle East has distinct features from the developed and developing regions, with 6 high risk, 1 medium risk and 6 low risk factors. The risk profile of the Middle East is similar to the risk profile of the consolidated regions with 7 high risk, 2 medium risk and 4 low risk factors. With 7 high risk factors, the safety and health issues in international construction are a serious problem from a global point of view. Considerable efforts are warranted to address this issue in the various regions.

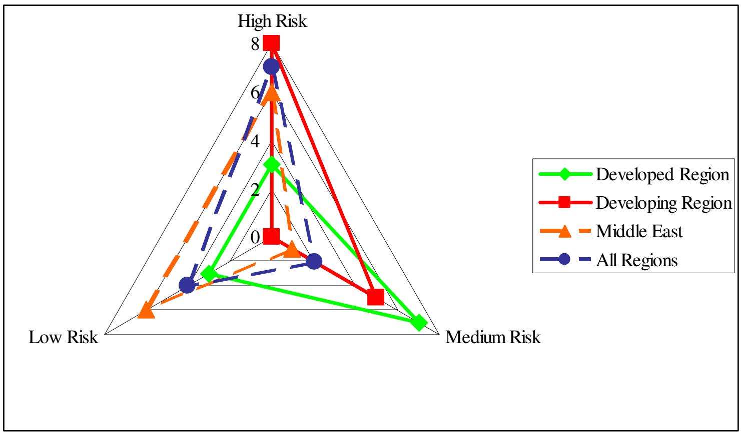

Figure 5. The risk profiles for the different international construction regions

THE CRITICAL RISK FACTORS OF THE THREE REGIONS

The most important risk factors of concern are those with high criticality index values in all three international construction regions. These critical risk factors can serve as a means for developing an effective risk management strategy that should be implemented in an efficient way. A score ranging from 1 to 3 was given to qualitatively explore the critical risk factors of the three regions. For a specific region, 1, 2, or 3 was assigned to a risk factor respectively if the risk factor was in a low, medium or high risk category. Table 7 illustrates the scores assigned to all the risk factors for each region and the average scores for the three regions are also calculated and listed in the right column. The labor risk received an average score of 3, meaning that the labor risk was high in each of the three regions. Five other risk factors had average scores of 2.67, including bad economical situations, cultural differences and conflicts, differences in laws & regulations, extreme natural conditions and language barriers. These five risk factors were categorized as high risk in 2 regions and medium risk in one region. Along with the labor risk factor, these should be regarded as the critical risk factors on safety and health issues in international construction. In summary, the large number of high critical risk factors (6 of 13 or 46.15%) confirms that the safety and health issues in international construction are serious problems from a global point of view and warrant serious consideration to properly address them.

Table 7. The critical risk factors for all the three regions

Risk Code	Developed Region		Developing Region		Middle East		Average Score
	Risk	Score	Risk	Score	Risk	Score	
BES	**Medium**	**2**	**High**	**3**	**High**	**3**	**2.67**
CDC	**Medium**	**2**	**High**	**3**	**High**	**3**	**2.67**
CR	Medium	2	High	3	Low	1	2.00
CU	Low	1	Medium	2	Low	1	1.33
DI	Medium	2	High	3	Low	1	2.00
DLR	**Medium**	**2**	**High**	**3**	**High**	**3**	**2.67**
ENC	**High**	**3**	**Medium**	**2**	**High**	**3**	**2.67**
LB	**Medium**	**2**	**High**	**3**	**High**	**3**	**2.67**
LIF	Low	1	High	3	Medium	2	2.00
LR	**High**	**3**	**High**	**3**	**High**	**3**	**3.00**
ND	High	3	Medium	2	Low	1	2.00
TA	Medium	2	Medium	2	Low	1	1.67
WA	Low	1	Medium	2	Low	1	1.33

SUMMARY AND CONCLUSIONS

The objective of this research was to assess the safety and health risk factors in international construction to provide a better understanding of the safety and health risks for the developed, developing and Middle East regions. According to the risk criticality index and statistical analysis, four criteria were developed to categorize the risk factors as high risk, medium risk, and low risk. The detailed outcome of this paper is summarized as follow:

1. Of the three international construction regions, the developing region has the greatest risk situation on safety and health issues in international construction. In the developing region, all the risk factors are in the high and medium risk categories. The high risk category for the developing region consists of 8 factors, namely labor risks, lack of infrastructure facilities, cultural differences and conflicts, crime, disease, language barriers, differences in laws & regulations, and bad economical situations.
2. Compared to the developing region, the developed region is less risky with 10 risk factors (76.92%) falling into the medium and low risk categories. There are three risk factors in the high risk category for the developed region, including labor risks, extreme natural conditions and natural disasters.
3. The Middle East has the distinct feature that differs from the developed and developing regions. There are 6 high risk factors and 6 low risk factors, with 1 medium risk factor. The 6 high risk factors are bad economical situations, extreme natural conditions, labor risks, language barriers, cultural differences and conflicts, and differences in laws & regulations;
4. A radar chart was created to illustrate the safety and health risk profiles for the different international construction regions, which distinguish the risk situation of the individual region perspective and the global point of view;
5. Six critical risk factors were identified through further analysis, which were categorized as high risk in at least 2 regions and were not marked as low risk in any regions. These critical risk factors comprise labor risks, bad economical situations, cultural differences and conflicts, differences in laws & regulations, extreme natural conditions and language barriers. With the critical risk factors for all the regions, a more effective risk management strategy could be developed and implemented on international projects.

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SAFETY MANAGEMENT OF EXPO 2010 SHANGHAI CHINA

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ABSTRACT
The construction of Expo 2010 Shanghai China Program is a big challenge for China, which comprises more than 200 pavilions and facilities projects in the 5. 28- square-kilometer Expo site. During the compressed construction period, how to establish an effective safety management system for all the projects in the park is one of the core issues. This paper analyses the main safety challenges, and provides a systematic resolution for it, which includes management objective, organization, and management approaches. The conclusion in the end could provide a reference to scholars and practitioners.

Keywords: Safety management, Major hazards controlling system, Site inspection, Humanism

1 INTRODUCTION

As the first registered World Exposition in a developing country, the construction scale of Expo 2010 Shanghai China (hereinafter referred to as 'Expo 2010') is the biggest in the Expo history (Expo History, 2006). The Expo Site covers a total area of 5.28 km^2, including the enclosed area and outside areas of supporting facilities, which is double the size of the Montreal Expo site. It spans both sides of the Huangpu River, with 3.93 km^2 in Pudong (the site on east side of Huangpu River) and 1.35 km^2 in Puxi (the site on west side of Huangpu River). The enclosed area measures 3.28 km^2, which is made up of 5 section areas—section A, section B, section C, section D and section E (Master Plan of Expo 2010, 2009). The planned floor area of the 2010 Expo site totals about 2 million m^2 and the total investment is about 3 billion US dollars. The site construction for Expo 2010 started in 2007 and shall be completed by in the end of 2009, and the event will officially begin on the 1st of May in 2010. Its master plan is shown in Figure 1.

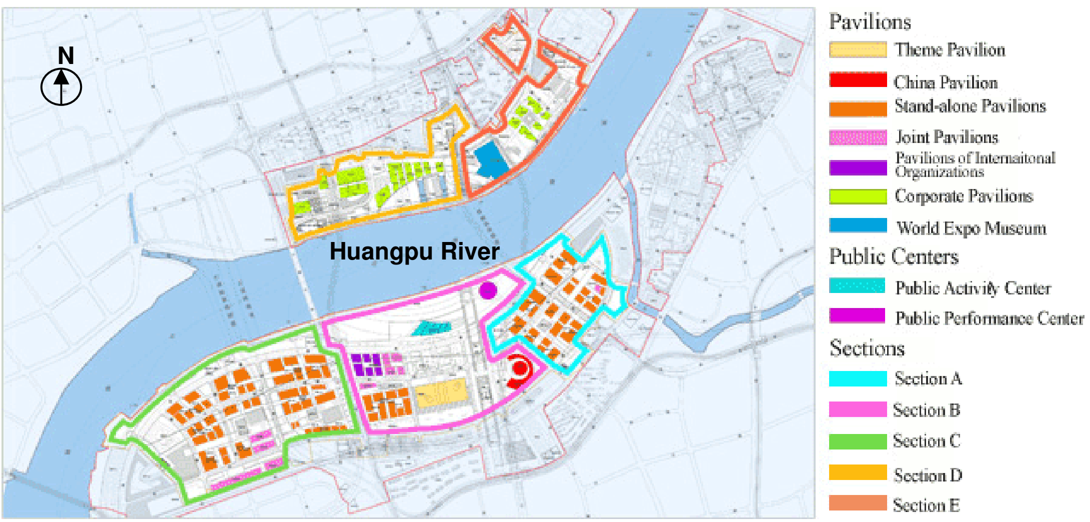

Figure 1. Master Plan of the EXPO site

As more than 200 pavilions and facilities projects shall be completed in three years, safety issues should be the first consideration in construction. This paper analyses its safety challenges and characteristics for Expo 2010, and makes recommendations for further research on resolution and implementation of stated issues.

2 SAFETY CHALLENGES FOR EXPO 2010 PROGRAM CONSTRUCTION

2.1 Program Characteristics

i. Lots of investors. Expo 2010 Program comprises more than 200 projects, including pavilions, parks, docks, supporting service facilities and municipal facilities, which are invested by numerous companies and organizations such as Expoland company (a stated company), Expogroup company (another stated company), municipal facilities departments of Shanghai government, foreign governments and enterprises.

ii. Mega construction scale. According to the plan, the investment for pavilions, parks, docks, supporting service facilities and municipal facilities in the Expo site may achieve 30 billion US dollars, and such investment excludes the constructions of new-built tunnel and metro.

iii. Lots of projects constructing in parallel. Since 2007, dozens of projects have been constructed in parallel; and in the October of 2008, there were nearly 200 projects being constructed in parallel at the Expo site.

iv. Compressed Construction Period. According to the construction schedule, the majority of pavilions and supporting service facilities have started since 2007; and they shall be finished in the end of 2009, which excludes pavilions of foreign governments and enterprises. Completing 2-million-m^2 –floor-area construction in three years is a big challenge for contractors.

2.2 Safety Management Objectives

Comparing with other project management objectives, the safety management objective is certainly clear i.e. zero death or injury during construction, and this requires tremendous effort from the site staff to achieve the goal. The client (owner) of Expo 2010 also requires that no fatal accident shall occur during the construction. In China, contractors (employer) usually employ workers (employee) from rural areas and provide accommodation. Migrant workers' living safety, health and welfare should also be of concern, which have positive impact on construction safety according to the research of LIU *et al* (2006). Consequently, the safety management context is more than construction site safety. Safety management of Expo 2010 program comprises of two main issues as shown in Figure 2.

Main Issue	Detailed Content
Construction Site Safety	1. Safety of scaffold system 2. Safety of formwork engineering of cast-in-place concrete 3. Safety of working at height 4. Temporary protection for special places (elevator shaft, holes or exits and son on) 5. Personal protection for workers 6. Safety of construction Machines 7. Temporary electricity use 8. Safety of Flood controlling (including typhoon, rainstorm, tidewater and flood) 9. Safety management system and files
Migrant Workers' Living safety, Health & Welfare	1. Food safety 2. Epidemic prevention facilities and management (including toilets, bathrooms, sewage facilities and so on) 3. Safety of fire controlling 4. Medical Rescue

Figure 2. Safety Management Content of Expo 2010

3 SAFETY MANAGEMENT ORGANIZATION

In Expo 2010, the investment and construction management of pavilions and supporting facilities in the Expo site are implemented by various organizations. Stated companies such as Expoland offer funds for the program investment; and the construction management works for the major projects at the Expo site are implemented by an organization, Shanghai World Expo Construction Headquarter Committee, which is led by Shanghai executive vice-mayor and comprises of all the directors of related construction department of Shanghai Municipality. Its routine work is executed by its standing body —Shanghai World Expo Construction Headquarter Office (SWECHO). SWECHO has established a unified management and coordination system to manage all the construction projects on site.

During the construction, SWECHO plays a major role in operating nine functional divisions and ten Project or Program Management Teams (PMTs). Every functional division is responsible for one function management task; and one is Safety and Quality Management Division (SQMD) which is responsible for safety management of all the projects in the Expo site. Every PMT takes on client duty of managing site construction of projects in various sections of the Expo site; and site safety management is one of their main tasks. SQMD and PMTs are comprised of the full safety management organization of the client as shown in Figure 3.

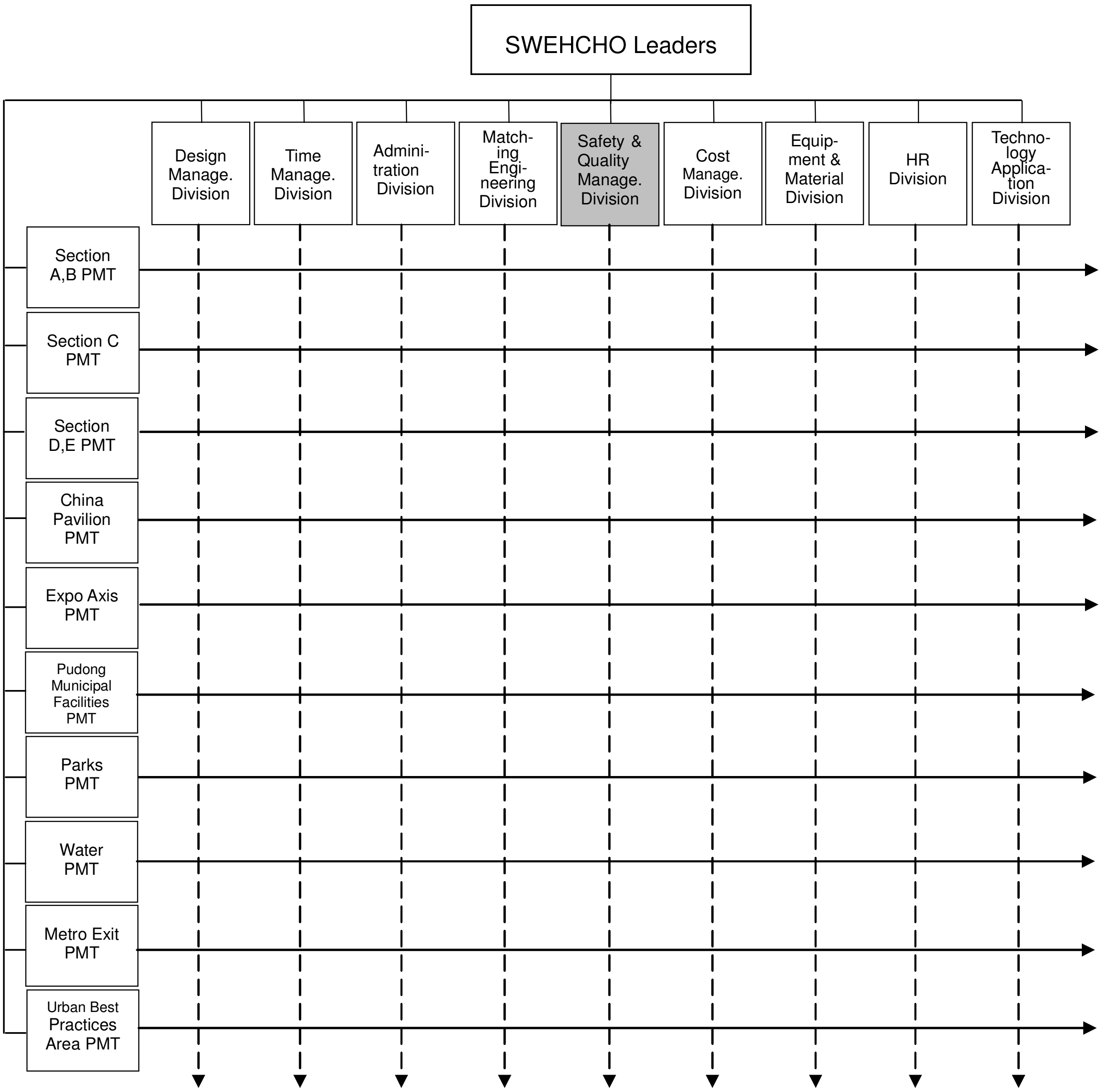

Figure 3. SWEHCHO Organization Structure

For the projects managed by SWECHO, safety management levels are divided into four levels as shown in Figure 4.

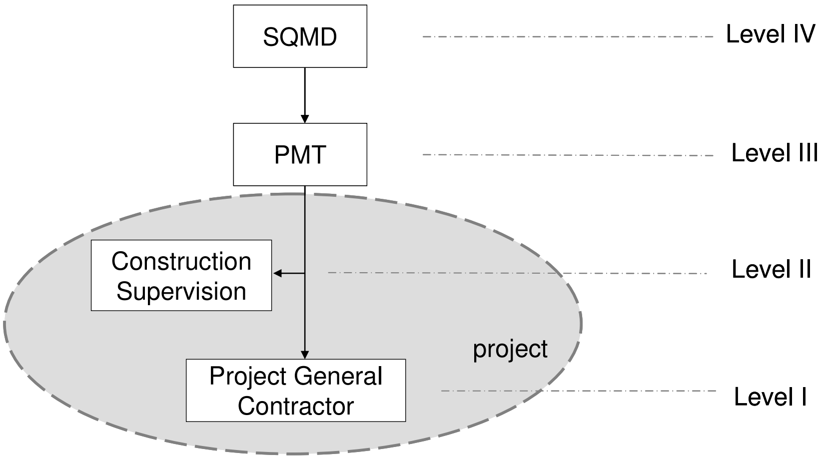

Figure 4. Safety Management Levels of Expo 2010

Level IV: As the safety functional division, SQMD has developed policies, standards, regulations, and processes of safety management; and established safety management systems and kept them operating effectively. Besides, SQMD takes other responsibilities as follow.

i. Promoting project construction safety management at the construction site, and making on-site safety inspections regularly.

ii. Assisting other divisions' work, and coordinating construction safety conflicts.

iii. Providing assistance in dealing with accidents.

Level III: PMTs have implemented SQMD's policies, regulations and processes; and managed general contractors and construction supervisors to meet the safety standards and requirements.

Level II: According to Chinese construction law, when the government-investment project achieves a specific construction scale, a national certified construction supervision company will be employed as the third party to ensure the implementation of all related state construction safety standards and regulations, which shall employ at least one full-time supervision engineer to control site safety.

Level I: In China, the government has developed very detailed construction standards and regulations; and construction safety regulations and standards are the majority. In relevant standards and regulations, it outlines detailed requirements on management team configuration and staff qualification, controlling process, controlling the requirement of safety management of the general contractors. The general contractor shall conduct the compulsory regulation and standards, which constructs the basic level of safety management system.

Besides, for other projects invested by foreign governments and enterprises, SQMD does not manage them directly, but monitors the implementation of safety management, and offers necessary support, such as making monthly site inspection to ensure the requirements are met in the construction.

4 SAFETY MANAGEMENT APPROACHES

4.1 Making Safety Management Polices, Standards and Regulations

As the top safety management level, SQMD has the responsibility of making safety polices, standards, and regulations, which with the following three type's documents are mainly concerned.

i. Safety clauses in contracts of general contracting and construction supervision. It includes safety management objectives; personal qualification requirements; safety management procedures and so on.

ii. Site safety assessment standard. In order to encourage site construction of general contractors, SWECHO has set up a prize fund for general contractors and established a construction assessment standard, which is called "Civilized Construction Assessment Standard (CCAS)". All the general contractors who pass the CCAS could receive extra payment as the prize. CCAS is developed and implemented by SQMD, whose assessment concerns construction quality; construction safety; and migrant workers' living safety, health and welfare. CCAS makes detail assessment standards on major hazard controlling, such as scaffolding system, form work engineering of cast-in-place concrete, work at heights, temporary protection for special places (elevator shaft, holes or exits and so on), construction machines, temporary electricity use and so on.

iii. Safety regulation of various engineering construction and seasonal construction. Nearly every season, SQMD may issue various safety management documents on presenting systematic safety dangers or notice for the next construction phase, such as safety management regulation in Typhoon weather; and fire controlling regulation in fitting-out engineering and so on.

4.2 Making Regular /Irregular Site Inspection

Among the site inspections of construction supervision, SQMD's site inspections can be divided into two types as follow.

i. Regular site Inspections: SQMD may judge whether there is any systematic safety danger in program construction site safety and take adequate measures. If necessary, SQMD may issue warning documents on the systematic safety danger and take correspondent controlling measures.

ii. Irregular site Inspections: If there is new safety management document issued, SQMD may carry out site inspection randomly to ensure its implementation.

By carrying out regular/irregular inspection, SQMD can get feedback from safety standards and requirements issued and ensure their effectiveness and efficiency on improving safety management.

4.3 Assist Establishing Major Hazards Controlling System

For major construction hazards, SQMD has established full-process controlling procedures as follows.

i. Before commencement of construction: For the major construction hazards, the contractor should provide the construction plan and safety management plan to SQMD for a feasibility check. Only the plans that pass the check, related engineering construction procedures can start.

ii. At the beginning of construction: The contractor should employ enough full-time safety engineers and a establish safety work responsibility system; and SQMD may arrange a site inspection to certify its effectiveness.

iii. During the construction process: In order to ensure general contractor's performance in accordance with the management plan and requirements, related PMT may arrange site inspections once a week; and SQMD may conduct random site inspections once a month. If there is any danger found during the site inspection, SQMD or PMT may inform the contractor directly and require the contractor to correct in time.

SQMD has made a record of safety engineers and safety supervisors of all the projects in the Expo site, which constitutes the basic safety management network of Expo 2010. In order to enhance their ability continuously, SQMD may hold meetings for them to release information and communicate.

4.4 Cooperating with Safety Departments of the Government

In China, the government pays much attention to work safety issues; and concerning construction safety issues, it also has more than ten government departments supervising various safety aspects of the construction industry. Every year government departments may arrange site inspections regularly. As a key government-invested construction program, the safety issues of Expo 2010 program have also been concerned with relevant departments of Shanghai governments. In order to strengthen the cooperation between relevant departments and SWECHO, SQMD on half of SWECHO has established a Safety Management Joint Meeting System (SMJMS) and developed cooperative supervision on safety management of Expo 2010. The government departments joining the SMJMS are shown in Figure 5.

Figure 5. Government departments joining the SMJMS

Through SMJMS, SQMD has established a multi-to-single effective communication system with related government departments; and they take joint actions as follow:

i. Arranging joint site inspections regularly, inspecting site construction safety, flood controlling safety, fire controlling safety and food safety.

ii. Organizing safety training regularly, which should focus on personal protection for workers, work safety, and emergency dealing and so on.

iii. Promoting irregular safety events, which should highlight personal protection for workers, work safety, food safety, A/H1V1 Flu prevention and so on.

In the past two years, SMJMS has worked very efficiently, which improves the traditional relationship between government departments and the client; and improves the work efficiency greatly.

4.5 Establishing Flood Controlling Emergency Management System

Shanghai is located at lower reaches of the Yangtze River, the longest river in China, on the west bank of the East China Sea and in the middle of China's coastline, so every summer natural disasters, such as typhoon, flood, tide, and rainstorm may affect industrial production and people's lives, and normal construction is also affected by these disasters as well. In China, controlling summer disasters is referred to as "flood controlling".

For Huangpu River and Bailianjing River across from the Expo site, flood controlling is also a main safety management work for SQMD in summer. According to Chinese construction practice, every year SWECHO takes up the necessary measures as follows:

i. Creates an emergency management plan; and establishes an emergency management organization (EMO).

ii. Checks on flood controlling facilities before the flood controlling period (from 1^{st} May to 1^{st} Oct.) to ensure the facilities such as the flood controlling gate, drainage facilities and others can meet the requirements.

iii. Establishes emergency rescue teams and necessary rescue materials and equipment.

iv. Establishes an emergency management plan dealing with accidents in rainstorms or flood.

v. Arranges night shifts during the flood controlling period at every construction site; and if there is any emergency, shall report to EMO timely.

vi. Establishes a four-class-alarm typhoon and rainstorm response system, and according to the alarm class released by the government, takes the corresponding action.

5 APPLICATION OF "HUMANISM CONCEPT" IN SAFETY MANAGEMENT

Among government-invested projects, SWECHO regards Expo 2010 as a model program which has impacted on the development of Chinese construction. In the construction management practice, establishment of necessary management systems has included the application of the humanism concept as a basic principal, which embodies in three aspects as follow:

i. Since the beginning of Expo 2010, migrant workers' living safety issues have been considered by the client, which is a major part of safety management content.

ii. By strengthening cooperation with related government departments, the client has made a lot of safety promotions and training to improve migrant workers' safety sense and skills, which are concerned with personal protection for workers, work safety, emergency dealing, food safety, and traffic safety.

iii. "Total safety Culture" (Fang 2001) has been practiced in the Expo 2010 program. In its safety management framework and levels, nearly all the stakeholders are concerned except the designers, which seldom take part in construction safety management according to Chinese practice; and all construction plans are usually made by contractors.

6 CONCLUSIONS

China is a developing country with mega construction project investment every year, and most construction workers are not industrial workers but migrant workers from rural areas who are in lack of professional sense and skill, so the general construction safety situation in China is very serious. For Expo 2010, the mega scale and compressed construction period makes safety even more challenging.

Hence in the program, the client has made lots of explorations in strengthening safety management, including establishing SQMD and PMTs, making standards and regulations, carrying out site inspections and so on. According to the report (MOHURD 2008), the Shanghai construction death toll is 61 persons in 2007 and the death ratio is 0.41 person every million construction area. Therefore, so far no fatal accidents have happened in Expo 2010 and the death ratio is lower than the local average level.

According to Huang and Hinze's research (2006), efforts of large projects' clients have paid off by the lower injuries on their projects; and the client's safety management practice of Shanghai Expo has proved it in some extent. The client of large projects or programs could play a more active and important role in safety management; and Expo 2010 may be a government-invested model program for building a more safe and health construction industry in China.

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FACTORS AFFECTING CONSTRUCTION SAFETY PERFORMANCE IN CHINA DURING TRANSITION

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ABSTRACT

This paper adopted a macro perspective to evaluate factors affecting safety performance in China during the transition period. It addressed the limitation of previous studies that merely attempted to identify factors affecting safety performance from the micro perspective of project management, without questioning why those factors, such as lack of the top-management support and training, existed. Historical reasons explained why construction workers, consist of mainly “farmer workers”, always had little bargaining power with either developers or contractors. In addition, contractual arrangements in the construction industry failed to consider construction safety, making construction laws the only protection that farmer workers have. This paper used province-level construction safety records in China from 1994 to 2000 to investigate factors affecting construction safety in China. The implementation of construction safety laws and the rate of subcontracting were found to be relevant factors, while neither the extent of using temporary workers, nor the availability of resources, nor the level of per capita GDP has any effects.

Keywords: Construction safety, Farmer worker, Contractual arrangement, Safety laws, Subcontracting

INTRODUCTION

This paper adopted a macro perspective, which covers contractual arrangement, legal framework and governance structure in the industry, to evaluate factors affecting safety performance in China during the transition period. It contributes to the literature as few studies have concentrated on construction safety in China, except perhaps only studies on construction safety management by Cheng, et al. (2004), Fang, et al (2004), and Tam et al. (2004).

A review of recent studies on factors affecting construction safety, geographically not restricted to China, showed that all the studies approached the matter from a micro perspective of project management. Most studies concluded that top management support (Cheng, et al 2004, Hinze and Rabound 1998, Jannadi 1996, Jaselskis, et al. 1996, Sawacha, et al. 1999, Tam et al. 2004) and safety training (Cheng, et al. 2004, Hinze and Gambatese 2003, Jannadi 1996, Jaselskis, et al. 1996, Lee and Halpin 2003, Tam and Fung 1998, Tam et al. 2004) are two of the most important factors affecting construction safety. Some believed that the employment of a safety officer (Hinze and Rabound 1988, Sawacha, et al. 1999) is important, while others used vague terms such as “organization structure” which is hard to follow (Fang, et al. 2004). An interesting factor was the provision of “a safe environment/working conditions” (Ng, et al. 2005, Sawacha, et al. 1999) or an “inadequate safety level” (Cheng, et al. 2004), which seem tautological.

Although many factors that apparently affect construction safety have been identified, no one has asked why this was so. More sensible questions would be why construction safety management has never been “supported by top management,” why safety officers were not employed on site, and why “a safe environment/working conditions” were not provided.

This paper seeks to provide an answer by analyzing the issue from a macro perspective. The rest of the paper will be arranged as follows. First, the historical background of “farmer workers”, the major workforce in the construction industry, will be given. This will explain why farmer workers always have little bargaining power with either developers or contractors. Then contractual arrangements in the construction industry will be discussed to show that safety issues were ignored by the parties to the construction contracts. The governance structure in the industry, in particular, the sub-contracting structure and the employment of temporary workers, will be discussed to give some clues on factors affecting safety performance. All the above analysis showed that the only protection the workers have is the relevant construction safety laws. The method of study will then be described followed by a discussion of the results. The last section concludes.

HISTORICAL BACKGROUND

Construction workers in China currently consist of mainly “farmer workers,” which is a concept unique to China. Farmer workers are those whose job category is registered in the Census Register as “farmer” and are mainly engaged in non-farming industries and earning wages as their main source of income.

Under the *Residence Management and Registration Ordinance of the PRC* enacted in 1958, the migration of rural residents to cities or towns was strictly prohibited unless they could find a job in a city/town or obtain admission by a university or special middle school. The industrialization process in the coastal cities since 1978 had created a large demand for labourers. At the same time, the reforms in agriculture greatly increased agricultural productivity, thereby freeing a lot of rural labourers. As a response to this situation, the authorities allowed “farmers” to work in the cities or towns without changing their registered residence category from “farmer” to “worker” (Drafting Group, 2006). The term, “farmer worker,” hence appeared and soon became popular.

Farmer workers often work for the lowest wages in the poorest working conditions. They do not have any of the social benefits that urban workers enjoy. Although they form the majority of work force in the construction industry, their safety problems have been largely ignored by scholars for many years except perhaps only Sha and Jiang (2003). These historical reasons explained why construction workers always had little bargaining power with either developers or contractors. First, most construction workers are farmer workers, historical arrangements have caused their low status in the society. Second, the education levels of farmers were generally low so that they were unaware of their rights. Thirdly, workers are not allowed to form unions in China.

Huang and Hinze (2006) concluded that owner’s involvement can favourably influence project safety performance and that contractual safety requirement is one important factor. Hence, the next section will inquire into the contractual arrangement in the construction industry to find whether safety issues have been considered by the parties to a construction contract.

CONTRACTUAL ARRANGEMENT IN THE CONSTRUCTION INDUSTRY

A construction contract is signed between a client and a contractor or between the main contractor and subcontractors. The provisions of a contract mainly deal with what the client requires. Time, cost, and quality are commonly recognized as the three most important measures of project management success, and they are normally all a client requires. In fact, the standard conditions of construction contracts deal mostly with these three matters. The selection of construction procurement strategies is also based primarily on these criteria. The difference of various procurement methods lies largely on the different level of emphasis placed on each of the factors. For instance, when time is more important, strategies facilitating an overlapping of the design and construction phases are often proposed. When cost is more important, lump sum contracts are proposed. Standard forms of contract have detailed provisions on controlling quality, including specifying, checking, and inspecting materials and workmanship.

The reason why time, cost, and quality are highly emphasized is that they directly affect developers who pay for construction projects. Time affects their cash flow. Cost directly affects their profits, which are their single most important goal if they are private and at least one of their most important goals if they are public. Quality affects the reputation of a developer and affects the selling prices of their properties. The overwhelming importance of these three matters attracts most of the attention of top management.

In contrast, safety matters rarely appear in minds of most contractors' top management in China. The clients do not demand safety requirements, under the rule of winning by lowest price, the contractors will not increase costs by employing safety officers or by providing a safe environment / working conditions. Main contractors will not bother to demand safety performance from subcontractors as well. Only workers who risk their lives are most concerned with safety issues. Unfortunately, these people do not have a say in the preparation of construction contracts. In addition, there are no written contracts between the contractors and the workers at all. The most common way of dealing with safety in construction contracts, if any, is to ask contractors to satisfy the current safety laws and regulations.

In addition to the lack of attention in construction contracts, the governance structure in the construction industry, in particular the extensive use of sub-contracting and temporary workers, might impact the safety performance as well. This will be discussed below.

GOVERNANCE STRUCTURE IN THE CONSTRUCTION INDUSTRY

In the construction industry, the client (the developer) usually signs a main contract, which covers all or nearly all the works required for a project, with the main contractor. The main contractor, however, does not carry out all the construction works, but usually sub-lets a portion of it to subcontractors. The subcontractors may have their own sub-subcontractors. The client may select the subcontractors or suppliers through the provision of *nominated subcontractor or suppliers* in the conditions of contract. Alternatively, a contractor may select its own subcontractor, which will work as its *domestic subcontractor* if this is not forbidden in the conditions of contract.

Few scholars have empirically examined the relationship between subcontracting and construction safety. Although Lingard and Rowlinson (1994) believed that one reason for the poor safety performance in Hong Kong's construction industry is the high level of subcontracting, they did not empirically test this statement. Intuitively, extensive subcontracting increases the difficulty of site management by the main contractor, and hence, will have a negative impact on safety.

In addition to subcontracting, China's construction sector appears to have a habit of employing temporary workers. For instance, in 2000, 80.5% of the total construction workers in Hainan Province were temporary.[1] The most obvious safety problem involved in the employment of temporary workers is a lack of training, which is considered by many researchers to be critical to safety (Cheng, et al 2004, Hinze and Gambatese 2003, Jannadi 1996, Jaselskis, et al 1996, Lee and Halpin 2003, Tam and Fung 1998).

As construction contracts do not make provisions on safety issues, and the governance structure of the industry might impact safety performance further, the only factor that might improve safety performance seems to be the legal framework, which will be discussed in the next section.

THE LEGAL FRAMEWORK ON CONSTRUCTION SAFETY

The Construction Law of the People's Republic of China (*The Construction Law*) was the most important law shaping the legal framework of construction in China. Chapter 5 of *The Construction Law* makes a few provisions on safety matters. For instance, contractors are made responsible for construction site safety.[2] However, the consequence of accidents was not made clear. One needs to refer to the *Safe Production Law of the People's Republic of China* (the *Safe Production Law*) which is dedicated to safe production. Clause 48 of the *Safe Production Law* stipulates that workers who suffer from safety accidents, in addition to protection by casualty social insurance, have the right to claim compensation when the relevant civil laws provide for such. Clause 43 of the same law stipulates that production units shall buy casualty social insurance and pay the premiums for their employees. Clause 95 stipulates that production units shall be responsible for compensating accident victims when people are killed/injured or others' properties are damaged.

[1] Source: *China Building Industry Year-Book* 2001.
[2] Clause 45 of *Construction Law*.

The *Safe Production Law* does not specify the amount of compensation to be paid, but the provisions in the *Work Injury Insurance Ordinance* may be indicative of what should be paid. Clause 37 of this ordinance stipulates that the standard of the one-off compensation for a work fatality is about 48 to 60 months of the average wage of the affected worker in the relevant area for the previous year.

Apart from the responsibilities mentioned above, the laws also make provisions on the responsibilities of the client, designer, contractor, and construction supervisor.[3] In addition, the laws further aim to reduce the possibility of accidents. Examples are:

(a) Allowance of construction costs for safety matters;[4]
(b) a safety licensing system for contractors;[5]
(c) reporting and investigating “serious accidents” in construction;[6]
(d) the authority’s supervision and administration;[7]
(e) the employment of safety officers;[8] and
(f) the adoption of a mandatory construction supervising system (Yung and Lai 2008).

The laws were mostly enacted during the 1990s and early 2000s. Although their application may not be perfect, it should be possible to observe gradual improvements on construction safety over the course of the study period.

The following section will develop testable hypotheses to evaluate the above factors.

HYPOTHESES

Under the current institutional arrangements, the market fails to properly consider construction safety, as evidenced by the contractual arrangements in the industry. Hence, improvements in construction safety could be observed when construction safety laws favouring construction workers have been implemented. Since various laws and ordinances were enacted and implemented during the study period (1994-2000), the effects on improvements in construction safety should have been observed gradually during the period. Thus, the following hypothesis has been developed:

Hypothesis 1

The gradual implementation of safety laws will improve safety performance gradually over the years.

Extensive subcontracting increases the difficulty of site management by the main contractor, and hence, will have a negative impact on safety. Meanwhile, the extensive use of temporary workers will reduce the overall level of training in the labour force, thereby making them vulnerable to safety hazards. Hence, a few more hypotheses were developed:

Hypothesis 2A

Higher rates of sub-contracting will negatively impact construction safety.

Hypothesis 2B

Higher rates of temporary workers will negatively impact construction safety.

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[3] Relevant provisions could be found in the *Construction Project Safe Production Administration Ordinance,* which was enacted on 24 November 2003 by Order No. 393 of the State Council and became effective on 1 February 2004.
[4] Clause 18 of the *Safe Production Law*.
[5] Clause 2 of the *Safe Production Licensing Ordinance*.
[6] This is stated in the *Provisions on the Procedures of Reporting and Investigating Serious Construction Accidents.*
[7] This is stated in the *Provisions on Supervision and Administration of Safe Production in Construction*, which was enacted on 9 July 1991 by Order No. 13 of the Ministry of Construction of China.
[8] Clause 23 of the *Construction Project Safe Production Administration Ordinance*.

The author has shown elsewhere (Yung and Lai 2008) that the availability of resources, human and non-human alike, could affect construction quality. The availability of resources could also affect safety performance. Cheng, et al (2004) showed that the “poor quality of construction materials and equipment” is one of the most important factors that affect construction safety.

This paper uses five measures of availability for both man-made resources, in particular the machinery and equipment for construction, and human resources, in particular construction workers. Hence, the following five null hypotheses were developed:

Hypothesis 3A:
The number of labourer per unit area of floor space has no effect on construction safety.

Hypothesis 3B:
The power of the machinery owned by contractors per labourer has no effect on construction safety.

Hypothesis 3C:
The power of the machinery per unit area of floor space has no effect on construction safety.

Hypothesis 3D:
The value (at constant prices) of the machinery owned by contractors per labourer has no effect on construction safety.

Hypothesis 3E:
The amount (at constant prices) of the machinery per unit area of floor space has no effect on construction safety.

As mentioned, the compensation for work fatalities could be based on 48 to 60 months of the average worker’s wages in the relevant area over the previous year. As China’s economy develops, the average worker’s wages have increased. Hence, the burden of compensation has also increased. In addition, as the economy develops, people begin to treasure their lives more. Hence, the following hypothesis was developed:

Hypothesis 4:
Construction safety will improve as the per capita Gross Domestic Product (GDP) at constant prices increases.

DATA AND METHOD

The mandatory reporting of “serious accidents” started in 1989 when the *Provisions on the Procedures of Reporting and Investigating Serious Construction Accidents*[9] came into effect. “Serious accidents” are classified into four categories as shown in Table 1.

Table 1 Classification of Serious accidents

	Accidents resulting in one of the following conditions		
Class	Fatalities	Injuries	Economic Loss
1	≥ 30		≥ RMB 3 million
2	10 - 29		RMB 1 – 3 million
3	3 - 9	≥ 20	RMB 0.3 – 1 million
4	≤ 2	3 - 19	RMB 0.1 – 0.3 million

[9] These were enacted on 30 September 1989 by Order No. 3 of the Ministry of Construction of China, effective from 1 December 1989.

There will be two measures of safety performance, namely the number of serious accidents (of Class 4 and above) and the number of casualties (including fatalities and serious injuries) per 10,000 workers in a particular year. The data on dependent variables, rates of subcontracting, and the rate of temporary workers were collected from the *China Building Industry Yearbook* and that on the five measures of the availability of resources and per capita GDP from the *China Statistical Yearbook*. Unfortunately, the former did not consistently publish safety data. Only six years of data (1994, 1996-2000), consisting of 211 province level entries, were available.

The purpose of this paper is to study how institutional arrangements affect construction safety. This type of study is best conducted during the transition period. The years from 1994 to 2000 best fit into this study. The fact that the authority stopped publishing these data showed that construction safety was a sensitive and political issue. This made the set of data even more valuable.

Although the formal laws were enacted in 1998 or later, it does not mean that the rules were suddenly established in 1998 or later. In China, the common practice is that the rules will appear in the form of ministry regulations before formal enactment of laws. There will be a few years of "trial" period. This does not mean that practitioners could choose not to comply with ministry regulations. The most persuasive example is the implementation of mandatory supervising arrangement. The requirement of mandatory supervising appeared as early as 1988, ten years before the formal inclusion in the Construction Law which was enacted in 1998. Hence, it makes perfect sense to expect that the implication of rules happened in the study period.

There is also a lot of missing information on the number of workers employed by subcontractors and the number of temporary workers in those data, as a result, 98 province-level entries were left. Nevertheless, the number of data is still enough for our regression analysis.

Table 2 shows the description of the dependent variables and independent variables. Nominal values have been discounted with appropriate indices to obtain constant prices in 1993. In particular:

a. The "Value of Machinery" was discounted with the "purchase of equipment, tools and instruments" index (one component index for Price Index of Investment in Fixed Assets) for each province published in the *China Statistical Yearbook* (available from 1991 only);
b. the "Gross Domestic Product" was discounted with the Price Index of Investment in Fixed Assets); and
c. when the entry for a particular province in a particular year was unavailable, the national average data in that year was used.

Table 2 Description of Data

Variable	Meaning	Unit	Min.	Max.	Mean	Stad. Dev.
Dependent Variables						
Acc_rate	No. of accidents rated Class 4 or above per 10,000 workers in a year.		0.000	4.456	0.656	0.629
Cas_rate	No. of casualties in the accidents per 10,000 worker in a year.		0.000	7.073	1.179	1.148
Independent Variables						
Hypothesis 1						
Year	The year of the observation		1994	2000	1997.5	1.933
Hypotheses 2A & 2B						
SC_rate	No. of workers employed by subcontractors as a percentage of the total no. of workers	%	0.28%	65.63%	14.49%	0.134

Tempe_rate	Rate of temporary workers (defined as the no. of temporary workers employed by main contractor) as a percentage of the total no. of workers	%	0.048 %	80.46%	26.84%	0.188
Hypotheses 3A – 3E						
Lab_m^2	No. of labourers per m^2 of floor area under construction	Person/ m^2	16.44	803.89	229.58	119.26
Power_lab	Power of machinery and equipment owned by contractors per labourer	10,000 KW/psn	0.647	32.21	4.281	3.155
Power_m^2	Power of machinery and equipment owned by contractors per m^2 of floor area under construction	100 KW/m^2	3.559	38.69	8.583	4.663
VM_lab	Value (in 1994 constant prices) of machinery and equipment owned by contractors per labourer	RMB 1,000	1.005	37.44	4.666	3.568
VM_m^2	Value (in 1994 constant prices) of machinery and equipment owned by contractors per m^2 of floor area under construction	RMB/m^2	28.29	407.81	89.93	45.362
Hypothesis 4						
GDP_cap	Gross Domestic Product per capita, deflated with the Fixed Asset Investment Index	RMB 1,000	1.51	25.60	5.96	4.064

Source: *China Building Industry Year-book* and *China Statistical Yearbook*, various years.

The two dependent variables will be tested with the multiple regressions technique and the results will be presented in the next section. The parameters will be estimated with Least Square method. If they are significant at 5% level or less, and they have the expected signs, the hypotheses will be confirmed; otherwise they will be refuted.

RESULTS AND DISCUSSION

Table 3 shows the empirical results of the multiple regressions. It is clear that the results of the two measures of safety performance (the accident rate and casualty rate) are quite similar. The variable, "Year," is very significant in both equations and has a negative sign. This confirms our hypothesis that as safety laws were gradually implemented from 1994 to 2000, safety performance over the years improved. Both the accident rate and casualty rate decreased over the years. Hence, Hypothesis 1 is not refuted.

Table 3 Empirical Results

Dependent Variable	**Acc_rate**		**Cas_rate**	
No. of observations	98		98	
Independent Variable	**Coefficient**	**Prob. of t-test**	**Coefficient**	**Prob. of t-test**
Constant	261.59	0.0000	482.72	0.0000
Year (Hypothesis 1)	-0.1309	0.0000*	-0.2417	0.0000*
SC_rate (Hypothesis 2A)	0.9879	0.0291**	2.1902	0.0374**
Temp_rate (Hypothesis 2B)	-0.0475	0.8282	-0.1445	0.7767
Lab_m^2 (Hypothesis 3A)	-0.0004	0.3732	-0.0010	0.3601
Power_lab (Hypothesis 3B)	0.0247	0.6643	0.0715	0.5901
Power_m^2 (Hypothesis 3C)	-0.0171	0.6974	-0.0160	0.8761
VM_lab (Hypothesis 3D)	0.0323	0.5483	0.0934	0.4568
VM_m^2 (Hypothesis 3E)	0.0042	0.3167	0.0087	0.3784

GDP_cap (Hypothesis 4)	-0.0104	0.4078	-0.0508	0.0837
R-squared	0.4472		0.4461	
Adjusted R-squared	0.3907		0.3894	
Prob(F-statistic)	0.0000		0.0000	

*: significant at 1% level or lower; **: significant at 5% level

The variable, “SC_rate,” is significant at the 5% level in both equations. Its positive sign indicates that the higher the subcontracting rate, the higher the accident rate and casualty rate, thereby confirming Hypothesis 2A. This may because there are too many subcontractors in a project. Many facilities are provided by the main contractor. Each subcontractor has only a short time to familiarize the conditions of the site.

Researchers have diversified views on the question why subcontracting appears. As subcontracting arrangements are not mandated by the government, hence, it must have appeared because the market thinks it fit. It was found that higher subcontracting rate is associated with poorer safety performance. However, without clear understanding on the question why subcontracting appears, it seems too hasty to make any recommendations now. This remains an interesting area for further study.

However, the variable, “Temp_rate,” is not significant, indicating that the level of temporary workers did not have any impact on construction safety. Thus, our previous intuition of the lower training level of temporary workers may not be true. A possible answer to this may be that “temporary” or “permanent” is merely a measure of the *nature* or *term* of an employment contract; it does not relate to the *experience level* or *skill*s of a worker.

None of the five measures of availabilities of resources is significant in either equation, indicating that the availabilities of plants and equipment and labour have no relation to construction safety. Hence, all five null hypotheses 3A – 3E are refuted.

The results of the variable, “GDP_cap,” are mixed. It is not significant in the equation for the accident rate, but significant at the 10% level in the equation for the casualty rate. Since 5% was chosen as the cut-off point, the variable will be regarded as not significant here. Hence, Hypothesis 4 is rejected. Although the compensation of fatalities is based on 48 to 60 months of an average worker’s wage over the previous year, the deterrence effects might be too small to generate obvious effects on safety.

The adjust R^2 of the two equations is about 39%, meaning that about 40% of the variations in the dependent variables could be explained by the independent variables. The other part of the variations should relate to the actual site management issues, probably identified in previous studies from the micro perspective of project management.

CONCLUSION

Unlike the literature on construction safety that approached the issue from the micro perspective of project management, this paper adopted a macro perspective of institutional arrangements. The institutional perspective covers the aspects of the historical contexts of farmer workers, contractual arrangements, the governance structure, and the legal framework in China’s construction industry. Publicly available “hard” data, ranging from 1994 to 2000, were tested with the multiple regression method. The major findings were:

(a) The gradual implementation of construction safety laws has gradually improved construction safety in China over the years;
(b) the extensive rate of subcontracting has had a negative impact on construction safety;
(c) the extent of using temporary workers did not have any impact on construction safety;
(d) the availability of resources did not have an impact on construction safety; and
(e) an increase in the level of per capita GDP did not have significant impact on construction safety.

Hence, there are obviously two ways to improve construction safety. First, the safety laws should be well developed and fully implemented. Second, extensive subcontracting should be avoided.

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A WEB CONSTRUCTION FAILURE INFORMATION SYSTEM USING CASE-BASED REASONING IN KOREA

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ABSTRACT

The purpose of this study is to develop a web-based failure information system for construction practitioners using case-based reasoning techniques, which can systematically accumulate, manage, and share valuable failure information. The system developed in this study can continuously accumulate and search data in the form of text, photographs and video clips and receive real-time information based on case reasoning. The web-based construction failure information system is composed of a construction code administration module, a failure case registration module, an index module and a reasoning module. In doing so, a relational case database technique was utilized to manage efficiently and effectively the failure case information classified into work condition, failure circumstance and causes, and countermeasure. Also a web programming technique was adopted to manage texts and photographs or u-tube of each case. The prototype system was validated with real failure cases occurred in the Korean construction industry. Through the validation process, which included examination by a number of construction practitioners, the system has demonstrated a promising result, indicating that it can be utilized as a valuable proactive tool to prevent future failures by searching similar past failure cases.

Keywords: Case-based reasoning, Construction failure, Construction failure information system, Web

1. INTRODUCTION

Advanced foreign nations are continuing with their studies on failure information in order to reduce occurrence of construction failures and putting efforts to collect and accumulate related information. Particularly in 1982, ASCE established Technical Council on Forensic Engineering (TCFE) to develop a guideline for failure investigation and has been conducting researches to find the means to provide failure information to construction practitioners. Occupational Safety and Health Administration (OSHA) investigates and manages failure cases on its own (Jeon, 2004).

However, construction failure information in Korea exists as documents such as reports and case studies, and it is difficult to accumulate information because the format of information collection is not systematic. This fact leads to deficiency of sharing failure information and communication tools, also causes the important factors (technical factor, managerial factor) which is suggested by Whittington (1992) and Andi (2005).

Therefore, for construction practitioners to accurately understand information about construction failures and establish measures to prevent same failures in the future, an efficient failure information system is needed. Such a system must be constructed based on a well-structured format which includes contents like the cause, type and circumstance of failure. This system should also allow easy accumulation and management of failure information and be able to efficiently search through past failure cases. In addition, learning effects can be maximized by providing visual data using photographs and movie clips instead of limiting to simple text information during failure case education.[10)]

[10)] Lee (2003) argued that education with photographs and movie clips is advantageous for cognition of information by providing interesting and lively environment to users.

Accordingly, this study attempts to construct a web-based construction failure information system (W-CFIS) using a failure information classification system and case deduction technique performed in existing studies to search and inquire failure cases and offer photographs and movie clips in addition to text information, thereby realizing an effective education on construction failures.

2. THEORY REVIEW

2.1 Definition of Construction failure

The definition of construction failure differs according to every researcher. Table 1 summarizes the definition of construction failure given by researchers.

Table 1: The Definition of Failure

Researcher	Definition
Leonards (1982)	An unacceptable difference between expected and observed performance
Hohns (1985)	(1) The act of falling short, being deficient, or lacking (2) unattainment or nonsuccess (3) nonperformance, neglect, omission (4) bankruptcy (5) loss of vigor or strength
Janney (1986)	(1) structural failure: the reduction of capability of structural system or component to such a degree that it cannot perform safely its intended purpose
	(2) construction failure: a failure that occurs during construction and they are considered to be either a collapse, or distress, of a structural system
Kaminetzky (1991)	A human act: omission of occurrence or performance; lack of success; nonperformance; insufficiency; loss of strength; and cessation of proper functioning or performance
Jeon (2004)	Not only structural failure and defect, but also safety problem, depreciation of performance, and potential defect which are caused by failure and defect

The early researches had focussed on required performance of buildings and subdivided it into construction, structural, and managerial issues. Recently, it has expanded to include structural collapse, safety, performance, and defects. This study defines the technical and management factor as failure causes. In addition, occurred failure cases are classified into 4 types (facility, element, work, and situation) to reasoning easily and prevent potential failure.

2.2 Construction Failure Information Classification and Data Type

A systematic information classification system is required to efficiently accumulate and manage construction failure information. Looking into construction failure classification systems proposed in existing studies, American Society of Civil Engineers (ASCE) suggested a classification system by classifying failure cases into the time of failure occurrence, type and source through its ‘Guidelines for Failure Investigation’. Park (2003) classified failure into general information about facilities, failure status information, cause and countermeasure. Also, Jeon (2005) considered properties of construction failure information and classified failures into facilities, parts, stage, type, cause and lesson. Construction failure information should include the circumstance at site, failure circumstance, cause and countermeasure.

Therefore in this study, failure information is classified into work condition, failure circumstance, cause and countermeasured with consideration on practical utility, as shown in Table 2. This classification will be utilized in the web-based construction failure information system to input and offer failure data as codes, photographs and movie clips. The cause and countermeasure for failures can be inputted and managed using texts.

Table 2: Construction Failure Classification

Primary Factors	Secondary Factors	Tertiary Factors	Data Type
Construction Work Situation	- Type of Facility	·Residential/Commercial Facility ·Public Facility ·Heavy Industry Facility	- Code - Photograph - U-tube
	- Type of Elemental	·Ground and Underground ·Civil Structure ·Structure Finishing Part	
	- Type of Work	·General Article and Cost ·Temporary Work(indirectness) ·Temporary Work(directness)	
	- Type of Structure	·Shear Wall Structure ·Core Structure ·Rahmen Structure	
Construction Failure Situation	- Phase that a Failure is Occurred	·Planning/ Design ·Execution ·Maintenance	
	- Type of Occurred	·Latent Failure ·Functional Failure ·Failure on Safety	
	- Failure Damage Pattern	·Partial Collapse ·Total Collapse ·Functional Defect	
Factor causing Failure	- Technical Factors - Site Management Factors - Organizational Factors	· String	Text
Construction Failure Preventive Measure	- Technical Measure - Site Management Measure - Organizational Measure	· String	- Text - Photograph - U-tube

(1) Construction Work Situation

Failures occur in various forms depending on the properties of construction projects, and it is necessary to closely investigate work conditions for examination of the cause. Thus, in an effort to understand the properties of construction projects, work condition is classified into facility type, part, construction type and structure type. In addition, a database is constructed to provide photographs and movie clips related to work conditions and to allow detailed examination of conditions.

(2) Construction Failure Situation

Since the failure situation can become important information in establishing preventive measures against the cause and result of construction failures, details must be delivered effectively. Construction failure can occur in all stages of construction including planning, design, construction and maintenance. The size of damage and future countermeasures differ greatly according to the stage in which failure occurs. It is also possible to establish countermeasures against construction failures that occur repetitively by analyzing the form and type of failures and connecting them with work situation. Failure situation is therefore classified more clearly into stage of occurrence, form and type. Photographs and movie clips are provided as failure data to efficiently deliver failure situation.

(3) Factor Causing Failure

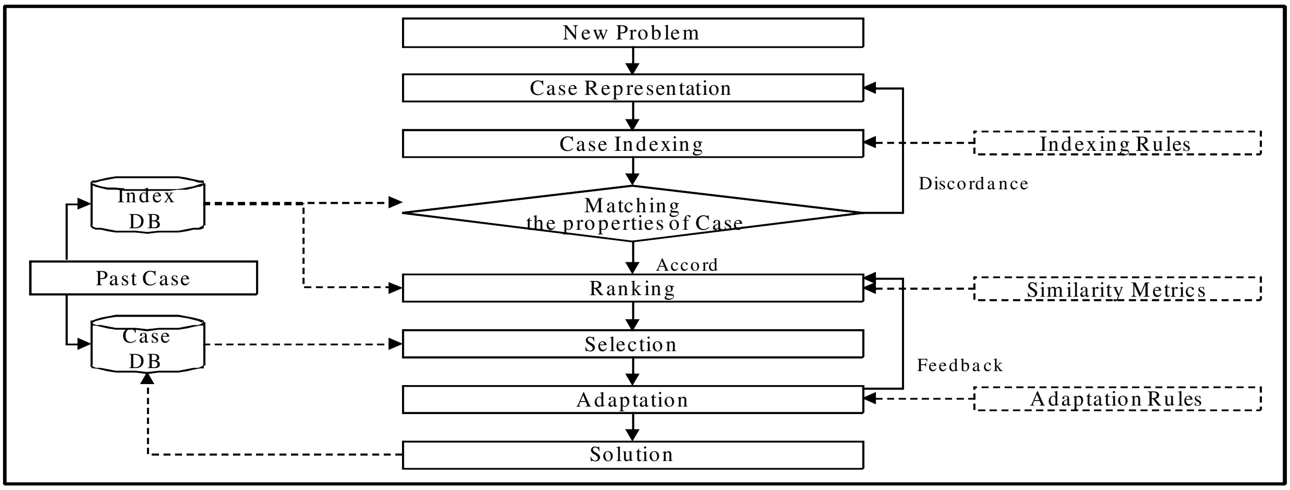
Construction failure is caused by many factors, and such factors are mutually correlated. In particular, Kim (2005) examined construction failure mechanism and classified the cause of failures into indirect and direct causes through correlation analysis on construction failure causes. Direct cause is technical cause and indirect cause includes organizational cause and site cause. The web-based construction failure information system in this study will apply this classification.

(4) Construction Failure Preventive Measure

Construction failure measures are taken to prevent same failure from occurring again in the future, by synthesizing the details of (1), (2) and (3) above. Especially, preventive measures should be established after understanding and analyzing the cause of failure. Failure measure is classified into technical measure, site measure and organizational measure. Data on preventive measures are inputted and provided in texts, photographs and video clips so that detailed measures can be prepared.

2.3 Application of Case Based Reasoning

Case Based Reasoning (CBR) is the method in which similar past cases are reviewed in order to solve new problems. CBR is applied to system developed in this study. The process of system is that information of work situation, failure situation, failure causes, and preventive measures is first saved into case data base, then it is second saved into index database to deduce similar case. This process allows measuring degree of similarity and grasps the accuracy of reasoning.



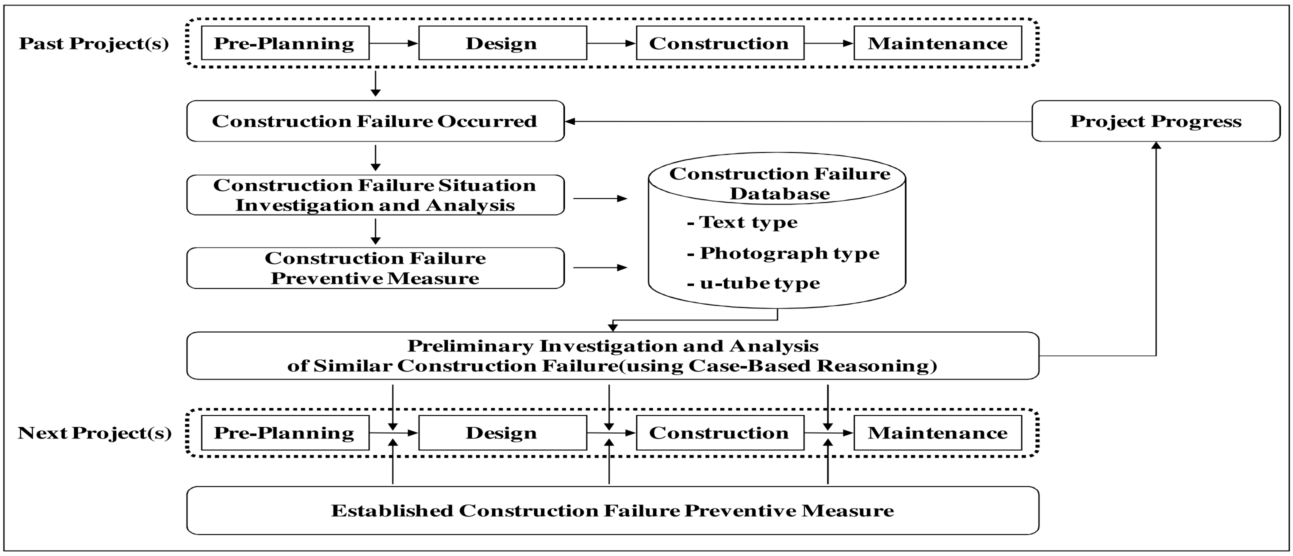
Figures 1: Process of Case Based Reasoning[11]

3. SYSTEM DESIGN AND DEVELOPMENT

3.1 Concept of Web-Based Construction Failure Information System

Construction failure information at Korean construction sites is being created in broad and diverse forms, but such information is being accumulated and managed in a non-systematic format and exists only as text. Long lengths of time and high costs are being spent on sharing and learning of construction failure information.

2) refer and adjustment "Continuous Improvement Model of Construction Process using Construction Failure Information(Jeon, 2005)"

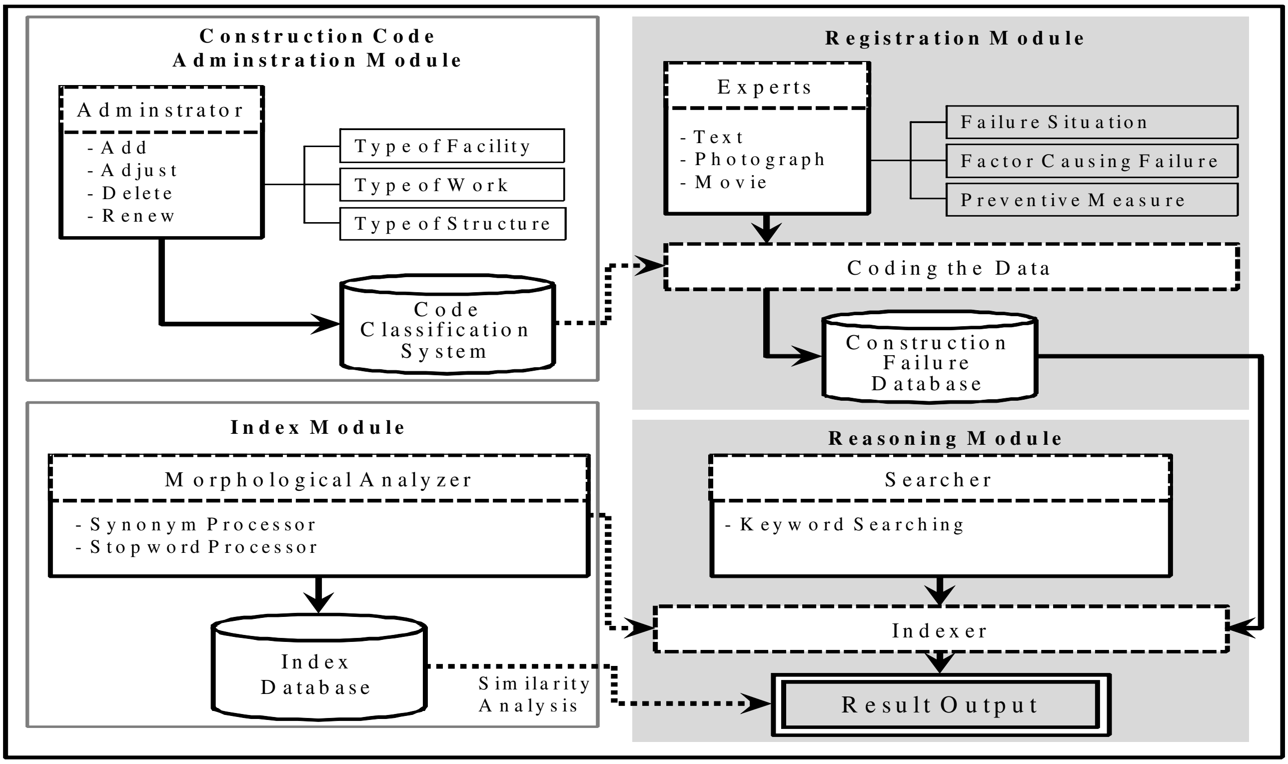


Figures 2: Flow Diagram of Conceptual Construction Failure Information System

However, with recent development of IT, large amounts of data can be inputted and outputted efficiently using computers without limitations on time and space. Data can be inquired and used on a real-time basis through the web-based internet. If construction failure information system is constructed based on the web, various failures at construction sites can be estimated and prevented in advance. Figure 2 is a conceptual model of the construction failure information system. Construction failures that occurred in preceding projects were analyzed through a well-structured classification system for utilization in future projects.

3.2 System Module and Case Reasoning Method

Construction failure information systems can continuously accumulate and search data in the form of text, photograph and video clip and receive real-time information based on case reasoning. For this, web-based construction failure information system is composed of a construction code administration module, failure case registration module, index module and reasoning module as shown in Figure 3.



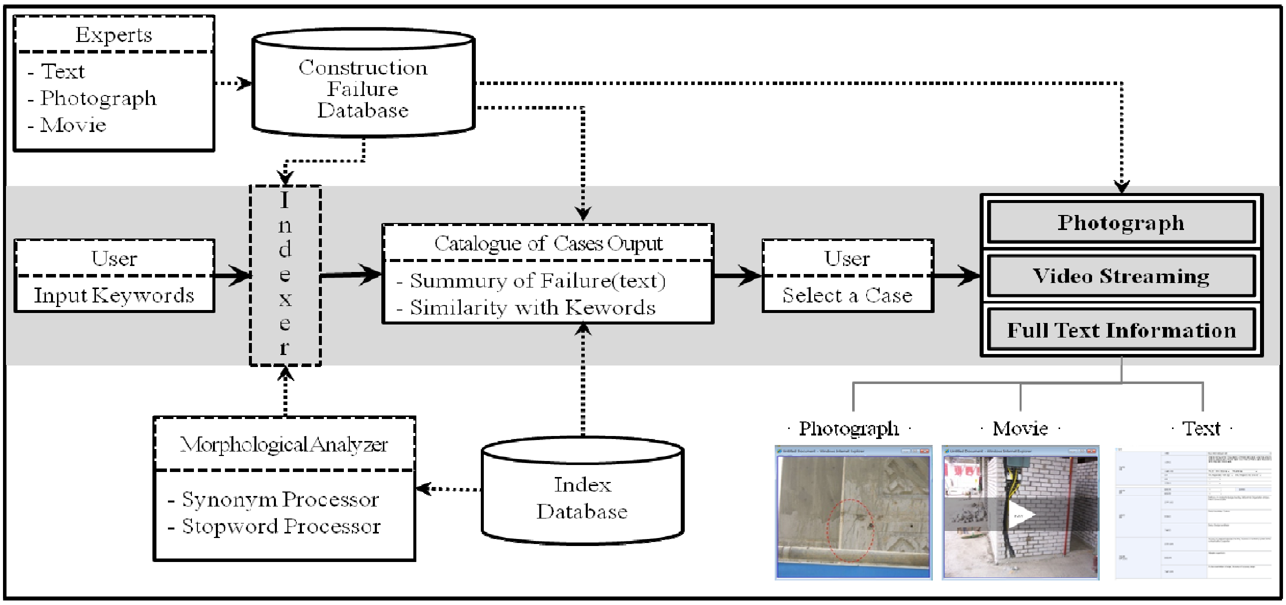
Figures 3: Structure of Web based Construction Failure Information System

1) Construction Code Administration Module
Authorities for construction code administration module are granted to the system administrator and managed based on the information classification system suggested in this study. Also, the module allows registration and management of information on new facilities, construction types and parts by granting new codes.

(2) Registration Module
The registration module can systematically input and manage failure cases according to work condition, failure situation, cause and countermeasure. Related expert or administrator can input details on the failure as a text with photographs and video clips.

(3) Index Module
The construction failure information system administrator needs to review, select and register data for accurate delivery of failure information. Therefore, the index module allows reasoning on failure cases demanded by users by creating a database of failure cases that were verified to have high utility.

(4) Reasoning Module
The reasoning module is the core module of the construction failure information system which provides information to search and view similar past cases and establish preventive measures against similar construction failures. If the reasoning is to be based on keywords included in failure cases, the module must be made so that it does not perform reasoning on unnecessary words. In the case of the Korean language, unnecessary words are excluded from the reasoning using word analyzer during indexing work. As illustrated in Figure 4, the reasoning module of construction failure information system performs its reasoning based on text. However, the module is believed to allow more detailed learning of failure cases by users if past failure cases registered in the database are provided together with photographs and video clips.



Figures 4: Reasoning Module of System

4. CASE STUDY

To verify the prototype of web-based construction failure information system constructed in this study, actual construction failure cases of Korean construction sites recorded in the database are examined.

4.1 Case Summary

As mentioned in 3.2, the failure case index is primarily classified as code into case name, type of facility, location and type of structure. Failure situation was divided into construction failure situation, factor causing failure and construction failure preventive measure. As described in 2.2, cause and preventive measure were segmented into technical factors, site management factors and organizational factors to allow users to more easily understand and search factors in the wanted field.

The target case is a failure case of pipe installation on the masonry walls of a gymnasium. Piping and masonry construction were conducted at similar time period, and pipes were imported to the masonry walls. In general, pipes are supposed to be separated from masonry walls. Importation in masonry walls is expected to create cracks in the walls and bring a high potential of risk.

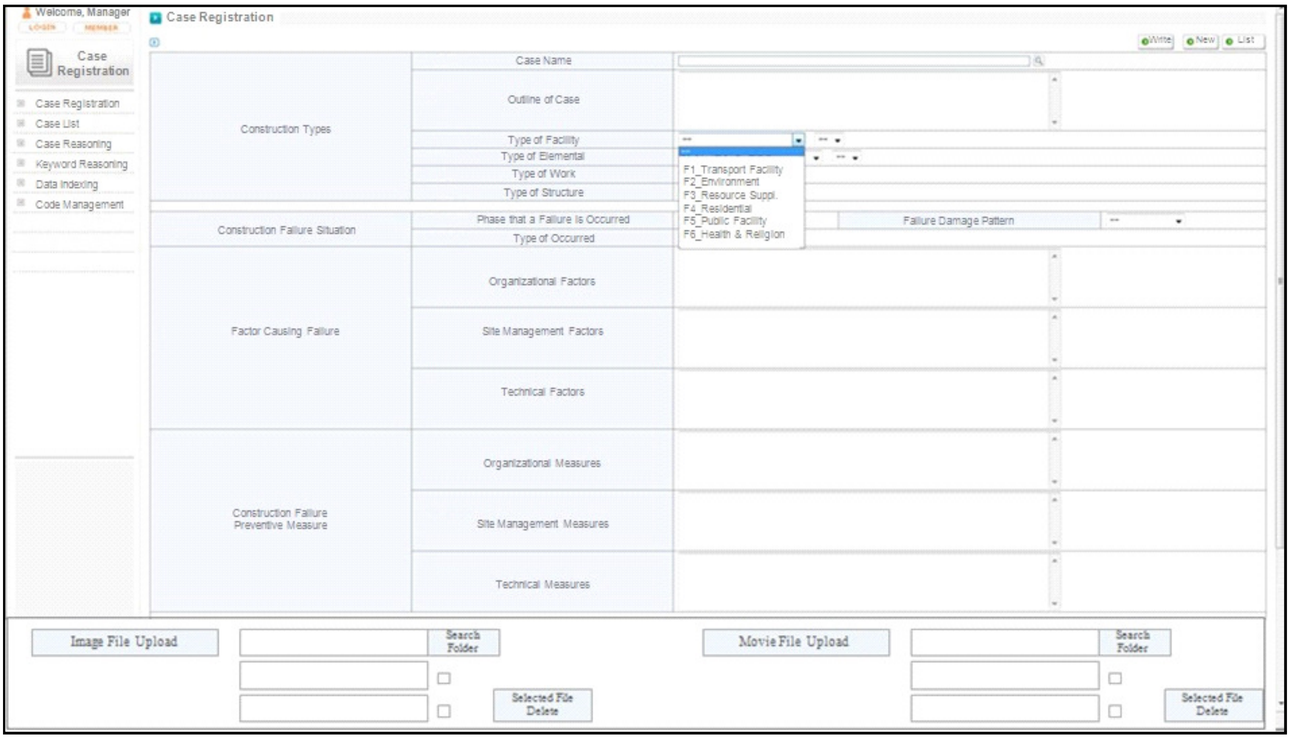
Table 3: Investigation Result of Construction Failure Case

<table>
<tr><th colspan="2">Case Name</th><th>Type
of Facility</th><th>Type
of Elemental</th><th>Type
of Work</th><th>Type
of Structure</th></tr>
<tr><td colspan="2">Pipe Installation Failure
in Masonry Wall</td><td>Health, Religion and Recreation</td><td>Basic Structure(wall)</td><td>Masonry Work</td><td>Masonry Structure</td></tr>
<tr><td rowspan="3">Construction Failure Situation</td><td>Phase that a Failure is Occurred</td><td colspan="4">Execution(Preparation, During, Afterward)</td></tr>
<tr><td>Type of Occurred</td><td colspan="4">Latent Failure</td></tr>
<tr><td>Failure Damage Pattern</td><td colspan="4">Functional Defect(Fracture, Crack, Strain)</td></tr>
<tr><td rowspan="3">Factor causing Failure</td><td>Technical Factors</td><td colspan="4">Design, Design coordination</td></tr>
<tr><td>Site Management Factors</td><td colspan="4">Design knowledge, Careless</td></tr>
<tr><td>Organizational Factors</td><td colspan="4">Deficiency in standard for design/checking, Deficient tool, Organization structure, Internal communication</td></tr>
<tr><td rowspan="3">Construction Failure Preventive Measure</td><td>Technical Measure</td><td colspan="4">Close examination of design, Insurance of accuracy design</td></tr>
<tr><td>Site Management Measure</td><td colspan="4">Knowledge sharing, Adequate supervision</td></tr>
<tr><td>Organizational Measure</td><td colspan="4">Accuracy standard for design/checking,Insurance of monitoring system, Active communication, Cooperation</td></tr>
</table>

Table 3 briefly shows information related to this case. Type of facility is primarily a health/resting/religious facility and secondarily an exercise facility. Type of structure is primarily a basic structure and secondarily a masonry wall. Also, construction type is masonry construction, and the structure form was classified as masonry. Causes of failure were lack of design standards, insufficient supervision, inappropriate organizational structure and unsmooth communication within organization for organizational cause, insufficient design knowledge and indifferent supervisor for site management cause, and design error and lack of cooperation with the constructor for technical cause.

4.2 Case Registration and Reasoning

(1) Registration
As Figure 5 shows, case registration is classified into construction work condition, failure situation, cause and countermeasure. Since type of facility, part, type of construction and structure format are encoded, users can select the code that corresponds to the wanted case. Photographs and video clips can also be uploaded as attachments.

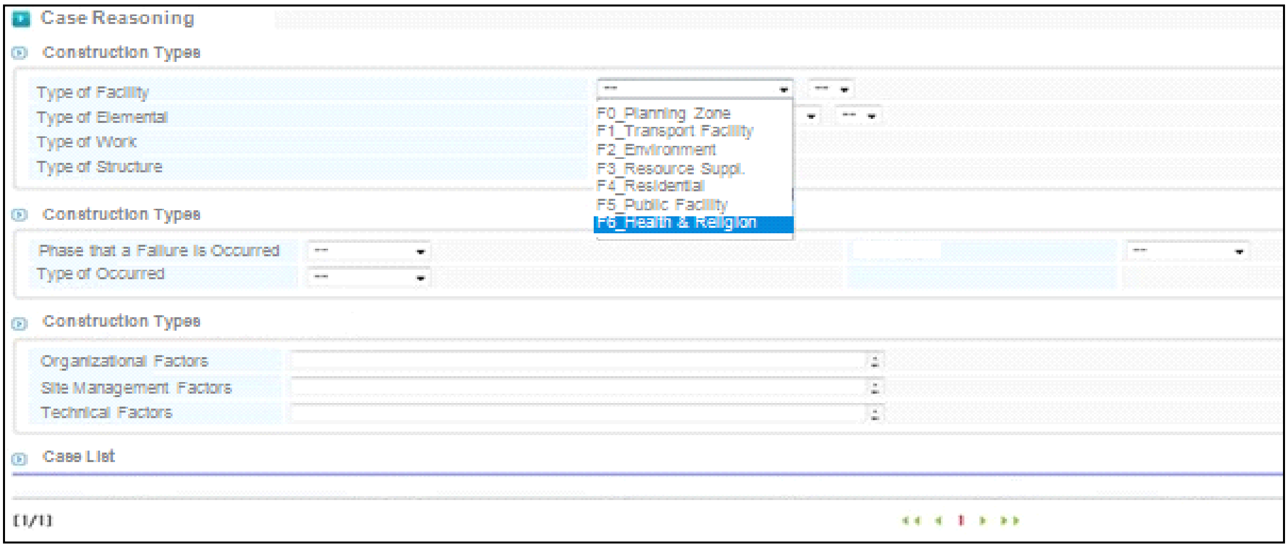


Figures 5: Snapshot of Registration Module

The outline describes details on work conditions. Failure situation, cause and countermeasure on such details are prepared in relation to each other to allow users to understand complex causes of construction failure based on organizational/site/technical perspectives. In addition, uploaded photographs are outputted on the screen as thumbnails and expanded as a pop-up screen upon clicking by users. Video clips provided as web streaming service can help users better understand failure cases.

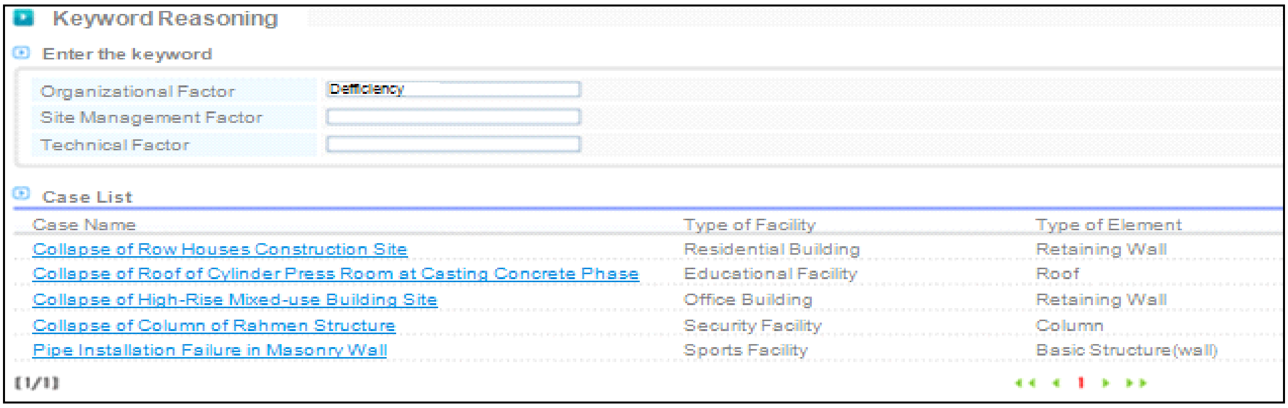
(2) Reasoning

Case reasoning can be done by clicking on the top-down menu or direct input of a keyword by users on type of facility, construction type and other information made into code, as shown in Figure 6.



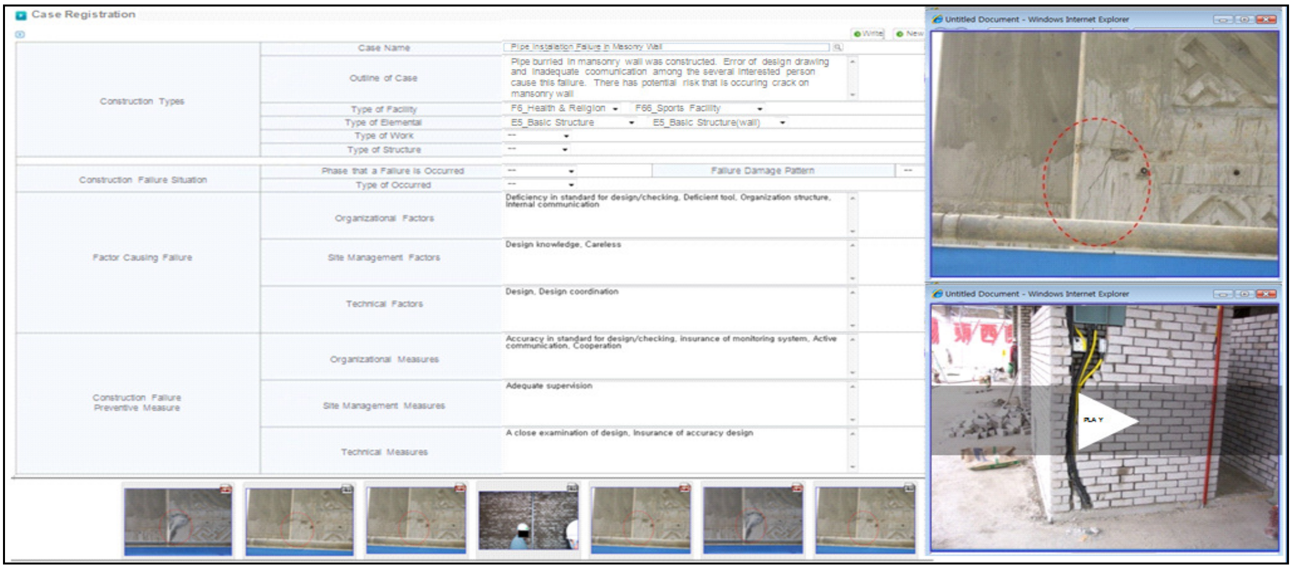
Figures 6 : Snapshot of Reasoning Module

Figure 7 shows the case reasoned through word analyzer. Search result outputs simple title and few keywords on the reasoned case with the degree of similarity.



Figures 7: Snapshot of Result Catalogue

Once the user clicks on a case name given in the search list, detailed information on the case shows up. As in Figure 8, a brief list of visual data can be seen on the bottom of the screen with text information. Here, photographs and video clips can be viewed as pop-up windows if the user clicks on the visual data. Secondary reasoning on similar cases can be performed on the selected keyword by linking the search module with the previously selected keyword.



Figures 8: Snapshot of Result Ouput

4.3 Expected Effect

To predict expected effect of the prototype, this study executed interview to 10 people(8 beside an executive director of major general contractor and president of medium construction firm) who are working in construction part over 10 years about satisfaction of prototype. The factors of satisfaction measurement refer to Delon, Goodhue, Ives for analyzing quality of system and information which are influence on satisfaction. The analyzing item and result is following.

Table 4: Factors of Interview

Factors
Availability of System Approach
Intuition of System Interface
Availability of System Usage(Inspection and Uploading of Information)
Definitude of Information Classification System
Update of the Latest Information(New Technology and Construction Method)
Availability of Information Feedback

As a result, by using the Web Construction Failure Information System**,** items are accessible, useful, and interview feedback indicated high satisfaction with the system. In particular, the systematic system, which have information classification system and it differs from excel and existing self-developed system, has very high satisfaction. According to well-appraised item, respondents' evaluation of this system has indicated value as a method of preventing failures and as an education tool. However, respondents pointed out that the system interface is difficult and the inadequate accumulation of data could be improved. Thus, after correcting the system interface and inspiring recognition participants of construction part to accumulate failure data, the prototype developed in this study has expected effect as followings.

1) Present the standard of systematic construction failure information storage system
2) Predict construction failure through analyzing of the past failure cases
3) Present the effective task process for preventing construction failure
4) Use as educational tool for participants of construction part

5. CONCLUSION

The purpose of this study was to construct a web-based construction failure information system for use as a learning tool in accumulating and managing diverse construction failures occurring in Korea and preventing them. The prototype of web-based construction failure information system developed in this study can systematically manage information using a coded classification system and providing video clips and photographs with text information, showing the possibility of an effective education. Therefore, if an institution is established to administer construction failure cases based on such system and accumulated failure information is used as a tool for understanding and education, the image of construction industry will improve and the system will contribute to development of overall industries.

However, the prototype developed in this study is limited by small number of data and unsmooth access of video information. Such limitations should be supplemented. In addition, in order to put a large amount of failure information into a database, construction practitioners, administrators and workers should not conceal their construction failure experiences and instead try to make improvements using failure cases as valuable lessons.

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A STUDY OF MIGRANT WORKER HEALTH AND SAFETY ISSUES IN THE UK CONSTRUCTION INDUSTRY

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ABSTRACT

This paper reviews recent literature regarding migrant worker safety within the UK construction industry. A case study investigation of migrant Polish workers is discussed and the current occupational health and safety legal framework of the UK construction industry is considered with specific regard to migrant workers. The paper is presented within two broad sections. The first section concerns health and safety with regard to migrant workers and identifies the basis of UK health and safety law and enforcement. Whilst the second section comments on the migratory nature of the construction sector and then specifically identifies relevant research on health and safety in the UK construction industry and migrant workers.

In summary, this paper serves to:

1. Review research concerning migrant workers within the UK construction industry and identify key emergent issues;

2. Identify emergent issues regarding migrant workers within the context of UK health and safety law and practice; and

3. Consider ways forward to enhance the safety of migrant workers within the UK construction industry.

Keywords: Migrant workers, Health and safety, Legislation

INTRODUCTION

On the 1st May 2004 the European Union (EU) enlarged its boarders with the accession of ten countries, eight of which were from Central and Eastern Europe (the A8 countries). Of the existing 15 EU member states only three countries (Ireland, Sweden and the UK) did not significantly restrict A8 migration. The other 12 countries introduced transitional measures to limit free movement. In an attempt to monitor A8 migrant workers the UK introduced a Worker Registration Scheme (WRS). This scheme though only targets those employed and registration with the scheme is not a proviso of entry to the UK. It is also apparent that an unknown number of A8 workers have entered and exited the UK without knowledge of the WRS scheme (Fitzgerald, 2005; McKay and Winklemann-Gleed, 2005; Currie, 2006).

Given this low level of regulation the precise number of A8 workers that work, or have worked, in the UK are unknown. Salt and Millar (2006) have though used a range of statistical sources to estimate new migration. They conclude that the entry of A8 workers to the UK is almost certainly the largest single wave of in-migration to the UK, with Polish workers constituting the largest ever single ethnic group. Regular WRS reports of A8 registration have also been released by the British government and the most recent of these indicate that since May 2004 949,185 workers have registered to work in the UK (Border and Immigration Agency, 2009). Of these registrations some 626,595 (66%) are Polish with as many as 380,000 working for recruitment agencies.

HEALTH AND SAFETY AND MIGRANT WORKERS

The International Labour Organisation have highlighted that occupational accident rates for migrant workers in Europe were twice as high as for equivalent indigenous workers (ILO, 2004). Whilst in a UK context the HSE recently recognised that migrant workers may be missing out on crucial health and safety training due to a lack of employer provision of procedures in languages other than English. Given this they jointly collaborated with the TUC to publish a health and safety leaflet in 19 separate languages (HSE, 2004). Although Bates (2006) has identified HSE officers visiting migrant workplaces with interpreters, there has been a reticence to undertake any major action, unless cost-effective, until there was strong evidence of risk. Given this 'lack of evidence' a study of England and Wales was commissioned by HSE in 2006 to gauge risk. The findings of the study (McKay et al., 2006) identified that even though there was not yet statistical evidence of increased risk due to an individual being a migrant worker, there was considerable need for concern. The authors argued that migrant workers were more likely to be working in sectors and occupations with a heightened health and safety risk. Further in interviews with over 200 migrant workers they found that up to a third had not been provided with any health and safety training. Moreover it was significant that twenty-five per cent had sustained some form of injury at work, which many had not reported. Injuries were often linked to a lack of acclimatisation to the job and workplace and significantly fatigue. Also highlighted were issues with regard to migrant self-employment and a lack of information on health and safety procedures.

This lack of information is interesting given the multi-lingual leaflet identified earlier, although this pre-supposes that the leaflet was widely distribution. Of interest is also that the TUC had secured agreement from the Home Office that advice and information on how A8 migrants receive national insurance numbers, pay tax and secure their rights at work would be supplied to everyone who registered on the WRS. Within the first six months of the scheme the TUC had received as many as 1,600 enquiries (UCATT, 2005). Although, at a TUC A8 meeting that one of the authors attended in 2006 it was reported that the distribution of these leaflets was only occurring intermittently. As well as this is the evidence of lack of A8 registration to the WRS scheme. Lack of information for A8 workers has been a theme throughout migrant research and often relates not to whether information is available but most importantly how accessible it is to A8 workers (Commission for Rural Communities, 2008; Fitzgerald, 2009).

In a European wide report prepared for the Polish government on the impact to A8 citizens of emigration Carby-Hall highlights a range of Health and safety abuse within the context of a five part scenario. Firstly, Carby-Hall claims that many A8 migrants display 'fear' when questioned about exploitative conditions; secondly, that this is often difficult to challenge as A8 migrants are widely scattered in a number of economic sectors; thirdly, that some of the worst excesses of exploitation are akin to 'forced labour' and 'modern slavery'; fourthly, that actual abuse is multi-faced and can not be tied down to a single practice; and fifthly, that gangmasters and some employment agencies play a significant role in this and often have a dominant controlling interest. In particular he highlights how this has a clear connection to poor health and safety practices and that in a UK context if migrants complain about their working conditions they are likely to be sacked with no legal protection in the first year of employment.

UK HEALTH AND SAFETY LAW

The Health and Safety law of the UK workplace is built upon the Health and Safety at Work etc Act 1974. The Act provides a foundation for UK construction health and safety law and also enables the development of a comprehensive framework of 'statutory instruments' (regulations) and associated standards and approved codes of practice.

Construction activity is subject to a range of humane regulations, of which compliance is a legal requirement, and disregard a criminal offence. Examples of some key UK construction-related health and safety regulations are listed in Table 1.

Table 1 - Time Line of Key UK Construction Health & Safety Legislation (Howarth and Watson, 2009)

Date	Legislation
1974	**Health and Safety at Work etc Act** This act provides the basis for British health and safety law. The Act came about as a response to constantly expanding, ever more detailed, UK health and safety law. The Act consolidated much legislation and provided for the development of a 'personal responsibility' approach to health and safety. The Act is an 'enabling Act' and has a provision for the development of a framework of health and safety 'statutory instruments' (or 'regulations') and any associated standards and approved codes of practice.
1981	**Health and Safety (First Aid) Regulations** Employers are required to have adequate and appropriate equipment, facilities and personnel for employees who suffer injury or illness at work.
1987	**Control Over Asbestos at Work Regulations – Revised 2002** Introduced to educate duty holders in the identification of materials containing asbestos and to provide guidance for its removal.
1988	**Control of Substances Hazardous to Health (COSHH) – (Amended 1994 & 1999)** Implemented as a method of ensuring that practitioners were aware of the dangers brought about through working with chemicals and other hazardous substances. The law required employers to control employee exposure to prevent illness.
1989	**Noise at Work Regulations – (Amended 2005)** These regulations concern all people at work (not just construction) and deal with risks to hearing, not other aspects of health safety and welfare. The regulations provide for an employer responsibility to protect employees from harm caused by exposure to noise.
1992	**Workplace (Health, Safety and Welfare) Regulations** These regulations serve to protect the health, safety and welfare of everyone in the workplace. They also give protection to other people who might have been affected by the work.
1992	**Management of Health and Safety at Work Regulations (Revised 1999)** The Management of Health and Safety at Work Regulations first came into effect on 1st January 1993 and were revised in 1999. The regulations were developed to implement the general provisions of the European Framework Directive (89/391/EEC) – '*measures to encourage improvements in the safety and health of workers at work*'. As such the Management of Health and Safety at Work Regulations developed UK health and safety management and brought about the requirement to use risk assessment to manage health and safety as well as requiring the undertaking of health surveillance and the appointment of competent health and safety assistants within the workplace.
1992	**Personal Protective Equipment at Work Regulations** The regulations implement the European Directive 89/656/EEC – '*to introduce minimum health and safety requirements for workers using personal protective equipment (PPE) at the workplace*'. Under these regulations an employer is required to provide suitable PPE when an employee is faced with a health and safety risk.
1996	**Manual Handling Operations Regulations** The regulations facilitate the prevention of musculoskeletal disorders caused by the manual handling of heavy goods in the workplace.
1994	**Construction (Design and Management) Regulations** **(Replaced by CDM2007)** The regulations were implemented to emphasise and improve the *management* of health and safety throughout all stages of construction projects. The regulations place responsibility on the client and designers as well as contractors and promote a pro-active approach to safety management.

1995	**Reporting of Injuries, Diseases and Dangerous Occurrences Regulations [RIDDOR]** These regulations serve to ensure that workplace 'occurrences' are reported to the HSE. The occurrences include: ▪ Fatal and serious accidents. ▪ Accidents that prevented employees working for 3 or more days. ▪ Dangerous incidents where people were put in danger. ▪ Specified diseases associated with a person's job.
1996	**The Construction (Health, Safety and Welfare) Regulations** (**Now revoked and replaced by CDM2007)** These regulations came into force on 2nd September 1996 and revoked (replaced) the Construction (Health and Welfare) Regulations 1966 and the Construction (Working Places) Regulations 1966. The regulations applied to all 'construction work'.
2005	**Work at Height Regulations** These regulations were introduced to further address the UK construction industry's single biggest cause of injury and fatality. The regulations apply to all work at height where there is a risk of a fall liable to cause personal injury.
2007	**Construction (Design and Management) Regulations 2007** These regulations were initially introduced in March 2004. The 2007 regulations (CDM2007) revoke and replace the 2004 regulations. CDM2007 also revoke and replaced the Construction (Health, Safety and Welfare) Regulations.

ENFORCEMENT

A breach of duty imposed by the Act or non compliance with regulations (issued under section 15 of the Act) is a criminal offence. Premises and work activities subject to health and safety inspection are identified in the Health and Safety (Enforcing Authority) Regulations 1998. Schedule 2 of these regulations details the Health and Safety Executive's (HSE) responsibility, which extends to building sites, factories and manufacturing, nuclear installations, railways, schools and hospitals. With specific regard to construction, the Health and Safety Executive employ some 134 inspectors to visit sites across the UK, undertake enforcement action and investigate accidents. This limited number of inspectors results in there being only a small possibility of a site receiving an inspection visit. Further to this the HSE periodically carries out 'national inspection initiatives'. These initiatives serve to strategically target activities where accident rates are viewed as increasing. One recent example of such a 'national inspection initiative' was a much pre-publicised targeting of refurbishment sites in March 2009. Disappointingly, of 1,759 refurbishment sites visited enforcement actions were served on 348 of the sites where serious safety risks were discovered (HSE, 2009a).

In carrying out the refurbishment inspection initiative, HSE inspectors considered the following good practice criteria (HSE, 2009a):

- Jobs that involved working at height had been identified and properly planned to ensure that appropriate precautions were in place;
- Equipment was correctly installed / assembled, inspected and maintained and used properly;
- Sites were well organised to avoid trips and falls;
- Walkways and stairs were free from obstructions;
- Work areas were clear on unnecessary materials and waste;
- The risks associated with exposure to asbestos were managed and carried out correctly;

- The work force was made aware of risk control measures.

Nearly twenty per cent of the refurbishment sites inspected fell seriously short of adequately achieving the above good practice criteria. This does not suggest a continuation of the statistical trend of construction health and safety enforcement of recent years (2002-06) where a steady decline has been evidenced in the issue of improve notices, prohibition notices, the number of informations laid, and the number of prosecutions (Howarth and Watson, 2009). It also does not suggest significant progress in delivering site level improvements in workplace health and safety management.

THE MIGRATORY NATURE OF THE CONSTRUCTION SECTOR

Construction activity is mainly location specific with cost-reductions often relying on the migration of labour (Baganha and Entzinger, 2004). Baganha and Entzinger (2004: 11) argue that EU regulation encourages employers to seek migrants from within, rather than outside the EU. Interestingly, Balch et al. (2004) argue that in a UK context cheap foreign labour is an '*embedded, structural feature of the UK construction sector*' (ibid: 191). This occurs at the mid to low skilled end of the labour market and is often based on informality, with a lack of enforcement of regulations, which is likely to be supported by recruitment agencies. More recently a study of 'bogus self-employment' has estimated that for every A8 construction worker directly employed there are 11 self-employed (Harvey and Behling, 2008: 24). If this is the case then the 36,750 A8 workers who have registered with employers in construction (Border and Immigration Agency, 2009), of which Polish workers make up approximately 63%, becomes over 400,000 who have actually worked in the sector. HSE (2009c) themselves have recently estimated that a quarter of foreign workers in UK construction were Polish. Given this UK context, including light touch regulation, the most obvious issues with a transitory foreign workforce are training and education with regard to new working environments. Most significantly, there is the pressing issue of who will assimilate an accession workforce into the health and safety culture of a UK building site. This is of course not least tied into language and terminology challenges.

As well as these particular UK factors are an added A8 country issue with regard to the informal nature of a growing section of the central and eastern European labour economies. Woolfson (2007, 2006; with Calite and Kallaste, 2008; and Sommers, 2006; Woolfson et al., 2003) argues that these newly 'freed' economies have moved from stable but repressive control through to a harsh free market. Informalism is increasingly as unemployment and poor trade union representation lead to domineering employers. The significance here is that entering accession these countries offered a cheap labour alternative, which has indeed been utilised in construction (Woolfson and Sommers, 2006). Important in Woolfson's work is his reference to fatalities and injuries at work not least due to a number of abusive employer practices (Woolfson, 2006). The significance for our argument is that the UK construction sector has a reliance on cheap foreign labour; a considerable number of the self and bogus self employed; and finally this is supported by recruitment agencies. When this is added to many of the conditions outlined by Woolfson an assumption maybe drawn that a number of existing workplace practices, including health and safety, will be undermined.

MIGRANT WORKERS HEALTH AND SAFETY IN CONSTRUCTION

Clarke and Gibling (2008) report that the Heathrow Airport T5 terminal construction project operated an exemplary health and safety system. This site included an on site CSCS test centre and a strong trade union presence. Although, the authors conclude that this approach to safety on a large construction project was not typical of UK construction projects (Clarke and Gibling, 2008).

In support of this conclusion, a study in the North East of England (Fitzgerald, 2006) found that the mainly Polish migrant workers were being exploited and abused. The clearest examples of abuse were expressed through direct violence towards workers and excessive hours of working. What bound many of these workers to the employer were their poor language skills and the reliance on the employer for their accommodation needs. It also became evident that many workers had self-employed or illegal contracts (confirmed by solicitors working with the project). There was no training identified and importantly industry regulation through such things as the CSCS card was also not evident. The project did not have health and safety as a central concern but two main examples are worth highlighting. The first was reported by a sub-contractor who spoke about new sub-contractors supplying Polish labour to the sector. He identified that a refurbishment site in Newcastle was being used as accommodation by a group of Polish building workers. It was accessed at night via climbing up the scaffolding surrounding the building. Secondly a trade union official reported that a Polish owned sub-contractor working on a housing development had been ‘caught’ using pallets for its Polish workers instead of scaffolding. Overall poor employer practices were underpinned by a lack of information about UK employment rights, including those relating to health and safety. This and poor language skills meant it was very difficult for Polish workers to initially change employer or seek assistance. On a wider note Dench et al. (2006) in a government funded study into employer use of migrant labour identified that some of the construction employers they spoke to provided no training for their migrant workers. They also highlighted that some had a poor attitude with regard to translation of English health and safety instructions. Also highlighted in a number of other studies, for example in Pemberton and Stevens (2006) in the North West of England.

There has been further discussion of what actually happens if migrants complain about workplace health and safety. For example Anderson and Rogaly (2005) identify that HSE construction inspectors admit to being powerless to assist migrants who are dismissed by their employers following a report of a health and safety incident. Owen (2007) takes our discussion further by actually accessing the available health and safety statistics, which are not broken down by ethnicity. He states that he was encouraged by a decline in fatalities and serious injuries in construction prior to 2006 and 2007. However, he notes a recent rise and remarks that this is likely to be due to the introduction of large numbers of migrants with poor language skills. Blackman (2007), the lead construction officer for Unite the Union is direct in arguing that this rise in migrant worker construction fatalities is due to the introduction of rogue gangmasters who had previously been operating in the food processing sector. He believes that their introduction into construction followed the Gangmasters (Licensing) Act 2004 legislation which lead to the formation of the Gangmasters Licensing Authority (GLA) in the food processing industry. He argues for an extension of the GLA into construction. Although, this was initially publicly rejected by government (BERR, 2008) the recent inquiry into construction fatalities does now recommend an extension of the legal framework in construction, including an extension of the GLA into construction (DWP, 2009).

THE STATISTICAL EVIDENCE BASE

The preceding case studies and wider research supporting a hypothesis that migrant workers are more prone to accidents at work mainly relate to small numbers of building employers in an industry which in 2006 had 186,107 firms (ONS, 2008). The central theme throughout all of this work is the need for statistical evidence with regard to migrant fatalities and injuries in the workplace. A recent piece of work by the Centre for Corporate Accountability (CCA) provides some assistance here with regard to fatalities at work. The study uses a Freedom of Information Act (FOIA) request to the HSE to report that since 2002 the HSE has been able to ascertain how many migrant worker deaths there have been in construction (CCA, 2009). This is of course based on reported incidents. They identify that migrant worker deaths in construction were almost a fifth of all construction deaths in the 2007-2008 period (ibid: 10). Further that migrant worker deaths in construction have gradually increased rising from two in 2002-2003 to three in 2003-2004. Following the accession the 2004-2005 period witnessed five deaths which grew to eight in the next period and then by a further fifty per cent in 2007-2008 to twelve. Overall HSE data indicate then that there has been a substantial three hundred per cent rise in migrant deaths in construction since the accession of the A8 countries. However, this HSE data is constituted via a manual trawl of HSE records and was not provided specifically by nationality. The CCA (2009) does though have their own managed database of migrant fatalities since 2001-2002, which although not exactly comparable to the HSE data has clear synergies and allows a closer inspection of the rise in fatalities since 2004 by ethnic group. Here of the 46 migrant worker deaths identified 24 were in construction. Further of these 24 construction fatalities 18 followed the A8 accession, of which forty-four per cent (8) were Polish.

The concern here is not only that this has occurred due to poor employer practices but also because of a gradually reduced HSE presence in the workplace. In a previous piece of work by the CCA for Unite the Union it was highlighted that there has been a gradual decline in the investigation of major injuries to workers in construction. In the 2006-2007 period when eight migrants died only fourteen per cent of all construction major injuries were investigated (CCA, 2008: 12). Whilst in the same period only two per cent of 'over three day injuries' were investigated. The CCA note that this was a twenty per cent decline in investigation of the former and fifty per cent decline of the latter since the 2001-2002 period. They conclude that '*in failing to investigate such high numbers of injuries and dangerous occurrences, the HSE has overseen the virtual institutionalisation of a culture of impunity… The HSE/C's failure to argue the case for more money for investigations shows they do not see accountability as a high priority*. (CCA, 2008: 30). Further more controversially that:

> *….the Government has set a context for the work of the HSE – both in terms of allocation of resources, and through its wider messages about 'burdens on business' – in which safety at work is increasingly devalued, and seen as an interference with the business of doing business.* (CCA, 2008: 31)

This is perhaps too harsh a criticism and the HSE have been actively involved in seeking to support vulnerable workers, which has been contributing to improvements in workplace health and safety in the UK. The term vulnerable has become common in Government and TUC dialogue and represents a range of workers, including those working for recruitment agencies and migrant workers. The HSE Construction Industry Advisory Committee (CONIAC) vulnerable workers group has highlighted the need for more freely available health and safety information for employers (HSE, 2009b). Interestingly, though, with regard to migrant workers the working group have three main recommendations. First that CONIAC should support the HSE construction division provision of more multilingual outreach workers; second that they should encourage more multi-media projects for migrants and; third that they should identify how the Construction Skills 'Safety Critical Communications' tools for migrant workers can be widely used.

CONCLUDING SUMMARY

This paper has identified five main areas which research has focused on when discussing health and safety and UK migrants. It has also introduced significant statistical evidence which supports this research in showing an increase in migrant worker fatalities since the May 2004 accession of the A8 countries. These areas are:

- Abusive and exploitative employer practices which underpin a working context. This can lead to fear of reprisals if lapses of health and safety are reported;
- A serious lack of information regarding a number of aspects of working in a new workplace – this of course makes movement away from poor employers more difficult;
- Poor migrant language skills and support which again feeds into the two areas above;
- A lack of basic employer health and safety training;
- Lastly a much wider issue, particularly in construction, of self employment.

ConstructionSkills, a UK industry body involving amongst others employers and trade unions, has attempted to alleviate these practices in construction. One early action considered was the setting up of a permanent 'On-site Assessment Training' (OSAT) centre in Poland in order to certify those seeking to work in construction in the UK (cited in Chan et al., 2008). However, in an industry such as construction there is a need for wider employer awareness that migrants require acclimatisation to unfamiliar construction sites. This is of particular importance when issues of language and differing health and safety cultures are likely to be a major feature in the early stages of employment. Although, employer engagement with this may be difficult, particularly at a time of economic recession, the recent suggestion of an extension of the construction legal framework is an encouraging step.

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THE INFLUENCE OF AGE IN THE SAFETY PERCEPTIONS OF CONSTRUCTION WORKERS: A FRENCH CASE STUDY

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ABSTRACT

The construction industry is known as one of the most hazardous industries globally. As such, important efforts must be made to develop a better safety culture and climate in construction companies. Labourers are at the core of this system and are the principal target of safety training and programs. The population is getting older and the consequent gap between young and old construction workers is widening. In the meantime existing research about workers' perceptions of safety regarding their age are limited and contradictory. Therefore this study compares the safety perceptions of French construction workers according to their age. The methodology for this study saw questionnaires distributed randomly amongst labourers of a French construction company, 'EGC Canalisation Briand' specialising in the gas and water networks installation. Questionnaires captured general data as well as data on 10 safety attitudinal statements on a 1-5 Likert scale. Questionnaires were distributed to 30 French construction workers. The results showed some differences in safety perceptions between old and young labourers. Two safety scales were related to age with older workers being more satisfied with 'company safety management' than younger workers and younger workers being more satisfied with 'company safety information' than older workers. The findings of this study, based on a random sample of 30 French construction workers, have some implications for the wider French construction industry. The findings suggest that age has some bearing on safety perceptions. Specifically the study finds that younger workers in the sample were more positive toward safety than older workers in the sample. However, previous studies have suggested otherwise. This study may influence approaches to safety training programs and safety culture implementation in French construction companies as yet un-adapted to new generational mixes of young and old staff. To be able to extend the findings of this study to the total French construction industry further research undertaken using larger samples is necessary.

Keywords: Age, Construction workers, Safety climate, Safety perceptions

INTRODUCTION

The construction industry is one of the most hazardous in the world. In 2007/08 in the United Kingdom (UK) some 72 construction workers lost their lives as a consequence of accidents and safety incidents at work and the rate of fatal injury was 3.4 per 100,000 workers. However the UK construction industry safety results are better than many other European countries (HSE, 2008). In comparison, in 2006, in France 158 construction workers died from accidents and the rate of fatal injury was 10.6 per 100,000 workers (Institut National de Recherche et de Santé, 2008). These safety statistics are a testament to the dangerous nature of construction which involves the undertaking of a number of hazardous activities such as carrying out repairs, renovations, modifications and demolitions of structures. In fact construction activities involve a variety of hazardous tasks ranging from fully mechanized activities to hard physical labour (Deacon et al., 2005). In the United States, it is well documented that construction workers have a higher risk of work related illnesses and accidents than workers in other branches of industry and the public sector (Agarwall and Everett, 1997; Burkhart et al., 1993; Kisner and Fosbroke, 1994; Peterson and Zwerling, 1998).

Developing a proactive safety culture can take a long time and requires significant investment in planning, investigating and implementing safety into each organisational aspect. Creating a culture of safety however is crucial since the safety of employees is a fundamental duty of care expected of employers (Hassan et al., 2007). Hinze (1997, cited in Hassan et al., 2007:272) suggests that '…safety is not a luxury but is a fundamental necessity'.

Safety culture is a subset of organisational culture used for practical purposes such as understanding safety behaviour and outcomes (Lingard and Yesilyurt, 2003, Trethewy, 2003). This research focuses on a subset of safety culture; specifically the safety climate which is the explicit set of values and attitudes expressed about safety by an organisation (Dingsdag et al., 2007).However Mohamed (1999 cited in Chan et al., 2007:126) suggested that 'The safety climate is largely a product of safety culture, and the two terms should not be viewed as alternatives'.

In recent years construction companies globally have recognised the importance of safety in the control and reduction of construction costs (Hassan et al., 2007). However, human behaviour which is a crucial factor in safety culture is difficult to control (Jannadi, 1995). Hazards can not be eliminated even with the most sophisticated management tools. Instead, danger and risk must be recognized and anticipated by workers. According to Mattila et al. (1993) the characteristics of effective safety supervision are the same as the characteristics for general supervision. The study demonstrates that communicating effectively with employees is important and counts towards the definition of effective management. Indeed labourers are at the centre of the construction industry and it is these employees who carry out the most significant amount of high risk manual tasks. Care of employees is an important factor and employee safety counts towards the profitability of organisations.

Personal data including demographics (such as age, gender, marital status and education level inter alia) have some bearing upon safety climates with implications for the collective safety of workers (Hinze, 1997). However there has been little research to examine the relationship between personal characteristics and the safety climate (Yang et al, 2005). Indeed existing studies relating to this topic are at times contradictory. Siu et al (2003) examined age differences in safety attitudes and performances. A sample of 374 Chinese construction workers from 27 construction sites in Hong Kong was collected and the correlations between age, tenure and safety attitudes were examined. It was found that older workers exhibited more positive attitudes toward safety. Conversely, Garcia (2004) developed a safety climate index (henceforth SCI) to measure safety climates in the pottery industry in Castellon (Spain). The study found no variation in SCI scores according to age, gender, education, children at large, seniority at work, or type of employment (Yang et al., 2005). Despite the absence of a research paradigm regarding the influence of personal characteristics on workers safety behaviour some research exists describing the effects of personal characteristics such as age on the attitude and behaviour of construction workers. For example, Siu et al. (2003) argue that personal traits such as vision, reaction time and hearing can deteriorate with age. Similarly Gherardi and Nicolini's (2002) study of the Italian construction industry reveals that more experienced workers take less 'care', yet display greater confidence in anticipating safety eventualities.

The fact that the attitude and behaviour of employees may be influenced by age is significant since the global population is ageing rapidly (Siu et al, 2003). This phenomenon can be attributed to various factors such as the 'baby boomer' generation (a result of increased birth rates in post World War two western societies), longer life expectancy, and reduced total fertility rates (Siu et al, 2003). The consequence is that in many countries the labour market is getting older to compensate labour shortages. Research undertaken to establish knowledge about the influence of age on safety behaviour has therefore proven useful to inform the design and implementation of safety programs and safety cultures.

In France (and in most European countries) construction worker populations are getting older and so the construction industry must plan around this phenomenon for the future. The relationship between age and safety perceptions amongst French construction workers therefore merits attention in order to develop adapted safety programs and safety climates.

THIS PAPER

Research into the significance of age on safety perceptions is limited and conflicting. Some studies (Siu et al. (2003) and Lee (1995)) found that older workers have different attitudes regarding safety. While other studies such as Garcia (2004) did not find any significant difference in workers' attitudes regarding their age. This study therefore adds to an understanding of the safety perceptions of French construction workers according to their age. The first objective of this study is to comment on any observed difference in the safety perceptions of French labourers according to varying age categories. The second objective of this study is to find which safety factors are perceived differently and how these differences might occur. To date, there are few studies into the significance of age in relation to safety perceptions in Western construction labour forces. The conclusions drawn from this case study of a French construction company have implications to the French construction industry regarding the implementation of safety programs.

METHODOLOGY

The safety climate measurement instrument named Safety Attitude Questionnaire (SAQ) used by Siu et al. (2002) on Chinese construction workers was chosen as a basis to develop a relevant questionnaire. The SAQ has been developed by the Safety Research Unit for British Steel over a number of years and is based on the principle that '…a large number of accidents are under control of those involved in them. The people involved may not intend to have an accident, but the behaviour that's leads them to the accident is intentional, and they are aware of what they are doing…' (Donald and Canter, 1993: 5). The SAQ was adapted to the research and then sent to a French construction company named EGC Canalisation Briand. This small sized company specialised in the gas and water networks installation was selected because it represented the majority of the French construction companies according to the size and turnover. The response rate of 42% with a total of 30 questionnaires returned was a little bit higher than the expected range of 20% to 40% (Futrell, 1994). The questionnaire has the key objective to evaluate the French construction labourers perceptions and attitudes toward safety. The first part of the questionnaire contains general questions such as age, experience in the construction industry and previous accidents. The second part is the rating of statements by workers on a five point Likert scale, under categories of 'strongly agree', 'agree,' 'no strong feelings', 'disagree', 'Strongly disagree'. Respondents were asked to judge favourably or unfavourably statements about safety. Table 3 shows the safety subscales and corresponding statements used in the questionnaire.

Table 1: Safety subscales and statement used in questionnaires

Safety subscale	Statement
TL1:Team leader satisfaction with the safety system	'My manager is satisfied with the safety training given to the workforce'
TL2: Team leaser knowledge of the safety system	'All supervisors have a sufficient knowledge about safety at work in their respective area'
M1: Management/supervisor encouragement and support	'My supervisor encourage me to report any safety problems that might occur to me'
M2: Management/supervisory safety environment/pressure	'The management of the company put productivity before safety at work'
A: workforce satisfaction with the system	'My workmates are satisfied with the safety procedures in general'
B: Work environment: hardware	'Before starting work, I always check safety equipment that I might need'
C: Work group encouragement and support	'My workmates encourage me to work safely'

Safety subscale	Statement
D: Workforce training	'I feel satisfied with the attention give to safety in any training I received'
E: Global self safety	'Overall, I think that I am safe in my work'
F: Safety information	'My colleagues are satisfied with the information they get about safety at work'

Respondents were classified in age groups (Table 4 below) as in the work of Sawacha et al. (1999).

Table 2: Age classification

Group	Age (years)
1	Under 21
2	Between 22 and 28
3	Between 29 and 35
4	Between 36 and 44
5	Aged 45 and above

Data collection has been computed (see appendix 4) and analysed with the Software Package for Social Science (henceforth SPSS) V.15.0. Table 5 shows the descriptive statistics of participants' age.

Table 3: Descriptive statistics of participants' age

	N	Mean	Median	Minimum	Maximum	SD
Age (years)	30.00	38	39.00	18.00	57.00	12.74

The participants' average age of 38 years is close to the French national average of construction employees which is 38.5 years old (Action BTP, 2008). This 'normal sample' would normally be tested with the use of parametric tests (Walliman, 2006). However data were measured with a 'nominal' Likert scale and therefore not organised in a 'curve form' as parametric tests required. Therefore nonparametric tests were used to detect statistically different means. Comparisons between five means were tested using the Kruskal-Wallis test, a nonparametric equivalent of the 'analysis of variance' (ANOVA) test (Kinnear and Gray, 2006). Comparisons between two means were tested using the Mann-Whitney test; a common nonparametric test for two independent samples (Kinnear and Gray, 2006).The threshold for significance of these tests was set at 0.05. Therefore statistical test showed significance if the p-value (probability of obtaining a value at least as extreme as the one obtained) was less than 0.05. However, Kruskal-Wallis detects only an overall difference between three or more means. Therefore the Mann-Whitney test was used as a post hoc test to identify specific differences between two means. Adjusting the post-hoc p-value with a Bonferroni procedure was not considered because it removed all statistical significance of the test results. In fact the Bonferroni procedures have been criticised by the past for its statistical severity (Nakagawa, 2004). Moreover there is no formal consensus for when Bonferroni corrections should be used, even among statisticians (Perneger, 1998).

RESEARCH FINDINGS

Table 6 shows the mean and standard deviation of statements' rating for each age group.

Table 4: Mean and Standard deviation of statements' rating for each age group

Statement	Kruskal Wallis p	Under 21		22-28		29-35		36-44		Over 45	
		Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
TL1	0.098†	2.25	0.50	2.00	0.00	1.75	0.50	1.80	0.45	1.50	0.52
TL2	0.290	2.00	1.15	2.60	0.55	2.75	0.96	1.80	0.45	2.00	1.04
M1	0.120	4.50	1.00	3.80	1.64	2.75	0.50	3.40	0.89	3.42	1.32
M2	0.027*	2.25	0.50	3.00	0.00	3.00	0.82	3.80	0.84	3.67	0.89
A	0.560	3.75	0.50	3.40	0.89	2.75	1.26	3.40	0.55	3.58	0.90
B	0.098†	2.75	0.50	3.20	1.30	3.00	0.00	3.00	0.00	1.92	1.08
C	0.180	4.50	1.00	3.20	1.10	3.00	1.55	4.00	0.00	3.67	0.98
D	0.380	2.50	0.58	2.60	0.55	2.50	0.58	1.80	0.45	2.33	1.23
E	0.350	2.25	0.50	3.60	1.52	2.25	1.26	2.20	0.45	2.17	1.11
F	0.047*	2.25	0.50	3.60	0.55	3.00	0.82	2.00	0.71	2.67	1.07

(*statistically significant ($p < 0.05$); †nearly statistically significant ($p < 0.1$))

Kruskal Wallis Test Observation

No observation or conclusion can be drawn from the means of the statement TL2, M1, A, C, D and E because their Kruskal-Wallis chi-square test results were highly not significant (p >0.1).

TL1: Team leader satisfaction with the safety system

The means of the participants 'Under 21'and '22-28' were higher than the other groups with respectively 2.25 and 2. The means of groups '29-35'and '36-44' were in the middle of the sample with respectively 1.75 and 1.8. Finally the mean of group 'Over 45' was the smallest with 1.5. These results suggest that younger workers are more positive than older workers about the team leader satisfaction with the safety system. However, the Kruskal-Wallis chi-square test was nearly significant beyond the 0.05 level: x2=7.841; p=0.098.

M2: Management safety environment and pressure

The means of the groups '36-44' and 'Over 45' were the highest of the sample with respectively 3.8 and 3.67. The means of the groups '22-28' and '29-35' were in the middle of the sample with respectively 3 and 3. Finally the mean of the group 'Under 21' was the smallest of the sample with 2.25. These results suggest that older workers are more satisfy than younger workers with the safety pressure/environment. The Kruskal-Wallis chi-square test was significant beyond the 0.05 level: x2=10.988; p=0.027.

B: Work environment

The means of the groups 'Under 21' and '22-28' were the highest with respectively 2.75 and 3.2. The means of the groups '29-35' and '36-44' were in the middle of the sample with 3. Finally the mean of the group 'Over 45' was the smallest with 1.92. These results suggest that younger workers are more satisfy than older workers about their safety routines. However, the Kruskal-Wallis chi-square test was nearly significant beyond the 0.05 level: x2=7.820; p=0.098.

F: Safety information

The means of the groups ‘22-28’ and ‘36-44’ were the two extremes of the sample with respectively 3.6 and 2. The other groups ‘Under 21’, ‘29-35’ and ‘Over 45” are in the middle of the sample with respectively 2.25, 3 and 2.67. The Kruskal-Wallis chi-square test was significant beyond the 0.05 level: x2=9.643; p=0.043.

Post Hoc Mann Whitney Test Observation
Table 7 shows the results of the post hoc Mann Whitney test for the statement M2.

Table 5 Statement M2 Mann-Whitney test results (p)

M2	22-28	29-35	36-44	Over 45
Under 21	0.025*	0.155	0.022*	0.015*
22-28		1.000	0.053	0.046*
29-35			0.193	0.139
36-45				0.953

(*Statistically significant (p < 0.05))

Post hoc Mann-Whitney tests found a significant difference between the following groups:

- ‘Under 21’ and ‘22-28’: U=2.50; p=0.025.
- ‘Under 21’ and ‘36-44’ U=1; p=0.022.
- ‘Under 21’ and ‘Over 45’; U=5.5; p=0.015
- ‘22-28’ and ‘Over 45’; U=12.5; p= 0.045.

Therefore the perception of company management in favour of productivity rather than safety was significantly different between the two youngest groups (‘Under 21’ and ‘22-28’) and the three other groups ‘22-28,’ ‘36-44’ and ‘Over 45’ .The two youngest groups either agree or strongly agree to the statement: “The management of the company puts productivity before safety at work”.

Table 8 shows the results of the post hoc Mann Whitney test for the statement F.

Table 6 Statement F Mann-Whitney tests results

F	22-28	29-35	36-44	Over 45
Under 21	0.020*	0.155	0.558	0.469
22-28		0.227	0.013*	0.055
29-35			0.090	0.442
36-45				0.214

(*Statistically significant (p < 0.05))

Post hoc Mann-Whitney tests found a significant difference between groups ‘Under 21’ and ‘22-28’; U=1; p=0.020. There was also a significant difference between groups ‘22-28’ and ‘36-44’; U=1; p=0.013.

Therefore the perception of colleagues satisfaction with the information about safety received at work is significantly different between the groups ‘22-28’ and the groups ‘under 21’ and ‘36-44’. The group ‘22-28’ being disagree with the statement ‘My colleagues are satisfied with the information they get about safety at work’

DISCUSSION

The sample was normally distributed. Table 9 shows the number of participants per age group.

Table 7 Number of participant per age group

Age group	Under 21	21-28	29-35	35-45	Over 45
Number of participant	4	5	4	5	12

The number of respondents in each age group was unequally distribute with 40% of participants (twelve respondents for every thirty) aged 45 years or above. This unequal repartition of workers in age groups is similar to the French construction reality. In fact in 2006 some 32% of French construction employees were more than 45 years old.

Looking at the ten statements measured in the questionnaires only two were statistically significant and two were nearly statistically significant. Therefore, it can be argued that there are no major differences between workers' safety perception according to their age. However the study results demonstrated differences of safety perception between workers according to their age on the 'Management of safety environment/pressure' and 'the safety information'.

Answers to question M2 demonstrate that younger workers believed that the management of the company put productivity before safety at work. On the other hand the older workers believed that the management of the company did not put productivity before safety at work. The fact that older workers are more positive than younger workers toward 'management safety environment and pressure' supports the conclusion of Siu et al. (2003) study. These results can tentatively being explained by the difference of work experience between young and old workers. In fact, older workers are probably working since a long time with the company management team. At the opposite younger workers are probably working with the management team since considerably less time. These differences of work experience with the management team between younger and older workers can affect the level of trust and therefore the perception of 'management safety environment and pressure'.

Answers to the question F indicate that the youngest workers (Under 21) were the strongest group believing that their colleagues were satisfied with the information they get about safety. On the other hand the workers between 22 and 35 years old believed that their colleagues were not satisfied with the information they get about safety at work. These observations do not corroborate any existing study. The fact that younger workers are more positive toward 'safety information' than older workers can also be tentatively explained by the difference of work experience. In fact older workers have probably witnessed or being victims of more accidents than younger workers. These past experiences can influences workers' perceptions of the 'safety information' they judge necessary. In other words older workers might expect more safety information than younger workers because they are more aware of the potential hazards of a construction site.

One common explanation to the two statistically significant differences of workers' safety perception appears to be the work experience. This observation suggests that one of the most influential factor on workers' safety perception and related to age is the work experience.

LIMITATIONS

This study offers a number of findings but there are also limitations in interpreting these.

Firstly, the sample was small (30) and undertaken at a particular time of the year. The results can therefore not be generalised in terms of time and in terms of the wider population of construction employees in France. In other words the findings of this study can only be applied to the sample of

30 workers from 'EGC Canalisation Briand' in May 2008. Secondly the Kruskal-Wallis test results can only be considered as nearly significant due to the fact that two of the age groups have only four participants against the minimum of five required for the full validity of this test. Thirdly, a limitation to the study is the fact that some of the workers do not have enough reading and writing skills to understand and answer the questionnaire without help. The fact that questionnaires were therefore 'assisted self complete' can temper answers. Another limitation to the study is the fact that some labourers may not read all the questions but simply tick the same number to all statements. This comportment of the participant cannot be measured or totally avoid but the researcher can detects some of those unread questionnaires. The statements 'M1', 'A' and 'C' were therefore transformed into negative form with negative bold words. This allows the researcher to detect questionnaires were labourers do not read the statements and always tick the same number of the Likert scale.

CONCLUSIONS AND FURTHER RESEARCH

This study suggests some difference between the perceptions of safety amongst French construction workers according to their age. It can be concluded that older workers in this sample have a more positive attitude toward safety, compared with younger workers. This result contradicts the conclusions of Garcia (2004) study who found no differences of safety perception between workers regarding their age. In the meantime this result corroborates the Siu et al. (2003) findings that older workers had more positive attitudes towards safety than their younger counter parts. Conversely, this research suggests that some younger workers may have more positive attitudes toward safety, compared with older workers. This result does not corroborate any existing research findings.

These results suggest that young and old workers exhibit differences in their attitudes toward safety. But most importantly this study tentatively suggests that older French construction workers are not always more positive about safety as previous studies suggest. These findings in this sense offer new knowledge on workers safety perception.
These results can be explained as follows. The decreasing number of accidents observed during the last decades might make younger workers feel that the construction industry is not as dangerous as older workers might perceive it to be. Therefore the safety vision of young worker could be less negative than old workers in the sample studied. Another explanation to the difference of workers' safety perception according to the age is the work experience which affects the relationship with the supervisory team and the awareness of the potential sites' hazards.

During the last few decades safety programs did not pay enough attention to these potential differences in workers attitudes. Nowadays the number of older workers is growing and in the future there will be a mix of young and old workers in construction sites. Therefore safety policies and procedures not adapted should be re-evaluated in order to face the new generational mix (Siu et al., 2003). Finally the communication channels among construction labourers should be developed to enhance the various aspects of workers safety attitudes and to create an efficient safety climate and culture in the construction industry.

Future work on workers safety perceptions using large case studies could confirm and extend the findings to all the construction industry. In addition it would be interesting to focus on the reason why and how these differences of safety perception occur between young and old (more or less experienced) workers.

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OCCUPATIONAL COMMUNITIES AND SAFETY CULTURE

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ABSTRACT

During the past 20 years, safety culture has become a topic of significant interest in the safety research community. Unfortunately, the research conducted has not led to the development of a universally accepted model. Differences remain in the conceptual and operational definitions of both safety culture and safety climate. The issue of the appropriate level of aggregation remains to be settled. Many culture researchers treat an organization's safety culture as monolithic, i.e., there is one safety culture for the entire organization. Others believe an organization has multiple subcultures. Schein 1996) posits three subcultures: executive, engineer, and operative, each with its own set of assumptions. He examines executives and engineers as occupational communities that draw their knowledge, beliefs, and values from their interactions with similar people outside the organization. Van Maanen and Barley (1984) have defined an occupational community as “a group of people who consider themselves to be engaged in the same sort of work; who identify (more or less positively) with their work; who share a set of values, norms, and perspectives that apply to, but extend beyond, work related matters; and whose social relationships meld the realms of work and leisure.” Based upon this definition, there would appear to be multiple occupational communities present on construction projects. This paper will examine occupational communities within construction projects; how an occupational community develops its safety culture; and how the safety cultures of the various occupational communities interact on a construction project.

Keywords: Occupational communities, Safety knowledge, Communication, Training

INTRODUCTION

Despite recent improvement, the construction industry continues to experience a disproportionately high number of injuries and fatalities relative to other industries in the US economy. In 2007, the last year for which statistics are available, 371,700 construction workers suffered recordable injuries and 1204 workers died from injuries received on the job (Bureau of Labor Statistics, 2008). Safety culture is increasingly recognized as an important contributing factor to safety and health performance (Choudry et al., 2007; Guldenmund, 2007). In general, safety culture refers to attitudes, beliefs, perceptions, behaviors, norms, values, and assumptions surrounding safety and occupational hazards (Cox and Flin, 1998; Guldenmund, 2000). However, extant research in safety culture rarely examines the manner in which occupational communities (Van Maanen & Barley, 1984) operate to shape safety culture. This is particularly important for the construction industry, where each craft may comprise individual occupational communities (Reimer, 1979). The principle aim of this paper is to develop a better understanding of occupational communities, their safety cultures, and the influence that they have on project safety culture.

ORGANIZATIONAL CULTURE

To understand safety culture, it is necessary to understand organizational culture. Schein (1992) defines culture as “a set of basic tacit assumptions about how the world is and ought to be that a group of people share and that determines their perceptions, thoughts, feelings, and, to some degree, their overt behavior.” He observes that culture manifests itself at three levels. The deepest level is the tacit assumptions that are the essence of the culture. The middle level is that of espoused values that often reflect what a group wishes ideally to be and the way it wants to present itself publicly. Finally, there is the outer level, which is the day-to-day behavior that represents a complex compromise among the espoused values, the deeper assumptions, and the immediate requirements of the situation. Culture serves to integrate the people within an organization such that the assumptions, values, and behaviors are uniform throughout the organization resulting in “The way we do things around here.”

The organizational culture literature focuses on the culture of the overall organization. However, this may obscure significant differences between sub-cultures in the organization. In his review of organizational culture, Cooper (2000) observes, “… although an organization may possess a dominating ‘cultural theme’, there are likely to be a number of variations in the way in which the theme is expressed throughout the organization.”

Schein (1996) recognizes the presence of subcultures within an organization. He postulates there are three subcultures, executive, engineer, and operative and characterizes them as occupational communities. Schein asserts that the executive and engineering cultures arise, to a major degree, from outside the organization. For engineers, the shared assumptions are based on common education, work experience, and job requirements. For executives, the assumptions result from the executive’s focus on maintaining the financial survival and growth of the organization and association with others facing the same challenges. In contrast, Schein postulates that the operator culture arises from within an organization because the technology and work processes employed by the organization are specific to that organization.

The construction industry constitutes an exception to the belief that the operator culture is local. In manufacturing and other industries, technology is always in flux and varies between firms in the same industry. Technology in construction is relatively stable with little variation between firms. Consequently, craft workers can move between employers with little or no learning curve because of their global culture.

Meyerson and Martin (1987) assert that culture, rather than integrate, may differentiate. This perspective is based on the lack of consensus between interpretations, experiences, and assignment of meaning in organizations. Differentiation can be on any basis: education, age, gender, occupation, suffered an injury, geographic location, profession, etc. Schein (1996) illustrates the differences between subcultures with examples of the assumptions h.eld by different groups. For example, he observes that “Engineers are proactively optimistic that they can and should master nature” while operators assume that “No matter how carefully engineered the production process is or how carefully rules and routines are specified, operators must have the capacity to learn and deal with surprises.” Grote (2004) recognizes this distinction in terms of managing uncertainty versus coping with it.

SAFETY CULTURE

Safety culture is a sub-facet of organizational culture in which shared values, beliefs, and assumptions influence workers’ behavior (Schein, 1992). It refers to an organizations “culture of safety” or those “cultural influences impacting safety” (Hale, 2000). Descriptions of safety culture in the literature tend to focus on the way people think and behave within a specific context (Cooper, 2000). This focus has created some confusion about the use of the terms “culture” and “climate” (Hale, 2000). Although the terms “safety culture” and “safety climate” are sometimes used interchangeably, the distinction between the two is important. Safety culture is a relatively stable and enduring phenomenon whereas climate is transient and thought to reflect the safety culture at a particular point in time (Guldenmund, 2000). Safety culture is viewed as the underlying norms, beliefs, commitments, and values that relate to how safety is practiced over time (Glendon & Stanton, 2000; Glendon, 2006). In contrast, safety climate refers to perceptions of how safety is practiced at a particular moment in time (Mearns, Whitaker, & Flin, 2001) within a particular context (Cooper, 2000).

Safety practitioners and academics have shifted their attention over the past two decades from engineering approaches to human and organizational elements. This shift is based on attempts to understand the influence that management systems and managerial practices exert on industrial safety (Hale & Hovden, 1988). Management influence is encapsulated in the concept of safety culture first put forward by the IAEA (1991) report released after the Chernobyl disaster. Safety culture can be a positive factor, reinforcing and supporting safety considerations at all levels of a construction worksite. Conversely, safety culture can also be a negative factor, such as when a culture places productivity ahead of safety and/or tolerates employee injuries as an inevitable part of construction.

Based on work by Cooper (2000), safety culture is conceptualized along multiple dimensions or perspectives. These dimensions include *behavioral* dimensions related to "what people do" regarding safety-related actions and behaviors; *safety management* dimensions such as "what the organization has" regarding policies, procedures, structures, and management systems; and *psychological* dimensions such as "how people feel" concerning individual and group values, attitudes, and perceptions about safety climate. These relate to the sociotechnical subsystems of personnel (how people feel), technological (what people do), and organizational (the policies and practices that provide the situational context which drive people's behavior.

Construction worksites with positive aspects on all three of these safety culture dimensions should have better safety outcomes than construction worksites with negative safety cultures. Typically, accidents, injuries, and fatalities are not chance events, nor can they be thought of in purely technological terms (Pidgeon, 1997). Instead, safety events arise from the interaction between human and organizational factors that comprise the sociotechnical systems in place to control adverse events (Pidgeon, 1997; Turner, 1976, 1978; Turner & Pidgeon, 1997). Human and organizational factors shape and are influenced by the safety cultural norms and beliefs in a reciprocal manner (Cooper, 2000). Safety beliefs and norms may be formally prescribed in policies, procedures, practices and rewards (Schneider, 1975). These norms may also be taken for granted and embedded in cultural practices within particular crafts (Cooper, 2000; Pidgeon, 1997).

OCCUPATIONAL COMMUNITIES

Van Maanen and Barley (1984) define an occupational community as: "a group of people who consider themselves to be engaged in the same sort of work; who identify (more or less positively) with their work; who share a set of values, norms, and perspectives that apply to, but extend beyond, work related matters; and whose social relationships meld the realms of work and leisure." They define four features of an occupational community (OC). First, an OC is composed of people who consider themselves "to be" members of the same occupation rather than people who "are" members of the same occupation. Second, the social identities assumed by most members include, in a prominent position, one based on the kind of work they do and, as such, it is often quite central in their presentations of self to others (particularly to those outside the community). Third, members take other members as their primary reference group such that the membership comes to share a distinct pattern of values, beliefs, norms, and interpretations for judging the appropriateness of one another's actions and reactions. Fourth, the blurring of the distinction between work and leisure activities, which occurs when leisure activities are connected to one's work or when there is extensive overlap between work and social relationships.

Members of occupational communities may be self-employed or may work for an organization. When employed within an organization, the culture of an occupational community is a significant factor in the performance of its members. A critical cultural issue is that of control of the work process, which refers to the occupational community's ability to dictate how the content and conduct of a member's work will be assessed. Van Maanen and Barley (1984) observed that occupational communities are premised on the belief that only the membership possesses the proper knowledge, skills, and orientations necessary to make decisions as to how the work process is to be performed and evaluated. Control over who enters the community and how an individual can progress in the occupation are central issues.

The above description of the features of an occupational community closely describe construction craft workers, who a) are members of a group that undergoes a significant socialization process; b) acquire a set of skills and technological capabilities necessary to perform a set of tasks that are readily transferable between employers; c) constitute an area pool of labor from which employers draw based on need; and d) have a relatively transient employment relationship with any specific employer. As Stinchcombe (1959) further states, "In construction all these characteristics of the work process are governed by the worker in accordance with the empirical lore that make up craft principles. These principles are the content of the workers' socialization."

Lave and Wenger (1991) observe that individuals become members of a "community of practice" by learning the norms and appropriate values and behaviors as they participate in the activities of the group. Participation in occupational communities leads to situated work practices and different domains of knowledge (Bechky, 2003; Boland & Tenkasi, 1995), leading to distinct interpretations of organizational [and safety] cultures (Schein, 1996). As construction workers are socialized into various crafts, it is likely that distinct, differentiated subcultures may develop that carry over into construction project sites (Martin, 1992, 2002).

CONSTRUCTION PROJECTS: SITES FOR OCCUPATIONAL COMMUNITIES

A typical construction project has numerous contractors and their employees on the site at various times and for varying durations. Contractor project organizations are comprised of individuals from the following groups:

- Permanent core organization consisting of executives, engineers, professionals, etc. who have varying lengths of tenure with the organization but are considered as permanent employees
- Quasi-permanent project management teams consisting of project managers, engineers, superintendents, etc. who are responsible for getting a project built within specified criteria
- Temporary supervisory personnel who typically come from the craft they supervise
- Craft personnel hired on an as needed basis for the project

Each of these levels may contain one or more occupational communities.

Although improving safety performance in construction requires organization-wide effort, we focus on the workface (where the actual work is performed and the injuries and fatalities occur) and the craft workers performing the work.

CONSTRUCTION CRAFT WORKERS

Any analysis or study of culture must be related to the specific work setting, production tasks, and organizational context. Construction craft workers acquire their knowledge, skills, and abilities through a combination of off-the-job training such as technical and/or vocational schools, apprenticeship programs, etc. and on-the-job training working under the direction of skilled, more experienced workers on a series of projects. Through this technical socialization, the budding craft worker learns the customary ways of doing things; how much to produce; how to dress, behave, communicate, etc; and basic beliefs about the craft through interaction with other members of the same craft. Riemer (1979) examines the life of construction workers with a focus on the socialization process by which an individual becomes a construction craft worker. This process begins early for many individuals because of family ties to the industry, continues through school and pre-industry training, formal off-the-job training, and day-to-day on-the-job training. It culminates in the worker fully identifying himself as a construction craft worker with the craft being very specific such as carpenter or electrician.

Stinchcombe (1959) states "Mass production may be defined by the criterion that *both* the product and the work process are planned in advance *by persons not on the work crew.*" In the construction craft organization, the designer defines the product while the craft workers who will perform the work plan the work process, including the following elements:

- The location at which a particular task will be done

- The movement of tools, of materials, and of workers to this work place, and the most efficient arrangement of these workplace characteristics
- Sometimes the particular movements to be performed in getting the task done [*This would include how to perform the task safely*]
- The schedules and time allotments for particular operations
- Inspection criteria for particular operations (as opposed to inspection criteria for final products)

As noted above, a construction contractor's project organization consists of two categories of employees: those with a relatively permanent attachment to the contractor and those with a temporary attachment, typically the life of the project. Individuals with a permanent attachment to the contractor will influence and be influenced by the prevailing culture of the contractor's core organization. This culture reflects the subcultures of the executives and engineers of the firm. There may be small variations between the cultures of each of the contractor's projects, but there is a prevailing culture for the contractor's overall organization. At this [organizational] level, Stinchcombe (1959) observes that members often possess a strong culture, which leads us to the notion of organizational culture.

SAFETY CULTURE DEVELOPMENT

How does safety culture develop within an occupational community? Gherardi and Niicolini (2000) view safety as "the result of practices shaped by a system of symbols and meanings that orient action…an emerging property of a sociotechnical system, the final result of a collective process of construction, a "doing" that involves people, technologies, and textual and symbolic forms assembled within a system of material relations." The authors further state that "Safety knowledge is…culturally mediated by forms of social participation, material working conditions, and the negotiated interpretations of action on-site. Safety knowledge…is dynamic and profoundly rooted in communities of practice, and it is historically situated in their cultural heritage." Thus, safety knowledge develops from the interaction of individuals in the performance of tasks and is passed on to members of the community through various socialization processes. Reimer (1979) provides excellent descriptions of these socialization processes.

Workers performing a particular set of tasks may be organized into a union, which provides a formal framework for the establishment and maintenance of an occupational community. Union members have increased opportunities to work with one another, thereby getting to know one another. Apprenticeship programs provide the means for socializing new members into the community. Formal and informal social activities provide further opportunities to strengthen the culture of the community. Unorganized workers have fewer and less formal means for community development. Whether union and nonunion pipefitter welders consider themselves to be in the same community is an empirical question.

SAFETY CULTURE AND TECHNIOTECHNICAL SYSTEMS

Grote (2000, 2004) examined safety culture from a sociotechnical perspective and looked at two assumptions: (1) that the technical and social subsystems of a work system need to be jointly optimized to allow maximum efficiency in the accomplishment of the system's primary task and (2) that a crucial criterion for joint optimization is the system's ability to control variances at their source. She argues that a high degree of self-regulation of work teams is beneficial to safety. Consistent with the sociotechnical approach, she finds that tasks allowing for a high degree of autonomy, task completeness, and task feedback will further an individual's intrinsic motivation. She cites Grote and Kunzler (1996) found that higher degrees of job autonomy were related to a stronger emphasis on the human as a risk factor and Leplat (1987) found a link between autonomy and taking over (safety) responsibility. Thus, Grote illustrates the engineer vs. operative issue as one of minimizing uncertainty (the engineer) vs. managing uncertainty (operative).

Stinchcombe (1959) in a comparative examination of approaches to work observed that in the bureaucratic approach to work, e.g., manufacturing, the design of the product and of the work process are done by persons not involved in the work process whereby in the craft approach of construction, the designer designs the product while the people who will do the work, to a large degree, design the work process. This design includes its safety elements. Thus, the construction craft worker's job design reflects his/her safety culture.

Grote's identification of the relationship between a high degree of autonomy, task completeness, and task feedback and an individual's intrinsic motivation is reflected in the work of Hackman and Oldham (1975) and their development of the Job Diagnostic Survey. They created a Motivating Potential Score as a function of Task Autonomy, Task Feedback, and the mean score of Skill Variety, Task identity, and Task Significance. A perception of high task autonomy should be reflected in the safety culture. The actual amount of autonomy a worker perceives that he has in his job and the amount of autonomy he believes he needs to do his job safely are relevant to safety culture. One way in which these various facets of safety culture may be manifested and spread are through communication practices.

COMMUNICATION, SAFETY, AND OCCUPATIONAL COMMUNITIES

Although important, relatively little attention has been paid to the significance of communication in relation to safety culture. Communication is crucial to the process of organizing (Weick & Sutcliffe, 2007), organizational culture (Keyton, 2005), and occupational safety in general (DeJoy, et al., 2004; Mearns, Whitaker and Flin, 2003; Real, 2008). Bechky (2003) notes that variations in cultural practices between occupational communities are often rooted in differences in language as well as locus of practice and views of the way in which construction work is performed. Understanding communication in relation to safety culture and occupational communities is important for at least three reasons.

First, communication can explain the spread of safety culture across a project site. Understanding the flow of safety messages, information, and cultural practices through social networks can help safety researchers and practitioners understand how safety culture develops. In social network terms, 'network contagion' refers to the spread of shared ideas, attitudes, culture and practices through interactions (Krackhardt & Kilduff, 2002). As Borgatti and Foster (2003) note, the spread of an idea or practice is a function of interpersonal communication. Actors in the network influence each other in ways that can lead to increasing similarity within specific groups or cultures. Similar to the notion of communities of practice (Wenger, 1998), actors may adopt certain practices as a function of the proportion of other actors to which they are tied have adopted these same practices (Borgatti & Forster, 2003). These ideas fit within notions of cultural knowledge in which practices are manifestations of culture. For example, Gherardi, Nicolini, and Odella (1998), in a study of a construction project, found that there can be as many safety cultures as there are communities or practice: "Dispersed communities have diverse and non-overlapping organizational information, world-views, professional codes, organizational self-interests, and different interpretations of what is happening, why it is happening, and what its implications are.   The spread of safety culture in a particular construction site may be related to the extent that workers are linked through and communicate in networks, communities of practice, and occupational communities.

Second, it is crucial that project leadership understand the importance of developing strategic safety communication with the values and assumptions of the various occupational communities in mind. An important implication of this may be that safety practices are not a function of safety communication but more likely embodied in the everyday practice of work (Gherardi et al., 1998). From this perspective, safety is not just an outcome of attitudes and perceptions (i.e., safety climate); indeed, safety is shaped by cultural practices that arise from the everyday work and communicative practices of craft workers (Scott & Tretheway, 2008). Because construction work is often different every day for craft workers, is is important to highlight the role of everyday talk in safety culture in occupational communities. In some groups, hazards are minimized in actions (e.g., not wearing safety harnesses when working at heights) and also in talk. For example, with the dominant discourse among construction workers being 'masculine', research has found that teasing and other sorts of male-based interaction can reduce workers willingness to don protective personal equipment (Scott & Tretheway, 2008). Moreover, other research has indicated a need to account for organizational hierarchy when accounting for workers' willingness to find safety information (Real, 2008).

Third, communication can play an important role in making sense of occupational identities within communities and the manner in which identity shapes safety behaviors. How construction workers talk and how this talk frames safety is linked to identity. Managing a sense of self through membership in an occupational communication is tightly linked to making sense of risk and hazardous work. Craft workers not only evaluate hazards in terms of material features but also through a lens of identity which is linked to what it means to be an authentic member of an occupational community (Scott & Tretheway, 2008). Identity is not only created through a cognitive and emotional sense of who one is, it is also produced and reproduced through language and interaction (Scott, Corman, & Cheney, 1998; Giddens, 1991). As such, membership in occupational communities has an influence on individuals' safety behavior. Moreover, occupational communities, because of their distinct identity-laden nature, operate to shape the safety culture of a given construction project.

IMPLICATIONS OF OCCUPATIONAL COMMUNITIES

Construction project organizations are not monolithic organizations. Even the organization for a the construction of a large project such as a nuclear power plant that is to be constructed by a single contractor consists of multiple occupational communities: project management, project controls personnel, quality assurance/quality control personnel, field supervisors, professional safety representatives, electricians, carpenters, etc. From a safety culture perspective, it would be desirable to have a single, integrated safety culture for the project, but that will not likely happen. A community's safety culture lies at its core and consists of the shared assumptions, beliefs, and values of its members. For example, professional safety specialists may assume that because of their specialized training, they are the most qualified persons to determine how to perform a job safely. Similarly, craft workers performing specific work may assume that their experience in performing the work makes them the most qualified individuals to determine safe work procedures. In developing project safety plans, it is important to remember that each occupational community has a safety culture and the manifestations of that culture.

An occupational community may have a geographic boundary, which is typically defined as the relevant labor market for the craft or the profession. Local construction unions in the United States are granted geographic jurisdictions by their national union. For some unions, that jurisdiction is a specified set of counties while for other unions the jurisdiction may be defined as an entire state. For executives and professional staff, the labor market may be national or even international.

Given the nature of the construction industry, occupational communities are not confined to specific firms; the community's safety knowledge and safety culture are based upon the community's work in a geographic area and/or industry. For example, the safety knowledge and safety culture of pipefitters working at an Exxon refinery in Baton Rouge, LA is not limited to that refinery, but is valid for work at petrochemical facilities along the Louisiana/Texas coast. If we consider the strength of an occupational community's safety culture to be represented by the standard deviation of the mean safety culture score, we can say that the smaller the standard deviation, the stronger the safety culture. We can postulate that there is an inverse relationship between the homogeneity of the membership of the community and the strength of the community's safety culture.

In the United States, until approximately forty years ago, membership in a local construction union was basically a closed system. Almost the entire membership of many local unions was drawn from a specific ethnic group, e.g., Irish bricklayers in Philadelphia or Italian stonemasons in New York. Sons, nephews, and cousins followed their relatives into the trade. Many members lived within the same geographic area and socialized with one another. Absent family connections, membership was gained through referrals from members of friends and neighbours. The result was a strong homogeneity and shared culture within the occupational community.

Since the late 1960s, homogeneity in the local construction unions has decreased because of two factors: (1) an increasing percentage of tradesmen want their relatives to become engineers, lawyers, and business managers rather than working in the trades and (2) government pressures to diversify the trades by opening up membership to women and other underrepresented groups. The community will still have a safety culture.

A subset of the community's membership, not necessarily representative of the membership, will be employed on a particular project. It is important that the community's safety culture be reproduced on that project. A simple way of explaining culture is that "It is the way we do things around here." Workers need to have confidence that their fellow workers will react and behave in specific ways in particular situations. A consistent safety culture will facilitate this confidence. Workers who react to situations in unexpected ways represent hazards.
Once the culture is reproduced, it is imperative that it be maintained. Construction projects are of varying durations and a project's workforce may change significantly over the life of the project, particularly for long-term projects. Younger and less experienced workers may replace older, experienced workers. Women may replace men. Workers from outside the normal geographic region of the occupational community may replace members from within the region. This may result in a weakening of the safety culture as the replacement workers may have had different experiences and associate different meanings with situations and have different beliefs and values. For example, women may experience situations very differently than men. When faced with a particular situation that requires the assistance of another person, a man may believe that asking for assistance may be against his "macho" image of himself while a woman fully realizes the need for assistance. Similarly, a worker who has been injured on the job may perceive a situation differently than a person who has not been injured.

An occupational community has an unequal reciprocal relationship with its environment; the community's external environment has a greater impact on the community than the community has on its external environment. Alvesson (2002) created the term "cultural traffic" to represent the flow of people and ideas across a unit's boundaries. People crossing the boundary into the unit bring their experiences and associated meanings, beliefs, and values with them. Interaction with community members results in sharing such that individuals may reassess these meanings, beliefs, and values. As a consequence, there may be an incremental change in the unit's safety culture.

Cultural traffic is not limited to the movement of people across the community's boundary. The flow of information is equally, if not, more important. Interaction with people outside the community provides opportunities for exchange. This may occur when working for a contractor who employs a different safety management system. It may also occur when working in a different part of the country within a different occupational community having a different safety culture. Information and messages may be conveyed through the media. Anti-smoking groups have used social marketing very effectively to reduce the percentage of the population that smokes cigarettes. Articles in industry publications have transmitted messages about safe work practices and safe work environments. Professional organizations such as the American Society of Safety Engineers and the National Safety Council have led efforts to change how one thinks about safety. Contractor, union, and consultant programs have been conducted to provide knowledge and change thinking about safety.

In spite of the significant volume of cultural traffic, occupational communities must maintain their safety culture for stability. Change, when perceived as necessary, will be evolutionary rather than revolutionary. Radical, rapid change results in turmoil and a lack of understanding as to how things should be done. When that happens, accidents and injuries occur.

An understanding of occupational communities is important in its own right, but the interaction of occupational communities is even more important for the construction industry. In a typical construction project (If there is such a thing) an owner enters into a contract with a general contractor to build a specified design. The general contractor does not perform all the work with his own forces. Instead, approximately 80-85% of the work is performed by subcontractors and their employees. These subcontractors are trade or specialty contractors such as electrical, plumbing, masonry, etc. Each of the specialty contractors will have one or more occupational communities represented in their workforce.

In accordance with the United States' Occupational Safety and Health Act as well as the United Kingdom's Construction and Design Management Regulations, the general (or prime) contractor is responsible for safety on a multiemployer construction site. In accordance with Schein's (1996) classification, the firm's executives, project managers, and operators would each constitute a separate occupational community. At the project level, the general contractor's project management team develops and implements its safety management system. When a subcontractor comes to work on the project, the occupational community of the subcontractor begins to interact with that of the general contractor.

Safety culture is a long-term, enduring phenomenon while safety climate reflects that culture at a point in time. What happens when two occupational communities interact? Because of its nature, safety culture is unlikely to change. Instead, a community's safety climate is more likely to change. There are three potential scenarios for this interaction: (1) each of the community's will maintain its own safety climate independent of the other, (2) one or both of the communities will adapt its safety climate as required by the situation, and (3) one community adopts the safety climate of the other. Which of these scenarios is chosen?" It depends upon two factors: (1) the power of one party relative to the other, (2) the duration of the interaction, and (3) the nature of the project.

A general contractor, for a variety of reasons, may decide to allow the subcontractor to maintain its own safety management system as long as safety performance is acceptable. If that performance is unacceptable, the general contractor may decide that it is necessary to require changes in the safety management system. At the opposite extreme, a general contractor may exercise power by including his firm's safety management system as an element in the general and supplemental conditions of the project's contract. Between the two extremes, adaptation is the rule. The dictionary defines adaptation as "adjustment to environmental conditions" (Merriam-Webster 2003). This does not mean that one party surrenders to the other. Adaptation can simply mean aligning one's safety management system with that of the general contractor. It can also mean negotiating a safety management system that is acceptable to both parties, one that requires changes on the part of both parties.

The second factor influencing adaptation is that of duration of the interaction. The longer the interaction (i.e., the longer the duration of the firm on the project), the more likely adaptation will be the approach chosen. On relatively short duration projects, subcontractors and their occupational communities may retain their own safety management systems. On long-term projects, the likelihood is that there will be one SMS. Lastly, the nature of a project (for example, work on operating oil refineries or nuclear power plants) may dictate that there must be one safety management system employed on the project.

OCCUPATIONAL COMMUNITIES RESEARCH ISSUES

With more and more attention being paid to safety culture, it is crucial that researchers develop a much better understanding of occupational communities, their safety cultures, and the influence that they have on a project's safety culture. This will require researchers to address several issues.

A fundamental issue that must be addressed is the degree to which construction organizations should be designed as mechanistic or organic systems. Grote (2004) has examined this issue in terms of uncertainty: design it out (mechanistic) vs. coping (organic). Research questions include which system provides the best safety performance as well as overall project performance; what are the characteristics of the workforce necessary for the success of each of the systems; and how should management systems be designed.

Management's desire is for an accident-free project. To achieve this, management must be able to influence the safety culture(s) on the project site, which will require management to understand how safety culture develops within an occupational community. This will require the identification of the factors taken into account; the roles are performed; who performs those roles; how new community members socialized regarding safety culture; gender; language issues; etc. With this knowledge, management can identify opportunities to influence the safety culture of a community, design change strategies, and implement those strategies. Management's goal is the alignment of the safety culture of the various occupational communities with that of management.

Management must have an understanding of how safety culture is reproduced on construction projects: who plays what roles; what actions or behaviors are undertaken; what role does communication play; and where the opportunities for management to influence the process are. Similarly, management must understand how safety culture is maintained.

Lastly, management must have an in-depth understanding of cultural adaptation to design cultural change processes. Achieving an accident-free project requires alignment of the safety cultures on a project site.

Improving safety performance on a construction project is going to require project's managers to manage the safety culture on the project. To do this will require project management to have an in-depth understanding of occupational communities and their safety culture. This will require a broad research program to provide management with the necessary knowledge.

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OPERATIVE EXPERIENCES OF CULTURAL DIVERSITY ON AUSTRALIAN CONSTRUCTION SITES – IMPLICATIONS FOR SAFETY AND WELL-BEING

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ABSTRACT

Australian construction sites are complex multicultural workplaces which present unique challenges for managing occupational health and safety. By surveying 1155 construction operatives on Australian construction sites and investigating the extent of cultural diversity and how it is experienced by operatives, this paper reveals significant negative sentiment towards diversity and inter-cultural behaviour which expose migrant workers and those around them to significantly greater safety risks.

Keywords: Diversity, Culture, Immigrants, Safety

INTRODUCTION

Around 20 per cent of all workers in the construction industry are overseas born and half of those were from non-English speaking counties (DIAC, 2009). This multicultural demographic is one of the defining characteristics of the construction industry and a considerable amount of research has been undertaken into the managerial challenges that this poses to a range of issues such as productivity, workplace harmony and safety (Ofori, 1994; Loosemore and Muslmani, 1999, Debrah and Ofori, 2001, Loosemore and Lee, 2002; Loosemore and Chau, 2002). However, despite the insights provided, there has been no research into the fundamental issues which underpin these challenges such as: the extent and nature of cultural diversity on Australian construction sites; the cultural groupings on Australian construction sites and their positive and negative functions; attitudes about cultural diversity and the implications this has for worker well-being and safety. The aim of this paper is to address these issues.

LINKS BETWEEN CULTURAL DIVERSITY AND SAFETY

Loosemore and Chau (2002) found that 40 per cent of Asian-Australian operatives had experienced workplace discrimination on Australian construction sites. More recent research indicates that construction workers of non-English speaking background are exposed to significantly greater safety risks than other workers and can expose other workers to higher safety risks because of their poor training and, inability to understand basic instructions and warning signs (Loosemore and Lee, 2002; Trajkovski and Loosemore, 2005; Loosemore and Andonakis, 2006). Indeed, the Australian Bureau of Statistics reveals that injuries to foreign-born workers account for about 29% of all "documented" occupational injuries, the vast majority occurring in labour-related occupations where migrant employment is strongest (WorkCover, 2005; ABS, 2005). There is an emerging consensus that negative experiences like racism and discrimination is associated with morbidity, especially mental health issues such depression, stress and anxiety (Paradies, 2006;

Williams et al., 2003). Examples on a construction site would be – for example – race hate talk as contrasted with unsatisfactory translating and interpreting systems. Mental health issues are recognised as an increasingly substantial component of future disease and ill-health in Australia (Begg et al., 2007) and Nicholas et al. (2001) revealed the links between the experience of racism and lower individual productivity within workplaces. The Equal Opportunity Commission in NSW (EOC NSW) estimated in the late 1990s that seventy per cent of workers exposed to racism would as a consequence take time off work and staff turnover has also been linked to experiences of racism and discrimination (Blank et al., 2004).

METHOD

Questionnaires were distributed by hand on twenty-eight construction sites in the Sydney metropolitan area, as well as in the offices of the Construction, Forestry, Mining, and Energy Union (CFMEU). These sites were chosen because of the size and high cultural diversity of those workplaces and because of high union representation which was important in securing trusted access to respondents. Where necessary the survey was translated into several languages (Korean, Mandarin etc) for non-English speaking background (NESB) workers and respondents were also permitted to openly discuss their views resulting in rich anecdotal data which provided further insights into the issues being investigated.

1155 surveys were returned in usable form and the sample structure is shown in Table 1.

Table 1: Respondent demographics

		Percent
Gender	M	99.7
	F	0.3
Age	under 18	0.7
	18-34	42
	35-54	46.9
	55-64	9.6
	65 & over	0.9
Education	No schooling	1.6
	Primary	6.6
	Secondary	82.7
	Bachelors degree	7.7
	Postgraduate	1.3
Birthplace	Australia	46.8
	Non-English Speaking Country	39.9
	English Speaking Country	13.3
Language other than English	YES	57.16
	NO	42.84
Religion	Christian	70.8
	Islam	6.2
	All other beliefs	3.3
	no religion	14.8
	inadequately described	4.8
	don't know	0.1

DISCUSSION OF RESULTS

In terms of cross cultural interaction, almost 31 per cent of respondents reported that they did not make an effort to interact with other groups. The vast majority of interaction that does occur is in the context of work related activities rather than socially. Despite this somewhat negative picture, 63.8 per cent of the respondents indicated that they would like to see more opportunities to mix with people from other ethnic groups while at work. When asked about their perceptions of other groups, the majority of respondents were comfortable with working with people of different ethnic groups (87.85 per cent). A considerable percentage of respondents (32.35 per cent) think that different ethnic groups should stay away from each other.

More than half of the respondents were able to speak a language other than English. Mandarin and Cantonese (9.4%), Croatian (8.56%), Portuguese (8.4%), Spanish (7.01%), Serbian (6.31%), Arabic (6.03%) and Bosnian (5.75%) were the most commonly spoken languages other than English. Despite this high degree of cultural diversity, the vast majority of the respondents (88%) stated that they did not experience any difficulties in reading and understanding English. Those workers who experienced language difficulties were mostly of a non-English speaking background (NESB). Most of the non-English speaking background migrant workers (73 per cent) indicated that they were competent in reading English despite the fact that some of them experienced serious difficulties in understanding and reading the questionnaire without assistance. Of course the 27 per cent who were not able to claim English language competency do constitute a group with significant communication issues.

Operative comments reveal that language barriers, and low English proficiency among certain groups, are thought to have direct impacts on safety. This issue was raised by many workers.

> *Cultural diversity is a good thing for construction sites, yes but need to speak and understand English for safety aspects (Questionnaire #**334**).*

> *People should be able to read English when working on sites to read safety notices (Questionnaire #**373**).*

This adds further weight to previous research which showed that language differences affect migrant workers' understanding of safety risks on construction sites (Trajkovski and Loosemore, 2006; Loosemore and Lee, 2006).

After referring to the language barriers between English speakers and Asian workers, one worker mentioned the ineffectiveness of greencard training: *"During greencard training they are simply giving the right answers to them. They don't learn anything, so that they don't know anything about safety rules"* (*Verbal comment, Field diary, September 2008, Large scale hospitality project, Sydney*). In field observations of Greencard workshops we recorded how the lecturer or trainer simply read notes. The structure of the workshop was difficult to follow. Even for English speakers it was thought difficult to understand the contents and to follow the trainer. For non-English speakers it would be tremendously difficult to understand the content. If requested by workers an interpreter is provided during workshops. However, it is not at all clear whether these people were always qualified interpreters. These findings reflect similar problems with Greencard training for NESB workers reported by Trajkovski and Loosemore (2006).

In gauging operative attitudes towards cultural diversity, almost 88 per cent of respondents were of the view that cultural diversity is good for society and the construction industry. The majority of respondents reported that they like working with people of different ethnic groups (87.9 per cent) while 82 per cent said they felt secure when they work with different ethnic groups. However, support for cultural diversity is not consistent and is context dependent. Almost a quarter of operatives reported that some groups do not work well together and 50 per cent of respondents indicated that there are groups that they do not like to work with. Multilingual speakers were more likely to be tolerant towards other groups. For example, there is a widespread belief among workers that Lebanese-Australians- have a different work culture reflected in their aggressive behaviour. The issues pertaining to Asian-Australians are different. There is a too common belief among workers that Asian-Australians dramatically reduce safety standards, wages and professional quality. For instance,

> [*as a response to question on whether different ethnic groups work well on sites] not always, Chinese are paid less wages than us. They reduce the wages overall. And when they are paid less, they don't do the job in a safe way. In the construction industry it is the biggest problem now, Chinese get low wages, reduce the safety standards. Their bosses pay less to them and in turn don't pay that much attention to safety standards (Verbal Comment, Field diary, November 2008, Large scale residential development, Sydney), .*

The assertion in the above quotation about uneven pay-rates is difficult to judge as to its reality. Uneven pay on the basis of ethnicity is illegal in Australia, although it is conceivable that pay-rates might be uneven depending on whether a worker is a permanent resident or guestworker, Nonetheless, the majority of respondents believed that there is equality of opportunity in the construction industry (71.11 per cent).

When asked about the different types of ethnic and cultural intolerance that are most prevalent on construction sites, the vast majority of the respondents (90.4 per cent) reported that they did not experience any physical threat at work. Our findings reveal that offensive graffiti and joke telling are the most common forms of racial harassment. Half of the operatives indicated that they had made derogative jokes about people of different ethnic backgrounds, although it was more common among younger workers.

> *We are sometimes racist without even noticing it. The jokes sometimes take a different turn. There are no clear lines between racist and non-racist behaviours. Racism is not black and white. Sometimes the jokes I make are racist. But I don't know that, the others are warning me and telling me that those are racist jokes. Sometimes other people make jokes not with a racist intention. But sometimes those jokes are too racist (Verbal comment, Field diary, December 2008, Large scale commercial development, Sydney).*

These data accord with international research that highlights how racism is most often manifest in these everyday forms (Essed, 1991). National survey research in Australia has empirically demonstrated that race hate talk is the most common form of racism, followed by exclusionary forms, discrimination and then physical attack (Dunn et al., 2009).

CONCLUSION

The aim of this paper was to examine the nature of cultural diversity on Australian construction sites, how it is experienced by workers and the implications for worker well-being and safety. Our key findings are that the vast majority of workers are comfortable with cultural diversity and think that it works well. However, they simultaneously perceive homogeneity to work well. The majority of people seem to interact with other ethnic groups during social situations and work-based activities suggesting that there is a good deal of cross-cultural interaction on construction sites. However, there are perceived barriers to interaction on sites for some workers particularly those of Asian ethnicity. Our work also shows that while ethnic groupings present organisational challenges for managers they also perform positive functions such as maintaining positive bonds among group members, group support and induction, and providing a sense of group safety. There is a general desire to see more opportunities to mix with people from other ethnic groups while at work and there is a wide-spread opinion that language barriers have a detrimental impact upon safety on construction sites. Finally, while the majority of respondents believe that there is equality of opportunity in the construction industry, there is evidence of racist acts and experiences, most prominently manifest as offensive graffiti and joke telling which could negatively impact upon worker well-being. Asian-Australians are seen as especially subjected to these forms of inequality, including uneven access to higher paying jobs. The next stage of this project will consider how these issues are currently managed on construction sites and how they can be managed more effectively to ensure that current and future influxes of foreign workers into the construction industry can be sustained in a safe, productive, efficient and harmonious way.

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FACTORS THAT INCREASE HEALTH AND SAFETY RISKS FOR MIGRANT CONSTRUCTION WORKERS

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ABSTRACT
The use of migrant workers in construction has become a particularly controversial topic in recent years, not least due to their exploitation and distinct lack of management, which many experts feel has created the most dangerous construction working conditions for a decade. The government's decision to open its migration gates to the Central and Eastern European accession states in 2004 has led to an influx of migrant labour of a level never previously experienced by the UK construction industry. This labour has undoubtedly helped to fill many of the skills shortages; however it has also provided fresh management challenges that the industry so far has failed to take responsibility for addressing. Factors that combine to produce increased health and safety risks for migrant workers compared to those experienced by indigenous workers are easily identified. Yet it seems the industry is taking only minuscule steps in controlling such factors and, with the London 2012 Olympic Project deadlines nearing ever closer, it would appear that an unprecedented number of migrants will be forced to deal with these health and safety issues in the coming years. The research aim was to determine whether migrant construction workers are exposed to greater health and safety risks when compared to indigenous workers, exploring possible reasons and proposing improvements in the management of migrant workers by contractors. A combination of data collection instruments was used, including interviews with migrant workers and health and safety experts, employer surveys and an analysis of classified accident records. These principally highlighted that additional health and safety risks faced by migrants are as a result of both poor site management and the nature of work that migrants predominantly undertake on site.

Keywords: Factors, Health, Migrant workers, Risks, Safety.

INTRODUCTION
Recent industry reports, including the IPPR (Institute for Public Policy Research) report Building *a New Home: Migration in the UK Construction* Sector (2008) highlighted the recent trend of A8 nationals taking up work in the UK construction industry. Evidence researched by the IPPR suggests that the numbers of migrant workers (foreign nationals who have arrived in the past 10 years) in construction increased from around 18,000 at the end of 2000 to around 93,000 at the end of 2007. The scale of migratory flows into the industry is clearly increasing rapidly. It is therefore unsurprising that the proportion of migrant workers in relation to all UK construction workers has seen a percentage increase over the same period. Although, this is a rise from a very low level - as IPPR's statistics show. In 2000, around 3 per cent of the total construction workforce comprised migrant workers and by the end of 2007, this figure had grown to 5.8 per cent (Chappell *et al*, 2008)

Recently released figures indicate the extent to which migrant construction workers will continue to play a pivotal role in the realisation of many UK construction projects in the next three years. The construction industry's low skill barrier of entry has attracted many migrant workers with no previous construction background to take up employment in what are often low-skilled, high-risk positions. As the UK sets itself to host the 2012 Olympics in London, it has emerged that 20,000 migrant workers registered for jobs in the main 2012 borough in the past year (Beard, 2008). The IPPR compares the construction of the 2012 Games with the 2004 Athens Games, when 60 percent of the 30,000 workers who built the facilities were not from Greece. It also looks very likely that Olympic bosses will rely heavily on hiring in foreign construction workers in the final months leading up to the start of the games to ensure the facilities are built on time. This is a particularly dangerous time on construction sites as corners will inevitably be cut wherever possible to save time. With the migrant's often limited experience of the UK construction sector and temporary nature of work, this scenario will place a massive threat to their health and safety.

The UK construction industry's health and safety record continues to be the focus of critical attention. Between April 2005 and March 2006, five migrant workers were killed in the construction industry in Britain. In the following year (between April 2006 and March 2007), a further five migrants were killed (HSE 2007). A recent *Contract Journal* poll showed that 97 per cent of readers believed that immigrant construction workers were not sufficiently aware of a site's health and safety issues (Keane 2007).

October 2007 saw the release of more worrying statistics, as the Health & Safety Executive (HSE) told how fatalities for the year had already surpassed the figures from 2006/7 which, at 77 fatalities, was itself a rise of 28% and the highest construction related death toll for five years. The HSE has said that a major factor in the increase in fatalities has been the continuing rise in the number of migrant workers employed on UK construction sites who have previously used less safe working procedures (Owen 2007).

This alarming evidence suggests there is a strong need for measures to be introduced to the industry that will combat the additional health and safety factors faced by migrants. To this end the HSE commissioned the Working Lives Research Institute at London Metropolitan University to carry out a study that assessed migrant worker health and safety risks. The research (McKay *et al.* 2006) suggests that it is not the case that risks which naturally present themselves in a particular type of work, only present themselves to migrant workers. However, what it does reveal is that migrants are more likely to be working in sectors or occupations where health and safety concerns do exist. It also went on to identify a multitude of factors that heighten these health and safety concerns and these are detailed later in this paper.

This paper extends the work of McKay *et al* (2006), seeking to set-out and evaluate the factors that increase health and safety risks for migrant construction workers. Research was carried out to ascertain migrant worker accident rates, identify weakness in current management practice and offer recommendations to improve levels of safety for migrants in future. The report, which drew on interviews with 27 migrant workers, 8 health and safety managers and the latest accident records throughout the UK, considered whether the position that migrant workers occupy within the UK construction industry puts their health and safety at increased risk when compared to indigenous workers.

This paper now purely focuses on the factors identified during the study that increase risks faced by migrants and later evaluates various management techniques as to their potential effectiveness in nullifying such factors. The next section discusses factors identified as a result of previous research. These factors are then evaluated in terms of their negative impact upon migrant workers' health and safety. A discussion follows that elaborates on current industry practices with regard to migrant worker health and safety, how they could be improved and the associated benefits such improvements would produce.

FACTORS COMPROMISING MIGRANT WORKER HEALTH AND SAFETY

The literature review undertaken as part of the desk study identified a large number of factors that were further proved by the study's later research. Findings from the literature review, employer survey, interviews and the statistical analysis of accident record information have been used to compile and discuss the following factors.

MIGRANT WORKERS LARGELY OPERATE WITHIN THE MOST UNSKILLED, DANGEROUS TRADES

Data from the Worker Registration Scheme suggests that between a third and a half of A8 workers registered as labourers. This suggests that migrant workers commonly undertake the so called dirty, difficult and dangerous jobs that UK workers are increasingly unwilling to do (Chappell *et al*, 2008). Interview and questionnaire responses for the HSE study also revealed how migrant workers are most often employed in more dangerous work environments and working patterns (long hours) that expose greater health and safety risks.

Chi-square tests were carried out to help identify causes of poor migrant worker health and safety behaviours. Test 1 proved that migrants have more accidents resulting from handling/carrying tasks, contact with and misuse of machinery and exposure to dangerous substances. This reflects the types of work that migrants predominantly undertake – the heavy, work intensive and largely unskilled trades. The misuse of machinery and exposure to dangerous substances also suggests a lack of training and experience. Similarly, Test 2 proved that migrants have more accidents resulting from the lower skilled, higher risk trades of groundwork, general labouring, bricklaying and carpentry. This supports the Test 1 explanation that the majority of migrants work in these trades, with few working in the higher skilled, lower risk trades such as plumbing and electrical work. Health and Safety managers didn't view these trades as more dangerous, but did state that they posed a greater danger to unskilled, inexperienced workers – a category into which many migrants fall. Most migrants also described their work as dirty, difficult and dangerous. Questionnaire responses also indicated that bricklaying and groundwork companies had the highest percentages of migrant labour and non English speaking migrant labour with most migrants employed in permanent, unskilled positions. Further, the majority of the 30 employers surveyed agreed that migrants enter the construction industry to take advantage of its unskilled nature.

MANY MIGRANT WORKERS ARE UNDOCUMENTED

Clearly the construction industry has long been involved in the employment of migrant workers, yet ConstructionSkills (2005) argue that there is a generally hazy and inaccurate set of official statistics on the construction labour market composition, in terms of migrant workers. Undocumented migrant workers (migrants working in the country illegally) are commonly employed in the construction industry. Along with sectors such as agriculture, catering, cleaning and hospitality, the construction industry has been identified as one of a number of sectors in which illegal working is a particular problem (Home Office 2002; Anderson and Rogaly 2005; Serious Organised Crime Agency 2006).

EXPOSURE TO WEAK HEALTH AND SAFETY GOVERNANCE IN MIGRANTS' COUNTRY OF ORIGIN

As a result of coming from different origins with contrasting health and safety ethics, it was also apparent that migrant construction workers had different perceptions of risk from their UK counterparts. Although most migrants claimed that they had a decent understanding of the risks and safety aspects of a UK construction site, many managers and co-workers could identify occasions when migrants worked in a dangerous manner. Sixteen employers also stated that migrants are more willing to take risks and cut corners. Perhaps this emphasises the need to stem the spread of dangerous working practices that migrants are bringing with them from their countries of origin. The majority (25) of employers agreed that migrants come from countries where health and safety standards are very relaxed.

Evidence from other European countries suggests that the lack of awareness with regards to health and safety regulations, together with the inappropriate deployment of such workers to dangerous site tasks, puts them at higher risk than their indigenous colleagues. The migrant workers had a general lack of awareness of the long-term health impacts of construction work. The study also found that many migrants are unaware of their responsibility to manage their own and others safety.

LACK OF TRAINING, TRADE-SPECIFIC SKILLS AND QUALIFICATIONS

Few employers checked migrant workers had the skills and qualifications for the work they were undertaking; with only two examples where a migrant had been asked to produce a CSCS card. Indeed, most participants stated that they were given a job after an appraisal of their own practical work**.** In interviews, all 8 managers said that previous experiences were not of direct interest and that as long as the migrant held an up-to-date CSCS card they would be allowed to work on their site. More than a third of the migrants interviewed had been given no health and safety training, with just a short induction afforded to the other two-thirds. Only a couple of interviewees mentioned refresher training and generally, larger contractors were better than smaller companies on safety training provision. Migrants had a very limited understanding of the UK health and safety system, specifically in terms of their health and safety rights and how to raise them.

LIMITED CONSTRUCTION EXPERIENCE

Research proved that most migrants have very limited construction experience, either in their home country or the UK. Only 30% of the migrant workers interviewed had prior construction experience from their home country and most employers cited the CSCS card as their entry filter for migrant workers (Dainty *et al* 2007).

SHORT, TEMPORARY NATURE OF WORK

It seems that it is their status as new workers that may place migrant workers at added risk, due to their relatively short periods of work in the UK.

LIMITED MEANS OF COMMUNICATION AND THE LANGUAGE BARRIER

From the employer's perspective, it was communication and language barriers that presented the most significant challenge. The research highlighted the lack of English language skills that many construction migrants have. Health and safety managers most commonly cited the language barrier as the biggest contributor to risks. Migrants themselves also agreed that it was a major problem and the majority of employers indicated that their migrants had difficulty communicating. Most employers also stated that many migrants do not understand all aspects of the site induction due to language issues, and this view was confirmed by migrants themselves.

There is no evidence of any checking mechanism used to ensure migrants do understand the training given to them. Worryingly half of the migrant workers' English language ability was not even checked by employers before commencing employment and to the health and safety manager's knowledge – no English classes had been held on their site. The most common entry filter used by employers in recruiting migrant labour was the CSCS card, which again supports the view that employers are not interested in a migrant's previous experience or language ability.

STRATEGIES AND TECHNIQUES FOR IMPROVING MIGRANT WORKER HEALTH AND SAFETY

These factors have led to measures being recommended to various industry bodies to facilitate the enhancement of migrant worker safety on UK construction sites. This section of the paper now discusses these measures. Measures were mainly concentrated around reducing risks pertinent with the language barrier; however it was also established that best practice guidance on the management of migrant workers should be distributed and enforced throughout industry. Only then will the industry be able to take a stranglehold on the spiralling number of workplace accidents involving migrant workers and in doing so, create a safer environment to the benefit of everybody.

The challenge of converting health and safety systems to accommodate a multi national/cultural workforce is being addressed using initiatives such as, translation of health and safety materials, use of interpreters and an increased use of visual methods for communicating health and safety messages (Bust *et al* 2007). These methods have to be qualified so that an international visual sign language can be developed that is meaningful and relevant to construction workers employed in multicultural contexts. Large employers saw the provision of translated health and safety information, the use of translators and the site induction process as the primary mechanisms for encouraging the safe working of migrant workers. A key problem is that no one single organisation is taking on responsibility for migrant worker issues in the industry. This is limiting the effectiveness of the array of good practice guidance that is available.

Part of the study undertaken by Bust *et al* (2007) included a telephone survey of 10 health and safety managers and directors of companies throughout the UK. The telephone survey results showed that the translation of health and safety information and the use of translators (Figure 1) are the most common methods used to manage migrant workers.

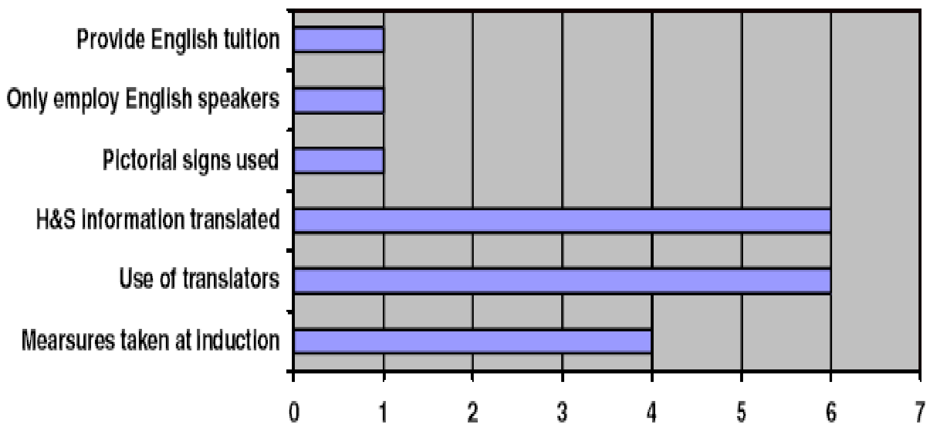

Figure 1: Means of ensuring workers understand their health and safety responsibilities

The Engineering Construction Industry Association (ECIA) produced documentation on employing and managing non-English speaking workers (ECIA, 2005 – cited in Dainty *et al.* 2007). Working with non-English speaking workers in terms of communication, supervision, training and competence certification are covered by the guidance. Companies within London have also produced similar guidance for the employment of migrant workers on the Olympic projects mentioned earlier. This includes methods for obtaining CSCS cards for migrant workers and information on how to verify foreign qualifications against UK standards (see Construction Manager 2007 – cited in Dainty *et al.* 2007). ConstructionSkills now also provides the 'Kickstart' site induction in multiple languages for migrant workers (Keane 2007)

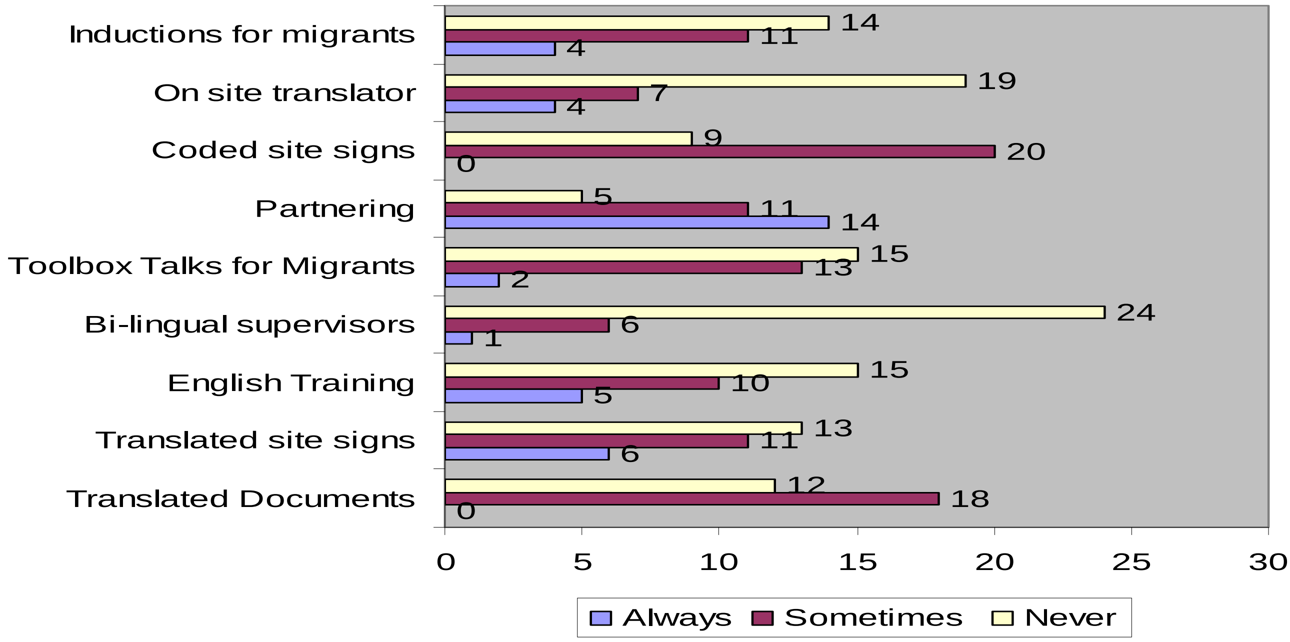

Figure 2: Management techniques frequency of use

Employers were asked to indicate how often they used a variety of good practice management tools to improve the health and safety for their migrant workers. The results are shown in Figure 2 and it is clear that the technique of partnering migrant workers with UK workers is considered to be the most effective.

Employer respondents were also asked to rank what they felt were the top three most effective management techniques from those presented in Figure 2. To arrive at an overall rank, a points system was used whereby 3 points would be awarded when a technique was ranked 1st, 2 points awarded when a technique was ranked 2nd and 1 point given for a third place ranking. Using this system facilitated a 'league table' (Table 1) to be constructed that shows how effective employers regarded the various techniques.

Table 1: Management technique league table

Rank	Technique	Points
1	Partnering	28
2	Bi-lingual supervisors	23
3	Inductions for migrants	19
4	Toolbox talks for migrants	17
5	Translated Documents	15
6	On site translator	13
7	English Training	8
8	Translated Site Signage	7
9	Coded Site Signs	1

It is interesting that some of the most highly ranked techniques (e.g. bi-lingual supervisors) are very rarely used by employers. This suggests that employers view the costs as outweighing the related health and safety benefits.

IMPROVE ACCIDENT REPORTING PROCESS AND ESTABLISH EXTENT OF UNDOCUMENTED MIGRANT WORKERS

As researched literature highlighted; it is not yet routine practice to record the accident victim's country of birth and if not from the UK, how long they have been here. This information would be very helpful in causal analysis studies. As stated earlier, migrants are also particularly poor at reporting accidents. It seems that the whole accident reporting process needs re-evaluating to facilitate accuracy of future investigations. The literature research also indicated that there are large numbers of undocumented workers in construction. This makes any analysis of data for migrant workers unrealistic and so findings have to be treated with caution. The industry needs to establish the extent of these undocumented workers to enable future research to be as accurate as possible.

EDUCATE EMPLOYERS ON EFFECTIVE MIGRANT MANAGEMENT TECHNIQUES

Partnering migrant workers with UK workers is the most popular measure among employers and they also feel it is the most effective. Migrant workers also liked the idea, but health and safety managers pointed out that they had no control over how employers deploy their workers. Bi-lingual supervisors were also richly viewed; however they are rarely used in industry, when it seems they should be. Employers need to be educated on the health and safety pitfalls of employing migrant workers with little industry experience and limited English language skills. Employers should also be encouraged to increase levels of migrant monitoring on-site and to keep regular contact in order to review working conditions.

TAKE STEPS TO REDUCE THE LANGUAGE BARRIER

An 'English only' language culture has to be the aim for UK construction sites. Achieving this will take time, but through good use of the following techniques it is certainly achievable. Rules should be introduced that require employers who employ in excess of a certain percentage of migrant workers to have to provide free of charge English language sessions to their migrant workers. This would see a reduction in the number of non-English speaking migrants on construction sites. The use of the CSCS card should also be reviewed. It should not be purely accepted as a sign of competence, especially as the test can be taken in the individual's own language. The literature review also revealed that Construction Skills now provides the 'kickstart' site induction in multiple languages for migrant workers and it is these types of mediums that need to be introduced to the industry to improve migrant worker safety on site. Literature also suggested that an international visual sign language should be developed. This view is echoed by migrant workers, who want to see more "symbol signs" on construction sites.

INCREASE LEVELS AND QUALITY OF HEALTH AND SAFETY TRAINING

Health and safety training also needs to improve for migrants, in terms of its intensity and its delivery. This research has yielded strong evidence that migrant workers have received little training in their lives, yet health and safety managers have said they are very responsive and willing to learn. Migrants should be encouraged to expand their skills base to ensure more migrants work in skilled, less hazardous trades. "Conversion courses", as suggested by one health and safety manager, could be just what the industry needs to ensure a safer, happier construction workforce for years to come.

CONCLUSIONS

This paper has discussed the use of migrant labour on UK construction projects, setting out the issues such workers face, the factors that exacerbate their health and safety on site and making industry wide proposals that would help cut the migrant worker accident rate.

Unofficial employment and a lack of consistency in the accident reporting process have combined to cloud the real extent of migrant worker employment. From the accident data, there appeared to be no difference in accident rates between indigenous and migrant workers. However what was clear was the increasing percentage of total accidents that migrants are contributing year on year. This seems to be as a result of, mainly, the type of trades that migrants are being forced into due to their unskilled backgrounds. These trade's, typically work-intensive and dynamic natures combine to provide the most challenging work conditions to invariably, what are, the most vulnerable groups of people on site. Another contributing factor is the large amount of migrants coming to the UK with limited or no construction experience and little health and safety knowledge. With limited exposure to quality health and safety training, it seems that migrants' bad working habits are all too evident in today's construction environment.

Further to the types of unskilled work they mostly carry out, an underlying factor that compromises migrant's health and safety is that of language barriers and the inability of the industry to work with migrants to break them down. In the long term effort must be directed toward migrant's English language development if the root of the language barrier problem is to be removed. Many migrant workers are walking onto construction sites without needing to speak a word of English to either their employer or the principal contractor. At present, health and safety training opportunities specifically tailored for migrant workers are minimal. Even health and safety training in the form of the pre-start induction is not being understood by many migrants, who continue to work as if operating in their home countries.

Overall, migrant workers were happy with their work and working conditions and many of the health and safety managers and employers could list good techniques they had used to improve their migrant's health and safety. Some techniques such as partnering migrants with UK workers are highly used and respected by employers and migrants alike. However scope remains for the site-wide integration of techniques such as bi-lingual supervisors and inductions specific for migrants as well physical improvements to the work environment such as coded site signage – an international language that everyone can understand. The concern remains that there seems to be no standard best practice mechanism in the industry to ensure migrant's safety on site is accounted for. Any safety initiatives need to be tailored towards the trades that migrants are most commonly found operating in, namely the groundwork, brickwork and RC trades. Any good practice guidance directed here is likely to have more impact on the industry as a whole. It remains for institutions such as the HSE and the Government to decide on a best practice approach for managing migrant workers and to ensure its policies and initiatives are dispersed to every construction site, big or small, in the UK. Only then will migrant workers' safety needs begin to be accounted for and their lack of health and safety awareness be improved to the benefit of all.

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ADULT EDUCATION THEORY AND LEARNING SAFETY: WHAT NEXT? THE CASE FOR A LEARNING CIRCLE APPROACH TO TRAINING FOR WORKERS WITH LOW LITERACY.

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ABSTRACT

People enter the construction industry with relatively low education levels. Up to 60% of subcontractors have no formal trade qualifications and the literacy/numeracy levels of the construction workforce are considerably poorer than those of the Australian workforce. They may have developed a negative attitude to school, which could extend to the paperwork requirements of the job and may partly account for their reluctance to undertake training. Construction workers often consider safety training as boring and a waste of time and precious resources. This may be because classroom training relies on the written word and very often uses a ‘banking’ style of pedagogy that involves the trainer telling the workers how they should behave. This paper is based upon empirical research conducted over many years, including interviews, participant observation, document analysis, reflective practice, and feedback from hundreds of OHS courses. 'Learning circles’ are effective as a method for constructing meaningful occupational health and safety learning experiences for construction workers with low English literacy because they work from the starting point of the participants’ knowledge and experience and minimise the importance of the written word. They are a training approach that actively engages the hearts and minds of the workers with the intent of creating a strong safety culture in the industry. The learning circle validates the safety knowledge that these workers possess and opens them to new trusted knowledge, by encouraging their critical reflection and reflective practice through talking, listening, sharing stories, and relevant visual material.

Keywords: Training, Learning circles, Literacy levels

INTRODUCTION

This paper first discusses the learning circle concept to demonstrate that it is a training/learning method that actively engages learners in a critically reflective practice. It then describes different situations in which the author has used this approach and details some of the practical techniques that constitute this teaching method. This is followed by explaining how the results have been evaluated using qualitative data, and recommendations for future research to more accurately measure effectiveness.

The discussions in this paper refer to OHS training conducted in Australia where the official language is English. The author talks about training strategies that he has found useful when conducting OHS training for two types of low literacy workers:

1. Those whose mother tongue is English but who have difficulty with reading and/or writing English
2. Those whose mother tongue is not English and who have difficulty speaking, reading and writing English

Both types of workers require a different approach: whereas the trainer can facilitate and participate in an in-depth verbal discussion with the first group, s/he cannot with the second.

LITERACY IN THE CONSTRUCTION INDUSTRY

People enter the construction industry with relatively low education levels. Up to 60% of subcontractors have no formal trade qualifications (ACIL, 1996), many have low education levels (ACIL, 1996, Kelly and Searle, 2000), and the literacy and numeracy levels of the construction workforce are considerably poorer than those of the Australian workforce in general (Construction Training Australia, 2001). To be successful in their work construction workers need to be good at doing their job, not writing about their job. Much writing performed on construction sites is done with a builders' pencil on scrap pieces of plasterboard or timber or cardboard roughly torn off packaging and discarded after use. This writing is highly situated and context specific with a specific social purpose (Balatti et al., 2006) of communication, often in the form of calculations, to deal with a well-defined situation. In previous research by the author a tiler notes that paperwork is not part of the job: *Tilers don't write; cat, rat, yes, no – they're ok* (Wadick, 2005).

A report from a literacy program in the Queensland construction industry advises: 'Approximately 50% of unskilled workers (in the construction industry) may need literacy or numeracy support if they wish to undertake training or up-skilling' (Carstenson, 2004) and this may have negative impacts on OHS outcomes, although low literacy and numeracy skills were not likely to affect the job performance of maintenance and construction workers (Black, 1998). However, research in Canada has found strong evidence suggesting that those people who work in high risk industries such as construction are more likely to be killed or injured if they lack reading and comprehension skills (Harvey, 2008).

Many of these people left school early and developed a negative attitude to learning (Golding, 2005) through the 'wounding learning practices' (Wojecki, 2005) of their school years. Construction workers often consider safety training as boring and a waste of time and precious resources (Wadick, 2006) and workers often come to courses with resistance. Some safety advertising weighs into the debate with comments such as 'Safety presentations are an excellent chance for some people to catch up on a quick nap…[and] have a reputation for being boring' (safety training brochure, 2006). A popular TV series, *The Office*, depicts a safety induction as being a ridiculous presentation of common sense issues that demeans the workers in attendance. Why has ohs training got such a bad name? After years of running thousands of OHS training courses, the author believes it is seen as boring because it is very often used as a venue to tell workers what the rules are, what to do, what to be careful of, and so on. That is, it is based on *being told what to do,* which is perceived as disempowering and showing a lack of belief in the workers' intelligence. It mainly focuses on the needs of the organisation or the need to "deliver" the learning outcomes, rather than the needs of the workers. For example, a Trainers Guide for the new national induction course for the construction industry (Commonwealth of Australia, 2006) provides a suggested course structure that puts the trainer in the role of expert who tells students what the course says they need to know. There is very little room for students to problematise actual implementation. There is more emphasis on the content than on its transformative power (Freire, 1993).

Within their own building industry workplace culture these same people feel powerful and validated. Training courses take them from a place and space of belonging and inclusion, and put them into a training room where they have never belonged and where they have previously felt excluded from learning technologies such as classrooms, tables, chairs, pens, paper, teacher-as-expert, timetables, and so on.

THE LEARNING CIRCLE

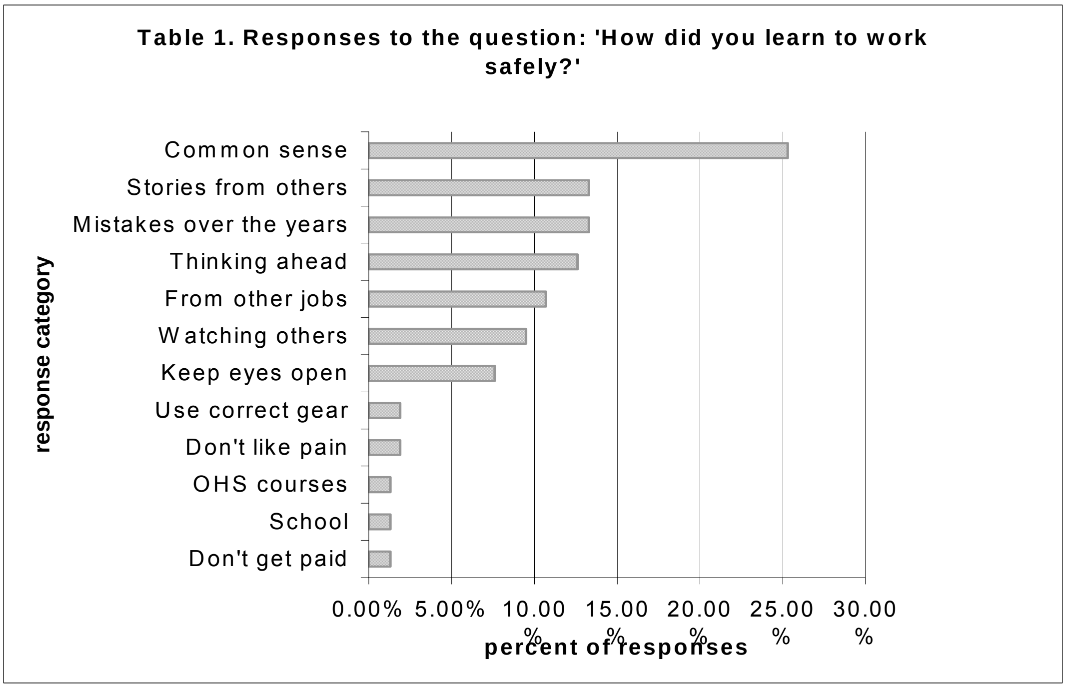
The learning circle is a training approach based on critically reflective discussion facilitated by a skilled trainer, which actively engages the hearts and minds of the workers. Many of the subcontractors in the industry have not had positive experiences of classroom learning, and modern OHS training often reinforces these sentiments. The learning circle is an attempt to validate the safety knowledge that these workers possess, by encouraging their critical reflection and reflective practice through talking, listening, sharing stories, and relevant visual material. The courses are conducted as focus groups with the aim of encouraging critically reflective practice. Reflective practice in this context is understood as 'the ability to evaluate critical incidents within daily work, using this evaluation as a means of improving practice and knowledge about work' (Macfarlane et al., 2005).

Reflective practitioners analyse a problem, seek to understand it within their context, think about the results of their actions, and puzzle over why things worked out like they did (White, 2002). The reflective practitioner is one who provides space for ‘new possibilities to be explored and realised’ (Moss and Petrie, in Macfarlane et al., 2005). An essential feature is that knowledge is constructed rather than reproduced. In the following quote from previous research of the author’s, the tiler is struggling to create new knowledge, a new way of doing things to protect himself

> *There’s one that I haven’t really come to grips with yet, but I’ve heard of um, when you cut with a saw, you cut a tile with a saw, the glaze is actually silicon based, and that dust causes silicosis, so coming to grips with that one is really difficult. You can put a mask on and it’s a bit of effort, but still you can put it on but then you’ve gotta sit there for five minutes while the dust dissipates, you know what I mean. So it’s a big one to come to grips with* (Wadick, 2005).

This reflective way of thinking is part of the construction industry culture (Wadick, 2005) and helps construction workers build up a ‘reservoir of insights and intuition’ (White, 2002) which enables them to problem solve in their many non-routine situations. This process is not formalised, nor is it named in the construction literature (ACIL, 1996), but an examination of the storylines of the research participants reveals a strong culture of reflective practitioners. Results from the research indicate that construction workers do not want to get hurt at work, they know construction sites are not perfectly safe, and they would like them to be safer (Wadick, 2005). The workers’ tendency to learn through reflection and their desire for safety are two ‘cultural levers’ (Eales and Spence, 2005) that can be included in their training experiences that will encourage their motivation, which is absolutely essential if they are to learn and transfer that learning to the workplace (Yelon, 1992, in Cornford, 2002).

A survey conducted by the author (Wadick, 2005: 93) revealed that construction workers place an enormous amount of trust in their common sense, which, on further examination, is informed by reflective practice – reflecting upon their mistakes, sharing stories and experiences, planning ahead and involvement with others at work (See table 1). Currently much of the reflective practice within the building culture occurs informally on the job in small groups or off the job at social occasions. However, with no experienced person to guide it, these reflections do not necessarily result in critical reflection, but are often constrained by the pervading underlying narrative of ‘how we do things around here’ - they reinforce traditional approaches, rather than create new knowledge. The goal is to construct new knowledge rather than reproduce old knowledge and grand narratives (Noble et al., 2006). With a skilled and knowledgeable facilitator conducting the focus groups, reflective practice can be constituted in particular ways that enable critical reflection to occur (Noble et al., 2006).



To maximize the benefits of the learning constructed through their informal reflecting, 'people need to bring what they are learning into conscious awareness' (Watkins and Marsick, 1993). Hence, as trainer, the author provides them with a safe place and space in which critical reflection can be modeled, trialled, explored and mentored. This is achieved in a classroom situation by posing relevant and context specific questions, or allowing the class participants to pose their own real life questions. In this way critical reflection is encouraged which will critically evaluate old practices in a culturally cohesive setting and encourage the group to pool their knowledge and skills to create the new knowledge required. The new knowledge needs to be unencumbered by the grand narratives that dominate site life, such as 'building work is dangerous – there will always be accidents and injuries', 'it costs too much', or the tendency to blame the injured worker for not being careful enough. When they are supported in the critical reflection process within their cultural group it has a 'powerful effect on the degree to which they are supported in letting go of older ideas and practices and attempting new ones' (Branford and Schwartz, 1999).

The trainer needs to be conscious of these influences and try to create a climate of caring and trust. The author has found that it seems to work because at times the discussion among participants is so energetic that they seem to forget where they are, why they are there and the presence of the trainer/researcher. The group situation therefore 'may reduce the influence of the interviewer on the research subjects by tilting the balance of power toward the group' (Madriz, 2003). The questioning of construction workers is a problem because the interviewer represents the very hegemonic discourse that attempts to subjugate the worker. The focus group may empower the individuals because they are part of a collective: they can minimise the control of the trainer/researcher over data by decreasing her/his power. 'The collective nature of the group interview empowers the participants and validates their voices and experiences' (Madriz, 2003). From a postmodern feminist standpoint, the group process is particularly suited to uncovering workers' daily experiences through collective stories and narratives that are filled with cultural symbols, words, signs and ideological representations that reflect the different dimensions of power and domination that frame their experiences.

Learning circles that teach and encourage the skills of critical reflection are being trialled successfully in the Bachelor of Human Services (Child and Family Studies) at Griffith University in Queensland (Macfarlane et al 2005). The learning circle provides an opportunity for self directed learning through 'shared inquiry and dialogue' (Karasi and Segar 2000, in Macfarlane et al 2005). These learning circles encourage students to become more self reflective, metacognitively aware and self directed learners. They find that the approach helps develop such soft skills as communicating ideas and information, working with others and in teams, and planning and organising activities. These are three of the Mayer Key competencies identified by Hager et al (2002) as critical for successful OHS outcomes, and Wadick (2005) as lacking on house building sites and negatively impacting on OHS outcomes for workers. They are also included as 3 fundamental employability skills in the Trainers Guide to the new National Construction Induction (Commonwealth of Australia, 2006).

METHODOLOGY

The information presented as data in this paper has been gathered by a number of qualitative methods, and guided by the author's inquisitive and critically reflective practice. It has similarities with action research in that teaching methods were continuously refined based on previous sessions, feedback from participants, and further research. The author has honed these methods over many years of training and shares his ideas with you. Monitoring, review and evaluation of results is also situated in the qualitative paradigm that gives credence to how people experience their own reality and communicate these perceptions to the researcher. The author who is at the same time a trainer and researcher, has become convinced that the learning circles help to create enthusiasm for OHS and give people practice at assertively speaking about their concerns. Further, unsolicited feedback sent to the author's employer after one 4-day course described the style of training as 'outstanding' and 'easy to understand for ESL people' (personal communication from employer). No quantitative measuring of enhanced performance was attempted. Hence, you may debate the validity because of this lack of statistical evidence. However, the many students themselves have convinced the author by their enthusiasm and engagement that they experienced substantive learning outcomes. They very often leave the classes with an eager fervor to improve ohs at their workplace.

However the author does make the recommendation that more empirical and longitudinal research is needed to quantify the results of this style of training.

GROUP 1: THOSE WHOSE NATIVE TONGUE IS ENGLISH

The author's experience with this group of workers is mainly with people from the construction industry who attend a 1-day compulsory OHS induction course.

As a trainer, the author knows that at least some proportion of his students at the course each day struggle with literacy; he also knows that these people are a little (or a lot) nervous and anxious about being exposed. They usually hide their illiteracy because it is portrayed as failure in our society, both at school and in general media representations. Interestingly, the author's experience of people who struggle with literacy is that they are in general not less intelligent, motivated or articulate than others. What sometimes tends to make them seem tentative, awkward, shy, or even lacking comprehension is their fear that they will be exposed and labelled dull-witted, stupid or unintelligent. Once they are so labelled, they tend to be offered more demeaning work with less responsibility and decision making. No wonder they are anxious.

The author now presents some examples of how he conducts his class so that it is inclusive of all English speaking people, no matter what their level of literacy is. Firstly, as he introduces the course, he makes it clear that there are no exams or written tests. This is absolutely fundamental so that the students with low literacy can begin to relax. Some trainers use the test as a threat to try to force people to pay attention and listen: *pass the test or else you fail the course and you'll have to do it again!* This concept is termed 'poisonous pedagogy' by Kenway and Fitzclarence (2006), and it demotivates the students in the class for going back to the workplace and striving for positive effects on the safety culture. It does not result in encouraging workers to have increased safety awareness, it does not encourage them to feel empowered enough to speak up at work. It may help them pass the test, but this is all. The author, as trainer, then outlines the course, stating that there are slides and written handouts throughout the day, but that 'if you don't like reading and writing, don't worry, because there is a lot of talking and everyone will get the chance to have an opinion'. He has learned to clarify these points in the introduction because on a number of occasions he has had nervous people come to him before the course begins and explain that they 'are not very good at spelling'. He takes this to mean their way of saying 'I'm not very good at reading or writing', or, 'I can't really read or write'.

Next, he gets each person to introduce themselves to the group. He shows a slide on the screen with about 6 questions that he wants them to answer. So as not to expose or threaten people who struggle with reading the directions, he reads them out for each person. Questions like: Name, general area you live, what construction experience do you have, why you've come to the course (this usually creates plenty of humour as they complain that they were forced to come). When they give negative answers to this question, he never disagrees or argue with them at this point, but he validates their feelings. For example, if they say that they had to come or lose their job, and that it's a waste of time and money and they resent being there, he reflects back to them what he heard them say, using their words so that they feel heard and understood. He empathises with them for having to miss out on a day's productive work and genuinely thanks them for their effort to come. Then he always asks them to describe to the class an example of one safe thing they do at work or in their lives. This gets them thinking about how they are personally involved in safety: it is the hook to get them engaged. He is setting a platform for the rest of the day. He will usually quiz them in a bit more detail about how and why they behave in this safe way. He intends to get them reflecting on their practice right from the beginning of the day.

During the course he uses a number of teaching aids – written words, pictures, video clips, discussion groups, experiential exercises, and a Socratic teaching style in which he asks people plenty of questions and gets them to consider justifying their responses. This mix offers opportunities for all kinds of learners to be involved. Sometimes he divides the class into small groups to discuss answers to some written scenarios. When handing out the worksheet, he clarifies his expectations of them by explaining: 'Elect a spokesperson in your groups, and this is the only person who needs to actually write down the answers for the group'. Again, the low literacy people can relax and enjoy the discussion without fear of being exposed.

When teaching the skills of risk assessments, he does the writing on the board, and makes sure to use their words to further validate them. He explains that he wants each person to describe a hazard they have identified from their workplace, or they expect to encounter when they enter the construction industry. While they think for a minute or so about their response, he draws three columns on the board with the headings Hazards, Risks, Controls. He then goes around the room, eliciting one hazard from each person, the risks posed by their hazard, and how they either eliminate of control those risks. After any particular person has had their turn, he invites comments and suggestions from everyone else in the class.

In summary, the author ensures a successful OHS training experience for these students (irrespective of their levels of literacy) by treating them with respect, seeing their world through their eyes, and getting them to think and speak by asking them in-depth and sometimes challenging questions. He starts off the day by creating a climate of trust, so that by the end, he can challenge long held beliefs.

GROUP 2: THOSE WHOSE NATIVE LANGUAGE IS NOT ENGLISH (NESB WORKERS)

In this section the author gives a brief description of two techniques he has found useful in training people from a manufacturing environment for whom English is a second language. He would like to say at the outset that this is not easy and can be challenging, because he only speaks English. However, there is often someone in the class who speaks both English and the language of the participants, so he enlists their help as translators.

The spoken and written word based approach will not work for people who do not understand the language of the words. We need to look for more universal communication tools. For his description in this section of two techniques he has used, he is deeply indebted to the UK Hazards online magazine, which hosts the International Labor Organization's publication: Barefoot research. The first technique is body mapping. For this, he draws on the board or a large sheet of paper a large outline of the body, both front and rear perspectives. He has different coloured markers and the trainer and students collaboratively agree on what colour represents what type of health or safety problem; for example, red for aches and pains, blue for cuts and bruises, green for illnesses, orange for stress, black for whatever the group decides. People in the group then have a chance to put a colored mark on the part of the body that is affected by their work. Once everyone had had enough turns, we then look for themes.

This then develops into the next exercise, called risk mapping, designed to describe where workers feel that the risks are posed throughout the workplace. He draws on the board a large map or floor plan of the workplace, including machinery location and processes. As a group we then identify what hazards and risks are associated with each area, and mark the diagram with differently colored stickers, markers or symbols to indicate particular hazards and risks. The group can also mark where accidents or near misses have occurred, or where illnesses have been reported (or not reported). This information is then collated with the body map to look for cause and effect. If possible, it is very useful at this stage to get the group to take the trainer for a walk around and show exactly what they are referring to. They often get very animated at this point.

These two exercises form the first 2 steps of the risk assessment process. To brainstorm controls, we usually combine the above information with their knowledge of their industry to work out how to make this place less dangerous, or even how to make this place a safe and healthy workplace that they love to come to. At this stage it is helpful to use visual aids such as drawings of things like fume extraction, gantry cranes, handrails, spray booths, bollards and even PPE if the risks can't be reduced to an acceptable level.

Caveat: A trainer must be aware in this situation of the power differential between many NESB workers and management. The workers may be involved in the risk assessment process, but feel too intimidated to take their concerns to management. They may come to Australia from backgrounds that do not support workplace health and safety initiatives, and feel that their job is precarious if they speak up. It is important that they use appropriate processes such as an OHS committee that contains bilingual people whom they can trust. This process is the legitimate means for raising concerns of workers to management.

CONCLUSION

The research described in this paper, although less rigorous than usually accepted research practice, provides a useful conceptual framework that could be used to inform future research. A significant proportion of construction workers' learning occurs informally on the job through reflective practice, and requires participation in the construction workplace culture. OHS training largely disregards this and views OHS learning as the acquisition of cognitively acquired individual competencies that will somehow be transferred to the workplace. This is disrespectful to the workers and ignores risk perception research, cultural studies, and adult education principles.

Safe working behaviour needs to be understood as more than following a list of rules, as this often results in minimum compliance. It would be better seen as a state of mind in which a person is always trying to think of safer ways to do things, becoming in the process a 'risk aware worker' (Hopkins, 2005) or workers who can work with an 'intelligent awareness' (Abrahamsson and Somerville, 2007). This paper has demonstrated how a learning circle approach to OHS training in the construction industry may encourage and develop the critical reflection of construction workers and is especially suited to people with low literacy because they can contribute to the discussions equally, without fear of marginalisation that classrooms often bring. This will help them to mobilise their own energy to creatively innovate new culturally accepted practices that will improve their safety at work.

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CONSTRUCTION OS&H: A COMPREHENSIVE TRAINING PACKAGE BY THE INTERNATIONAL LABOUR OFFICE

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ABSTRACT
In 1999 the International Labour Organization (ILO) initiated the "Decent Work", programme, followed by the "SafeWork" programme which aims to create worldwide awareness of the occurrence and consequences of work-related accidents, injuries and diseases. Construction remains one of the industries with very high accident rates and ill-health, a problem at least partially related to lack of proper training. A worldwide analysis by the ILO in 2007 concluded that there was a shortage of comprehensive training materials in the public domain and that the private sector holds the majority of relevant materials. Thus, access to these materials is determined by economics rather than need, so many of those most in need are excluded from these materials.

Production of a universally applicable package for Occupational Safety & Health training, within a project management context, relevant to a global audience and applicable in a variety of legislative environments, bespoke for the construction sector and aimed specifically at four sets of 'participant groups': clients, design and project management teams, contractors and workers, and made easily available in the public domain.

The paper describes this training package, entitled ILO Construction OS&H, and the principles on which it is based. It summarises the research base, educational philosophy, structure, content, presentation and the use of 'new media' to encourage its dissemination and use.

This paper is based on the draft package and this conference will be its first public exposure. Comment and perhaps additional inputs from conference participants will be welcome. These will be considered as the package goes through the process of peer review and final editing.

Keywords: Occupational safety and health, Construction industry, Digital training package

INTRODUCTION

"In construction at least 108 thousand workers are killed on site every year, that figure represents 30 per cent of all fatal injuries. That is one person dying every five minutes because of bad, and illegal, working conditions. The construction industry has a deservedly notorious reputation as being dirty, difficult and dangerous."

"Workers are killed, injured and made sick whilst carrying out routine jobs. The hazards are well known and so are the prevention measures. The overwhelming majority of "accidents" are absolutely predictable and preventable. They are caused by failure to manage risks, or by straightforward negligence on the part of the employer."
(Building and Woodworkers International (BWI): http://www.bwint.org)

In 1999 the International Labour Organisation (ILO) initiated an extensive programme entitled “Decent Work”, followed by the “SafeWork programme” which aims to create worldwide awareness of the occurrence and consequences of work-related accidents, injuries and diseases.

“The primary goal of the ILO today is to promote opportunities for women and men to obtain decent and productive work, in conditions of freedom, equity, security and human dignity.”
(Juan Somavia, ILO Director-General)

“Work is central to people's well-being. In addition to providing income, work can pave the way for broader social and economic advancement, strengthening individuals, their families and communities. Such progress, however, hinges on work that is decent. Decent work sums up the aspirations of people in their working lives.”
(ILO's vision of decent work http://www.ilo.org/global/About_the_ILO/lang--en/index.htm)

“For the BWI, the most effective way to ensure that worker's interests are protected in the work place is through legislation and regulation. In this connection, we work with the International Labour Organization (ILO) to lobby for the implementation of ILO standards and their respect in World Bank agreements.”
(BWI: http://www.bwint.org)

The training package called “*Construction OS&H*” described in this paper is based on this vision of ‘decent work’. It has been produced by the ILO and Building and Woodworkers International (BWI), working in partnership.

This paper has the following structure. The aims and objectives of the training package are summarized, followed by a statement of the expected ‘profiles’ of the tutors and ‘participants groups’ (clients, design and project management teams, contractors and workers) for whom the programmes in the package are intended. The educational basis is then explained, followed by an outline of the structure, which is based on 15 themes drawn from a ‘knowledge base’, leading to a flexible, modular, digital training resource. Finally, the need for a ‘sharing network’ for tutors is argued, within an Internet portal that will make the whole of *Construction OS&H* freely available.

AIMS AND OBJECTIVES

Construction remains one of the industries with very high rates of accidents and ill health, a problem at least partially related to lack of proper training. A worldwide analysis by the ILO in 2007 concluded that there was a shortage of comprehensive training materials in the public domain. The private sector holds the majority of good quality, relevant training materials. Thus, access to these materials is determined by economics rather than need, so those most in need are excluded from these materials.

Overall aim

The overall aim was to compile a comprehensive international Occupational Safety & Health (OS&H) digital training package, made available in the public domain by the ILO.

Overall objective

Production of a universally applicable package of OS&H training materials, within a project management context, relevant to a global audience and applicable in a variety of legislative environments, bespoke for the construction sector and the main ‘participant groups’ within the sector. This will be made available in the public domain to provide equality of access globally and to ensure that those most at need have access to good quality and current OS&H and project management educational materials.

PROFILE OF THE TUTORS

Construction OS&H provides tutors with information, teaching and learning materials and general guidance. No effective teaching and learning materials can be prepared unless there is a clear view of the essential characteristics of those who will use them, so in order to compile this package, some assumptions have had to be made about the experience and abilities of the intended tutors. In brief, these assumptions are that the tutors will:

- Have a good understanding and some practical experience of working in or with the construction industry
- Be experienced tutors: that is, they will be able to present and explain the content effectively, and will have the organisational and interpersonal skills to manage a training programme with the intended participants
- Be competent in the use of simple information computing technologies, such as the operation of a personal computer and software such as Microsoft Word, Excell and PowerPoint
- Be able to prepare simple visual aids, including the use of simple compact digital cameras

PROFILES OF THE PARTICIPANTS

Construction OS&H provides distinct training programmes for the four main 'participant groups' in the construction industry: clients, design and project management teams, contractors and workers. An essential requirement for the design of a training programme is to have a clear view of the intended recipients, so when designing and compiling *Construction OS&H*, a profile has been assumed for each of the participant groups, together with their needs for knowledge of OS&H policies and practices and these are summarised in the following sections.

Clients

The clients for construction works are probably as diverse as life itself. Clients for major public works projects will be represented by employees who have a high degree of technical and project management knowledge and will have experience of managing construction projects. On the other hand, for private clients, regardless of the size of a project, it may be the first such project in which they have been involved.

In order to respond to this broad range of participants, they have been assumed to need a grounding in the theory and practice of managing construction projects.

Clients tend to focus on end results rather than the design and construction process, so OS&H may not be uppermost in their thoughts at the beginning. So, they will benefit from a good review of OS&H, especially the need for comprehensive OS&H management systems and the inclusion of strong contract clauses requiring diligent OS&H compliance in all contracts.

In the final analysis, since the client has to pay for everything, there may be difficult discussions about the cost of comprehensive OS&H practices and procedures. There is, therefore, a need for serious consideration of ethics and humanity, the rights of individuals to lead safe and healthy working lives, and perhaps the 'business case' for OS&H. An important consideration is that good design and effective project management can eliminate many hazards and risks 'by design' rather than by providing additional safety measures at additional cost, and clients should insist on the application of this principle when engaging designers and construction managers.

Clients also have a duty of care to their own employees and the general public, consequently they will need some specific and detailed knowledge of OS&H policies and practices in this context.

Design and project management teams

Design and project management teams are made up of professional designers, such as architects and engineers, specialists (such as interior designers) and projects will be managed by professionals who plan and control the project and its costs. Most design teams will have experience of construction projects, but historically they may view OS&H to be entirely the concern of the contractor. They may also tend to focus on the completed works rather than the process by which they are realized in practice, so the key phrase for them is 'OS&H by design'. This will require an understanding of the management of construction projects and technical knowledge of construction work.

Contractors

Throughout the World, the construction industries operate in a way that by far the largest proportion of a nation's construction work is done by a relatively few major companies, but the industry as a whole has many very small companies, most of them employing less than 10 people. Although in the contemporary industry construction companies work for their clients in many ways and in a wide variety of contract forms, the general term for them, used throughout the world, is 'contractors'. There is some evidence that larger companies manage OS&H more effectively than smaller ones:

"When the size of an organization undertaking construction work falls below a critical mass then the resources and facilities to enable safe construction are not readily available" (Rowlinson, 2004, p4).

The ILO hopes to make a contribution to eliminating this problem by making *Construction OS&H* freely available, but the safety record of the industry is such that many contractors need comprehensive exposure to the contents of *Construction OS&H*.

Workers

Workers have much less control over their own OS&H than any other group in this programme. Crucially, they must know their rights and be prepared to argue for them. They must also be knowledgeable and skillful in the use of OS&H practices and the equipment provided for their use. It is very important for them to know what their employers are expected to provide in order to safeguard their safety and health.

It must be accepted also that workers have obligations to themselves, their fellow workers and their employers to behave in a prudent manner and to engage seriously in striving for a high level of well-being for all.

Additional participants

Although *Construction OS&H* has been designed for the four sets of participant groups described above, it will also be useful to other groups, an obvious example being safety specialists, such as government inspectors and company safety officers. The package has been designed in a very flexible way, so that Tutors may adapt it quite easily for other participants.

EDUCATIONAL BASIS OF THE PROGRAMMES

The following well-known principles and practices were used in the design and drafting of this training package.

Training Methodology

Adult learners bring their experience and knowledge to a training course and - as a generalisation - expect it to be recognised and extended within a context of discussion and practical examples. The methodology is active learning rather than didactic teaching methods. The content has to relate fairly directly to their work and organisation.

ASK: Attitudes, Skills and Knowledge

It is generally accepted that Attitudes, Skills and Knowledge (ASK) are the main elements of most training programmes; for example Bloom (1956) "identified three domains of educational activities":

- Affective: growth in feelings or emotional areas (*Attitude*)
- Psychomotor: manual or physical skills (*Skills*)
- Cognitive: mental skills (*Knowledge*)

It is generally recognised that **knowledge** is the easiest of the three to teach. Development of **skills** requires the knowledge to be applied; this takes time and requires exposure to practical tasks. Relevant and positive **attitudes** can be very difficult to develop, but are a very important feature of successful health and safety management.

Participation
This package is based on another well-known principle, using a quotation from Confucius:

"I hear and I forget"

"I see and I remember"

"I do and I understand"

An effective training programme must have an appropriate balance of formal lecturing, visual stimulation and active participation through such exercises as discussions, case studies and site visits.

Behavioural objectives
So far as possible, the training materials should be designed on the basis of what the participants can actually do as a result of the training, which they could not do before. The original work on this topic is by Mager (1975), who states that:

"An objective is a description of a performance you want learners to be able to exhibit before you consider them competent. An objective describes an intended result of instruction, rather than the process of instruction itself."

For example, "at the end of this training session, participants should be able to conduct a risk analysis for a simple construction operation" is a more effective training objective than "to teach risk analysis for simple construction works".

Evaluation
Evaluation is essential to any training programme because it is an element in a quality assurance system and can contribute to further development of the programme. The 'evaluation' used in many training courses is simply an end-of-programme participant questionnaire ('happy sheets'), which are of limited value on their own, partly because real learning can sometimes be very challenging and not always pleasurable. For *Construction OS&H*, the following process is suggested, which has been used in ILO courses before:

Simple 'tests' to establish the participants' knowledge, attitudes and skills. These are given at the beginning and end of the programme, perhaps also during a long programme. This process gives some indication of the effectiveness of the training, and may also assist the trainers to relate to the participants' specific needs and ambitions. These need not be given as formal 'tests', but embedded in exercises which form part of the training.

End-of-programme questionnaire and discussion. Did the programme achieve its stated aims and objectives? Did the participants find it to be interesting, relevant and stimulating? What were the most/least useful elements? The discussion element is important because it requires the participants to justify and elaborate on their written opinions.

Action plans. Participants are required to draft an action plan which describes how they will implement some (ideally all) of what they have learned.

Follow-up. Ideally, the trainers should contact the participants (or a sample of them) and perhaps their employers to review the implementation of the action plans and assess how the materials taught have been used and what broader effects it has had on the individual's job and on employers and others.

This evaluation model is obviously compatible with the four levels of training evaluation model proposed by Kirkpatrick (1998), which measure:

- Reaction of student: what they thought and felt about the training
- Learning: the resulting increase in knowledge and competences
- Behaviour: extent of enhanced behaviour and competence and its implementation
- Results: the effects on the organisation resulting from the trainee's performance

Kirkpatrick's model is widely used in training and development programmes.

A flexible training resource

The construction industry presents an extensive and complex arena for trainers. When designing a training event, trainers will almost always be presented with a unique set of requirements, based on the needs of the intended participants and/or their employers, their attitudes, skills and knowledge, and the time available. Thus, although the package is designed for four sets of participant groups, it has not been designed as four distinct and rigidly defined programmes because to do so would be to offer training solutions to undefined problems. Furthermore, there will be obvious overlap between the topics to be taught, since some aspects are common to more than one of the participant groups; provision of OS&H clauses in contracts being an obvious example. Thus, *Construction OS&H* has been designed as a flexible training resource, provided in both printed text and digital form, so that trainers may select the elements that they require for a specific programme and edit them accordingly.

STRUCTURE OF *CONSTRUCTION OS&H*

As shown in Figure 1, *Construction OS&H* is made up of six main components:

Tutors' Guide. This is the core of *Construction OS&H* because it explains the content of the package and how to use it. The **Guide** is in the form of an introductory book with all the main content on a CD.

Knowledge Base. This provides the sources of all the content of the package, so enabling the Tutors to enhance their knowledge in order to deliver training programmes based on this package effectively. The **Knowledge Base** is supplemented by **Downloads** of some of the main sources of information, and all of it is included in the **Tutors' Guide**.

Theme Summaries. *Construction OS&H* is based of 15 **Theme Summaries**, which provide the educational content of the programme. They are extensively illustrated and written so that training materials (such as handouts, PowerPoint presentations and assignments) can be easily produced for a wide range of programmes and events.

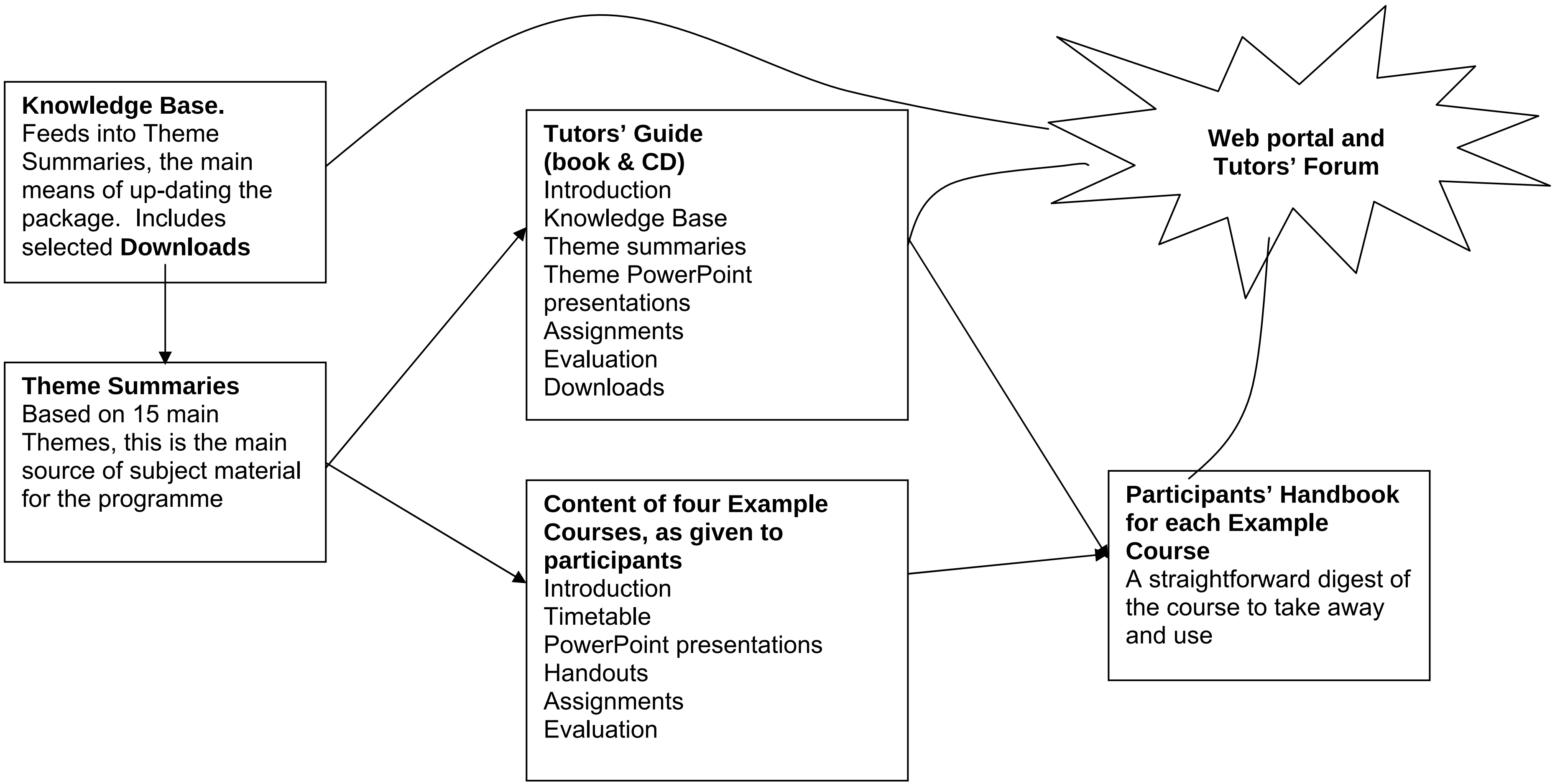

Figure 1: Construction OS&H structure diagram

Example Courses. *Construction OS&H* is a very flexible training resource and the content can be used in many ways: for example, one-day seminars, longer courses of a week or more duration, and part-time courses on a one-day a week basis. In order to give the Tutors some guidance on the use of the package, four Example Courses are provided, one each for clients, design teams, construction companies and workers. These courses have been designed within a modular structure, so that the modules can be used individually or in different combinations; for example, a module could be the basis for an afternoon seminar or as for evening of a part-time course. These courses are in the Tutors' Guide and CD.

Participants' Handbooks. The content of each Example Course has been summarised in a printed **Participants' Handbook** that can be given to the participants at the end of the course so that they may use it as a reference to use in practice what they have learned.

Web portal. All the above will be available through the ILO web site, for free downloading. It is hoped to extend this to create a web portal which will include a 'Tutors' Forum' so that users of *Construction OS&H* can exchange experiences and offer further training materials and information.

Theme Summaries

The example courses have been developed on a modular basis and each module draws its information from one or more Theme Summaries. There are four sets of Themes: Fundamental, Project Management, Technical, and an Integration and Concluding theme. Much of the information on OS&H and project management for construction projects that is generally available has some applicability to all the programmes for the different 'participant groups', so it is best to summarise this information in a these Theme Summaries then adapt it for specific training events.

The Themes were formulated from a study of the principal literature on the subject of OS&H within the construction industry, within a project management framework. ILO publications had a strong influence because this is an ILO programme. These included: the Code of Practice (ILO 1992), Guidelines on occupational safety & health management systems (ILO 2001) and Austen and Neale (1984). Other publications included Davies and Tomasin (1996) and much other information from international Internet sources.

The main topics in each of these publications (given in the chapter and section headings) were assembled in one large table, and by careful inspection and the exercise of experienced judgement, the outline structure and content of 15 Themes was formulated. The structure was also influenced by thinking about the possible recipients of the training programme, which led, for example, to a separating the use of the plant and equipment (in such Themes as 'Vertical movement') from a consideration of the equipment itself ('General plant and equipment') because it is likely that those who use the equipment will be different from those who maintain it. By building up the Theme structure from this detailed array of topics, it was possible to minimise overlap, although some overlap cannot be avoided; for example concrete pumps are used for both vertical and horizontal movement.

An important aspect of the thematic structure is that it is based on end results rather than process or equipment, which facilitates comparisons of methods to determine the safest way of achieving the desired result; for example, a comparison of concrete pump versus crane and skip. This is consistent with the specified systems approach. The Themes are shown in Table 1.

The Theme Summaries are provided in digital form so they can be easily converted to PowerPoint presentations and adapted for use by the Tutor. PowerPoint presentations derived directly from each Theme Summary are provided, and these have been augmented by exercises and assignments, which provide the participative elements which have been described above in the section on the educational design.

Table 1: Themes used as the basis for Construction OS&H

Fundamental themes	**Technical themes**
Fundamental principles	Personal protective clothing & equipment
General duties	General plant and equipment
Safe and healthy working environment	Vertical movement
Workers' perspectives	Horizontal movement
Project management themes	Working at or below ground
Principles of safe project management	Working at height
Planning and control for OS&H	**Integration and concluding theme**
Processes and systems	Project & Concluding case study & discussion
Welfare and project site	

Participants' Handbooks

When the participants have completed a course they may have a large collection of course instructions, handouts, PowerPoint Presentation print-offs, exercises, suggested solutions to exercises, suggestions for further reading, and so on. This will be an unwieldy package of documents for further use, so this body of information has been condensed to a 'Handbook' for their future use. However, a standard 'Handbook' may not be suitable for workers' courses and an appropriate form of documents for them to take away is still under discussion.

"RELEVANT TO A GLOBAL AUDIENCE"

This requirement seemed to be quite daunting at first, because of the obvious range of national cultures, legislation and locally available construction technologies. The reality is that there is a surprisingly consistent basic approach to OS&H throughout much of the world, based on a simple hazard-risk-method analysis. A 'basic global approach' was synthesised from a large body of information gathered internationally, and this was used as the systematic spine of this whole package.

The relevance to the global audience will be further developed through the ILO's peer review process, which will begin with an expert workshop in Dar es Salaam at the end of October 2009.

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A SAFETY AND PRODUCTIVITY SIMULATION GAME

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ABSTRACT
The relationship between construction safety and productivity is extremely complex and very difficult to convey through traditional pedagogy. Nevertheless, it is vital for construction engineering and management (CEM) students and construction managers to understand how safety and productivity are interrelated. To create a rich learning experience, an active simulation game was created that exposes the relationship between safety and productivity. The objectives of this paper are to describe the design of the game and the results of implementation. The game was designed to be played in an outdoor setting using a 5 ft by 8 ft tarp, ten tennis balls, a stopwatch, and a set of simple instructions. Through multiple rounds of play, students were exposed to the factors that affect both safety and productivity including teamwork, communication, number of hazards, predictability of hazards, and learning. The game was successfully utilized in an introductory construction engineering and management course with ninety-four undergraduate students and a small graduate course that focused on construction safety and quality. Post-implementation assessments indicate that students had a better understanding of how distractions from hazards reduce productivity, how productivity pressure and focus on task achievement reduce safe work behaviour, and how productivity and safety can be simultaneously achieved when communication is strong, teams work together to achieve a common goal, and hazards are few and predictable. It is expected that this simulation game could be used by educators as an alternative teaching strategy and by construction professionals to train workers in a fun and hazard-free environment.

Keywords: Safety, Productivity, Education

INTRODUCTION

In order to successfully complete a modern construction project, managers must effectively utilize resources to ensure that the facility is delivered on time and under budget while meeting specified quality requirements and acceptable safety standards. Frequently, cost, schedule, quality, and safety are in conflict and require strategic management to meet project objectives. For example, cost may be compromised if too many resources are allocated to ensure quality and safety but if quality and safety are not adequately managed, the overall cost of the project is likely be compromised due to increased rework, injuries, and delays. University researchers and educators strive to better understand the interrelationships of these factors and convey the salient knowledge to their construction, engineering, and management (CEM) students. One of the most difficult topics to describe using traditional pedagogy is the safety-productivity relationship as it is relatively complex and is affected by numerous confounding factors.

Until recently, many representatives of the construction industry viewed safety management as an additional expense that hinders productivity. Industry representative believed that traditional safety management strategies do not add value to production and compliance requires significant effort and resources (Mitrolpoulos et al., 2005). While some aspects of this belief remain true, recent researchers have found that some safety management strategies improve productivity through reductions in delays and distractions, increased teamwork, cleaner and more orderly worksites, and improved ergonomics. A challenge for professors and instructors is to demonstrate how safety and productivity are intrinsically related and the management strategies that can be used to simultaneously promote both aspects of project performance.

This paper presents the instructions for and results of a simulation exercise that illustrates the complex relationship between safety and productivity that can be used in University classrooms or in the field as a teambuilding and training exercise. The objective of this paper is to present a detailed explanation of the simulation exercise, the associated learning objectives, results of implementation, limitations of the exercise, and suggestions for future development.

BACKGROUND

In order to provide context for the simulation game, salient literature related to the relationship between safety and productivity is explored. As will be shown, the findings of studies that focus on the safety-productivity relationship are equivocal. Not surprisingly, publications in this arena tend to focus primarily on how safe work practices enhance productivity. Nevertheless, the writer found a significant body of literature that discusses both the benefits and drawbacks of safety management from a productivity standpoint. The results of this literature review are summarized in this section and are used to build theory about the safety-productivity relationship. This evidence was also used to inform and structure the simulation game that is the focus of this paper.

Mutual achievement of safety and productivity

Researchers often attempt to show a positive relationship between a safety intervention and the productivity of a work crew using long-term analyses. For example, Hare and Duff (2006) conducted a study for the UK Health and Safety Executive (HSE) that found that losses in productivity were higher with safety violations than with preventive safety. Hinze and Applegate (1991) found similar evidence concluding that safety management has a positive influence on productivity because injuries reduce task achievement to zero for the entire crew for several hours, there is a long-term decrease in productivity of the injured worker, there is often associated damage to equipment and materials, and time must be spent on required recordkeeping, accident investigation, and training.

Shikdar and Sawaged (2003) and McLain and Jarrell (2007) studied the relationship between safety and productivity from the management perspective. These studies concluded that companies with a higher level of environmental and safety problems consistently resulted in lower rates of productivity and increased teamwork, communication, and learning enhances both safety and productivity.

In his book, Hinze (2006) introduces the Distraction Theory, a theory focused on the relationship between safety and productivity. Hinze postulates that a worker will have a higher rate of task achievement if the distractions from a known hazard are minimal and the rate of task achievement is minimal when there is a high level of focus on the distractions posed by the hazards. This theory points out that productivity is compromised when the distraction due to hazards is high and that safety risk must be mitigated in order for safety and productivity to be simultaneously improved.

In addition to the relatively large body of literature that argues how safety and productivity are positively related, there is some literature that discuss the trade-offs. In their study of managers' perceptions, Choudhry and Fang (2008) found that managers believe that there is not enough time to perform work safely and that safe work practices decrease productivity. Similarly, Evans et al. (2005) studied employees' perception of productivity climate and found that workers who perceived a stronger climate for productivity reported higher numbers of accidents. Of the 526 surveys more than half of the respondents believed that productivity and safety should be viewed as trade-offs because emphasis on productivity increases risky behavior. The impacts of schedule pressure have been studied by others as well. Hinze and Parker (1978) concluded that schedule pressure increases injury rate and Probst et al. (2007) found that workers would often cut corners on safety performance in order to be more productive for fear of losing their jobs.

Choi et al. (2006) systematically demonstrated the amount of lost productivity that occurs when workers use a personal fall arrest system in residential roofing operations. Researchers observed twelve properly trained male volunteers and tracked productivity before and after the initiation of fall protection systems. Once the fall protection systems were instituted, productivity reduced dramatically. The subjects used up 6.8%, 9.1%, and 11.2% of their 2-hour production time for adjusting the lanyards at 18°, 26°, and 34° slopes, respectively. A large amount of time was also spent on adjusting the personal fall arrest lanyard, which translates into a decrease in effective work and an increase in essential contributory work (i.e., lost productivity).

Only one study tracked the short-term and long-term productivity impacts of a safety intervention. Muadgalya et al. (2008) studied the impacts of instituting a multi-faceted safety program on productivity, quality, and cost performance. The study found that there was a strong negative correlation between safety and productivity when new strategies were first implemented. Over time, however, the correlation became positive and, after several months of using the new safety strategies, there was a 66% increase in productivity and a 44% increase in quality. They also found that companies that have a formal process for building safety into new projects at the design stage, during installation, and at start up discover both safety and productivity improvements more quickly. The safety efforts with the greatest short-term productivity gains are housekeeping improvements, safety orientation and training, and personal protective equipment (PPE).

To summarize, the major findings from literature are as follows:

- The introduction of a safety intervention generally results in short-term decreases in productivity resulting from time associated with performing the safety management tasks or using personal protective equipment (PPE) and long-term increases in productivity resulting from fewer distractions and delays due to injuries;
- The fewer distractions on site, the higher the productivity;
- The more attention paid to productivity, the higher the potential for an injury;
- The more attention paid to a hazard, the lower the potential for an injury and the lower productivity; and
- Organizational learning, communication, and teamwork increases both safety and productivity when efforts are focused on improving existing procedures.

In order to enhance learning in an undergraduate CEM course, a simulation exercise was created to produce a hands-on experience that effectively demonstrates the relationship between safety and productivity. Simulation exercises are highly effective for enhancing psychomotor, professional, and social skills in a consequence free environment (Boehrer and Linsky, 1990; Christensen, 1991). The game was created to specifically highlight the salient findings from literature and is designed to be completed in one and a half 50-minute class periods (approximately 75 minutes of class time). The following sections describe the learning objectives of the exercise, the preparation requirements, instructions for play, discussion points, and assessment of the learning objectives.

Learning objectives

As a result of the activity and the associated discussion, students shall be able to:

1. Identify and describe the factors (communication, team work, learning, hazard predictability, and risk leveling) that promote both safety and productivity;
2. Describe the impact of management strategies on safety and productivity (e.g., schedule pressure and preconstruction planning);
3. Model and discuss the complex relationship between focus on hazards and task achievement; and
4. Design a safety management intervention that balances improvements in safety and reductions in productivity.

INSTRUCTIONS FOR THE SIMULATION EXERCISE

Game Intent

The appropriate student to instructor ratio is 1:10. Instructors may accommodate more students by involving teaching assistants, graduate research assistants, industry representatives, or other experienced individuals. The instructors' role is to explain the play of the game, to monitor play and keep students focused, to lead the subsequent discussion, and to assess the achievement of the learning objectives.

Preparation

The writer suggests reviewing the importance of construction safety with the students prior to playing the game. Alerting the students to the relative frequency, magnitude, and costs associated with construction industries can be enlightening, especially for students with little to no construction experience. Understanding the importance of construction safety is essential for students in introductory courses because some students tend to view safety management as a superfluous topic. The following statistics generally catch the attention of students who aspire to be project managers and project engineers:

- The construction industry accounts for a fatality rate that is five times greater than the all-industry average (NSC, 2006);
- The fatality rate is as high as 13 per 100,000 workers in the European Union (Carter and Smith 2006);
- In 2004 there were 1,194 fatalities in the US and the average direct cost of each of these fatalities was approximately $1,150,000 (NSC, 2006).
- Construction injuries account for over 15.6 Billion in lost revenue each year in the US alone (NSC, 2006); and
- The total cost associated with construction accidents accounts for 7.9-15% of the cost of new, non-residential projects (Everett and Frank 1996) and the average worker's compensation costs are estimated to be about 3.5 percent of the total project cost (Coble and Hinze, 2000).

In addition to covering this material in the classroom and providing real-life example of the impacts of injuries on workers, families, and companies, the instructor must hold a brief conference with any other instructors who will be involved with the exercise and assemble the required materials for the game.

Materials needed

The materials required to play the game are readily available and relatively cheap. For every 20 students, an instructor will need: (2) 10 ft x 15 ft tarps, 8 tennis balls, 2 stopwatches, 2 pens, and recording sheets with randomized team assignments.

Instructions

Every twenty students should be randomly organized into four groups of five. Teams are then paired and each pair is given one 10 ft x 15 ft tarp, four tennis balls, a stopwatch, and a recording notebook that includes written instructions and a worksheet for recording the results of the game. A sample form is provided in the Appendix of this paper. To prepare for the game, the pairs are instructed to lay the tarp out flat and stretched out. Once the pairs have their materials, one of the teams in each pair is assigned as the 'work' team and the other as the 'hazard' team. These roles alternate so that each team serves as the hazard team and the work team once in each round.

During each round of play, the work team is instructed to stand on the tarp. The instructor must inform the work team that their task is to flip the tarp and have all five members of the team standing on the other side as quickly as possible without having any member step off of the tarp. If a member steps off the tarp and touches the ground, the team must freeze for 20 seconds. This is a relatively challenging task that may take teams up to two minutes to achieve. The objective of flipping the tarp and the associated penalty for touching the ground remains constant throughout the eight rounds of play. During each subsequent round a new rule or condition is introduced. The purpose of these successive rounds is to produce an experience for the students that illustrates the importance of communication, planning, learning, hazard predictability, and risk leveling. The specific rules and conditions of each round are discussed below and summarized in Table 1.

Round 1

For the first round, the work team must meet the general objective of flipping the tarp while the hazard team simply records the time of the work team and learns from the other team's mistakes. This round serves as the baseline to which the results and experiences from subsequent rounds are compared. Once the work team has successfully achieved their task, the teams switch roles and repeat the exercise.

Round 2

After both teams have played one round, 'hazards' are introduced to the game. For the second round the work team is informed that there will be four 'hazards' on site represented by the four tennis balls held by the hazard team. The task for the work team remains the same as the first round; however, the hazard team is now instructed to lob the balls toward the tarp while the work team is attempting to achieve their task. Four of the five hazard team members are instructed to lob the tennis balls while the fifth member records the number of failed catches and the time taken by the work team to achieve their task. The throwing members of the hazard team surround the tarp with one member at each edge and may lob their ball at any time. Once a ball has been thrown, it cannot be thrown again. If the work team is able to catch the balls there is no penalty. If the work team fails to catch a ball that is lobbed, they must all freeze in place for 20 seconds. It is important for the validity of the game that the hazard team makes their throws catchable.

Round 3

The instructions for round three are the same as for round two with one notable exception: the members of the work team are not allowed to speak to one another during play. Speaking during play results in a 20 second penalty added at the end of the round.

Rounds 4 and 5

In the fourth round, the instructions are the same as for round two except that the hazard team is allowed to lob eight balls toward the tarp during play (each member may throw their ball twice). Again, the balls may be thrown by the hazard team members at any time during the course of play. The fifth round is the same as the fourth but the work team is not allowed to communicate during the play of the fifth round.

Round 6

The sixth round involves a different relationship between the work team and the hazard team. In this round, there are four hazards (i.e., the hazard team members can only throw their balls once) and they can only throw a ball once every 15-seconds. The timekeeper informs the all team members when the time interval has been reached, and the hazard team member assigned to that interval throws their ball. The work team is informed of this interval but not of the location from which the ball will be thrown.

Round 7

The seventh round is the same as the sixth with the exception that the balls must be thrown in counterclockwise order by the hazard team at 15-second intervals. During this round, the hazard team members must stand on their assigned edge of the tarp and behave predictably.

Round 8

The eighth and final round is the same as the first round as there are no balls thrown and the work team is encouraged to communicate freely. This round serves as a comparison round that demonstrates the level of learning from the beginning to the end of the exercise.

Table 1- Rules of play

Round	Directions
1	No hazards
2	4 hazards randomly lobbed
3	4 hazards randomly lobbed; no communication among work team members
4	8 hazards (hazard team members can throw their ball twice)
5	8 hazards, no communication
6	4 hazards, lobbed at predefined intervals
7	4 hazards, lobbed at predefined intervals from known locations
8	No hazards

Discussion points

The eight rounds of play generally take 30-40 total minutes. Following the rounds of play, the class should be asked to brainstorm parallels between the construction work and the exercise. Identifying these parallels is an essential aspect of the activity as it enlightens the students and encourages learning and internalization of the experience. Immediately following the exercise, the writer asked the student teams to brainstorm the various elements of construction sites that the activity simulates. During these discussions, students identified the following parallels:

Rate at which you flip the tarp → Productivity
Thrown ball → Dynamic hazard
Number of times balls that hit the tarp without being caught → Number of accidents
Catching the ball→ Near miss
Predictability of the balls → Identified/predictable hazards from effective safety management
Concentration of the balls → Concentration of construction hazards
Time spent discussing the best way to flip the tarp and avoid accidents → Planning
Time spent watching other teams → Learning
Communication on tarp → Communication among workers

The instructor should use his or her construction experience to add rich examples to the discussion. The writer has also found that involving a guest speaker from industry to assist with the implementation of the game and subsequent discussion adds significantly to the quality of the exercise.

In the class period immediately following the day of the exercise, students should be assessed to determine the level of achievement of the learning objectives. The following section of this paper presents the results from implementation of this game with over 140 students in multiple courses.

RESULTS FROM IMPLEMENTATION

To assess the achievement of the learning objectives, students were given an unannounced quiz two days following the exercise. To recall, students participated in the exercise and were asked to draw parallels between the exercise and the industry. In this quiz students were asked to describe how safety and productivity are related and the various factors that affect the complex relationship. Students were directed to provide at least three examples that they learned from the simulation game. This method of assessment specifically addresses the first learning objective which is appropriate for introductory level construction courses for students with little to no construction experience.

After the simulation game had been used with 76 students, two analyses were performed on the results. First, the achievement of the learning objectives was assessed. Second, the results of the activity (i.e., productivity rate and number of 'accidents' for each scenario) were analyzed. The results of the simulation exercise indicate that this learning objective was achieved. Fifty-one of 76 students (81%) provided at least three examples that met the learning objectives. The average number of examples per student was 3.17. The students adequately described the impact of communication (86%), planning (47%), learning (34%), increase in hazards (55%), predictability of hazards (74%), and risk leveling (21%) on the safety-productivity relationship.

The exercise also produced extremely strong and interesting results from a statistical standpoint. The results were analyzed using the Statistical Package for the Social Sciences (SPSS). T-tests were used as the data were approximately normal, the F-tests confirmed equal variance, and the data were independent. When teams were allowed to talk, they were 20% more productive (i.e., took 20% less time to flip the tarp) and had 4 fewer 'accidents' (p-vale <0.05). When hazards were predictable (i.e., the balls came from pre-specified locations at known intervals), teams were 12% more productive and had 288% fewer accidents (p-value < 0.01). Finally, when hazards were spread out in regular intervals, teams were 53% more productive (p-value = 0.05) and had three-times fewer injuries (p-value < 0.05). Figure 1 shows the relationship between safety and productivity for all scenarios was moderately strong (r-squared = 0.52) given the relatively small number of test groups. Finally, the trends in productivity were positive and the number of accidents was negative as subsequent groups participated in the activity indicating that subsequent groups were learning. While these results are not essential to the activity, the stability indicates that the activity is reliable when conducted appropriately.

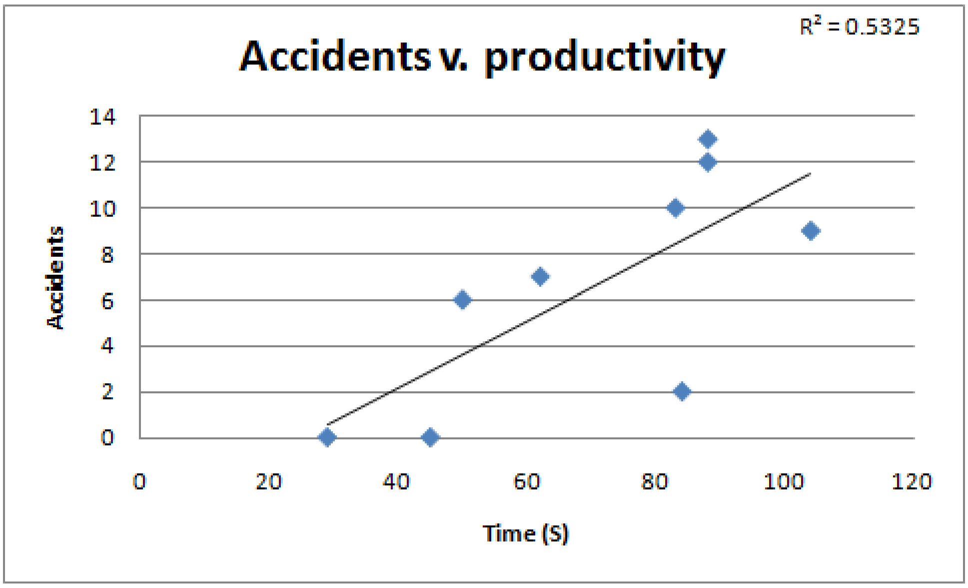

Figure 1 – Safety v. Productivity

LIMITATIONS AND RECOMMENDATIONS

The limitations associated with this exercise must be recognized. First, the achievement of the learning objectives for this exercise rests largely on the instructor's ability to spur interest in safety and productivity prior to the game, to keep the class focused on and serious about play, and to lead and enhance the discussions that follow. In the writer's experience with the exercise, students may become distracted or lose focus if they are not engaged. For this reason, it is recommended that one instructor supervise no more than two pairs of teams during a class period. This ensures that no students are idle. Second, the technique does not illustrate the impact of an injury to the worker, the worker's family, crew morale, financial stability, etc. The game only addresses the relationship between safety and productivity. For this reason, this game may not be appropriate when there is little time to address safety in a particular course. Finally, this game must be played outdoors or in a large open space. If such space is not available or if weather is poor, the game may be difficult to implement.

Despite its limitations, the writer and other instructors have had success with the technique in multiple settings. Some of the greatest benefits of the game are that it is active, played outdoors, and involves teamwork. Students rarely have an opportunity to learn in this manner when traditional teaching strategies are implemented in the classroom. This experiential learning strategy is a prime opportunity to involve graduate students with aspirations for academic positions. This strategy is an alternative to the traditional lecture and in-class activities that may encourage new faculty members to consider experiential learning strategies that challenge the traditional pedagogy. In addition, the active participation of the graduate students can relieve some stress and pressure of the instructor who otherwise must monitor multiple groups.

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Appendix 1 – Example recording form

Round 6
4 hazards, lobbed at 15-second intervals

Team member names
1 ______________________
2 ______________________
3 ______________________
4 ______________________
5 ______________________

Total time to complete (seconds)	
Total number of failed catches	
Total number of mistakes (steps off from the tarp)	

Observations of team performance

Suggestions for improvement

THE NATIONAL ASSOCIATION OF HOME BUILDERS' SAFETY EDUCATION AND TRAINING EFFORTS

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ABSTRACT

This paper presents and discusses the efforts of the National Association of Home Builders (NAHB) to develop and disseminate occupational health and safety education and training. For over 20 years the NAHB has been creating and distributing a vast array of training materials for the residential construction industry. The first training sessions started with presentations at NAHB's annual convention. This was followed with safety training materials being published in conjunction with the Home Builders Press, NAHB's publisher. To date six handbooks and videos on various safety topics have been published by the NAHB Safety Department. The paper also discusses safety training materials developed by funding from the Susan Harwood Training Grant Program of the Occupation Safety and Health Administration (OSHA). These materials were delivered to over 5000 individuals. The paper will also review the NAHB–OSHA alliance that has been in place since 2003. The NAHB-OSHA Alliance focuses on providing the association's members and others in the residential construction industry, including non-English and limited English speaking employees and trade contractors, with information, guidance, and access to training resources. The NAHB has developed and delivered training for OSHA Compliance Officers regarding residential construction. These sessions were split with morning classroom instruction followed by afternoon visits to construction projects. NAHB's efforts in developing relevant safety training materials and activities with the OSHA Alliance have contributed to improving the safety practices in the residential construction industry.

Keywords:

INTRODUCTION

Founded in 1942 the National Association of Home Builders (NAHB) of the United States of America is composed of more than 200,000 member firms that are builders, remodelers, or in a business related to the home building industry. Most of the NAHB member firms have employees and the activity of the association actually influences millions of employees in the construction industry. The association's mission is to enhance the climate for housing. The NAHB is a member driven organization with a 2,800 member board of directors representing the members of over 800 state and local associations. Its volunteer organizational structure is supported with a professional staff of approximately 300.

Most of the work of the association is performed by a matrix of committees and councils supported by the professional staff. This structure allows members with similar interests and backgrounds to work together to reach the goals of the Association. The 21 member Safety and Health Committee's (SHC) mission is to provide NAHB members and state and local associations with assistance and resources that will help builders to operate safe jobsites, comply with Occupational Safety and Health Administration (OSHA) of the United States of America regulations, and lower workers' compensation costs through injury prevention. The Committee also makes recommendations for presentations to key government decision makers on legislative and regulatory safety related issues.

The publication of safety related materials and resources are a major activity of the NAHB Safety and Health Committee (SHC). Members of the SHC serve as Subject Matter Experts (SME) and work with staff to produce the content of the publications that are then produced and distributed through Builder Books, a subsidiary of NAHB. Builder Books is also responsible for the sale of the publications. The publications are available to the general public but NAHB members do receive a discount on the purchase price. The development of several of the publications was funded by OSHA grants.

PUBLICATIONS

Handbooks:
In 1996 the handbook NAHB-OSHA Jobsite Safety Handbook was published. This handbook focuses on safety issues that residential builders can use to reduce jobsite injuries and fatalities. It also includes guidelines for establishing a safety program and identifies safe work practices that counteract common jobsite hazards. This edition sold out rapidly and a second, slightly revised second edition was published in 1998. An English-Spanish version of the Jobsite Safety Handbook was introduced in 2006.
NAHB's first English-Spanish publication was a revision of the ToolBox Safety Talks released in 2002. This handbook contains 52 short safety related talks that are arranged so the English and Spanish pages can be viewed simultaneously. In 2004 the Scaffold Safety Handbook: English-Spanish Edition was published. The handbook includes clear explanations and photos for using fabricated frame, pump jack, mobile, and many other scaffold types and aerial lifts. It includes the proper assembly, use, and disassembly of common residential construction scaffolding. The NAHB-OSHA Fall Protection Handbook, English-Spanish (2007) describes safe work practices that residential construction professionals can use to comply with OSHA fall protection standards. The handbook can also be used to assist in the development of a written fall protection plan. Also in 2007 Home Builders' Safety Program with CD was released. This publication is a revision of an earlier publication that focuses on the implementation of a total loss control safety program. It is packaged with a CD that includes a model safety program that can be customized for most residential construction operations.

The most recent publication is the NAHB-OSHA Trenching and Excavation Safety Handbook, English-Spanish (2009). This handbook uses text and illustrations to reinforce procedures and safe work practices for trenching and excavation.

Table 1 is a record of the sales of the various publications:

Table 1
Lifetime sales of NAHB Safety Handbooks

Title	Lifetime Sales
NAHB-OSHA JOBSITE SAFETY HANDBOOK	14,853
NAHB-OSHA JOBSITE SAFETY HANDBOOK ENGLISH-SPANISH	127,499
TOOLBOX SAFETY TALKS ENGLISH-SPANISH	1,161
NAHB-OSHA SCAFFOLD SAFETY HANDBOOK ENGLISH - SPANISH	8,865
NAHB-OSHA FALL PROTECTION HANDBOOK - ENGLISH SPANISH	12,805
HOME BUILDERS SAFETY PROGRAM	2,165
NAHB-OSHA TRENCHING & EXCAVATION SAFETY HANDBOOK ENGLISH-SPANISH	229

Videos:
Beginning in 2005 the NAHB produced companion videos to the handbooks. The videos are released as a DVD. The first, Jobsite Safety Video contains a twenty minute long English and Spanish versions. It provides a synopsis of safety issues relevant to home building contractors. This was followed by the 2007 release of the Fall Protection Video. This DVD contains two thirty minutes videos in both English and Spanish. The topics include ladders, fall protections systems and emphasizes safe work practices in framing and roofing operations. In 2008 the Scaffold Safety Video was released. The two thirty minute videos, one in English the other in Spanish concentrate on how to correctly erect, use and dismantle scaffold systems that are commonly used

on home building sites. The most recent production of the association is the Trenching and Excavation Safety Video. This dual language safety video focuses on methods to protect workers performing work in residential trenches and excavations. At the time of writing this video has not been released. The Table 2 is a record of the sales of the various videos produced by NAHB.

Table 2 Lifetimes Sales of NAHB Safety Videos	
Title	Lifetime Sales
JOBSITE SAFETY VIDEO	3,526
NAHB-OSHA FALL PROTECTION Video	10,229
SCAFFOLD SAFETY VIDEO ENGLISH-SPANISH	5,964
NAHB-OSHA TRENCHING & EXCAVATION SAFETY VIDEO ENGLISH-SPANISH	0

Quick Cards:
The NAHB Health and Safety committee is currently developing a series of "Quick Card" for use in the home building industry. The cards, based on OSHA Quick Cards, can serve as a quick reference for safety concerns on residential sites. Based on material gleaned from the Fall Protection Handbook and the Trenching and Excavation Handbook the cards will be available by a download from NAHB.org.

EDUCATIONAL PROGRAMS
One of the missions of the NAHB is to be the premier resource for education of those involved with the home building industry. The health and safety committee has responded to this by creating six training programs since 1997. In conjunction with the NAHB Research Center, Inc. the safety committee has been awarded Susan Hardwood Training Grants (SHTG) for the development and delivery of four of these programs. This annual competitive grant program is awarded to nonprofit organizations to provide training and education on topics selected by OSHA.
The first training program *The "Big-Four" Safety Hazards for the Home Building Industry* was designed to concentrate on the fall, electrocution, struck by, and caught in hazards on residential sites. This included the instructional materials for a six hour training course emphasizing these topics on a home building site.
The first grant awarded in September 2003 focused on the implementation of safety and health management programs in home building. The $156,134.00 grant included funding for the development of training material and delivery of the material to individuals involved in residential construction. Attendance at the seminars was free and open to members and nonmember of NAHB.
In September 2006 another SHTG was awarded to conduct 40 fall hazard seminars in the top 20 home building markets across the country. The $295,464 grant provided funds for the development of instructor material and delivery of a four hour seminar. The content of the seminars was centered on the NAHB Fall Protection handbook. This program was extended the following year by a $241,248 grant to extend the delivery to other markets. It included funding for 35 seminars delivered in English and 5 Spanish language presentations.
In 2008 another SHTG was awarded for the development and delivery of 35 scaffold and ladder safety seminars. The 2 ½ hour seminars were available in both English and Spanish.

Table 3 is a record of the number of individuals that attended the various seminars:

Table 3 Total Seminar Attendance and Date Ranges		
Program Name	Number Trained	Duration of Training
The "Big-Four" Safety Hazards for the Home Building Industry	1200	October 2000 — September 2002
The "Big-Four" Safety Hazards for the Home	1575	October 2002 —

Building Industry for the Spanish-Speaking Sector		September 2003
Develop and Implement a Home Builder Safety and Health Management Program	1054	October 2003 — September 2005
Fall Protection for Residential Construction	1830	October 2006 – April 2008
Fall Protection for Residential Construction Industry Grant	1560	October 2007 – September 2008
Scaffold and Ladder Safety Training for Home Builders Grant	1006	October 2008– to present

NAHB OSHA ALLIANCE

On May 8, 2003 Kent Conine, NAHB's president and John Henshaw, Assistant Secretary Occupational Safety and Health Administration signed an agreement that established an alliance between NAHB and OSHA. This established a relationship to nurture a safer and healthier working environment for the home building industry. Under the Alliance NAHB and OSHA will provide those involved in residential construction information, education, and leadership to reduce and prevent worker injuries on home building sites. In addition the Alliance will increase the awareness of the Spanish-speaking segment of the residential construction workforce of safe work practices. The original agreement was for a period of two years and has been renewed on October 18, 2005 and June 7, 2007.

Since the inception of the Alliance NAHB representatives have worked with OSHA staff on numerous projects to increase the awareness of safe work practices on home building projects. Including:

- Enhancing the portions of the OSHA website: (http://osha.gov/SLTC/etools/construction/index.html)
- Promoting OSHA's compliance assistance products on NAHB's electronic newsletter *Nations Building News*.
- Providing copies of NAHB Safety Handbooks to OSHA National, Regional and Area offices, State Plan States and On-site Consultation Program staff
- Presenting workshops at several National Safety Congress & Expos
- Having OSHA administrator participate in NAHB Board meetings and the annual International Builders Show.
- NAHB has developed and presented to OSHA staff a daylong seminar, "How to Build a House". The seminar has been presented:
    - November 1, 2007 in Laurel, Maryland, USA.
    - October 5, 2006 in Elyria, Ohio, USA.
    - May 26, 2006 in Indianapolis, Indiana, USA.
    - November 15, 2005 in Red Bank, New Jersey, USA.

AWARD PROGRAM

In 2006 the NAHB Construction Safety and Health Committee initiated the Safety Award For Excellence (SAFE) to recognize individuals, companies, local NAHB associations, and government officials for their contribution to safety in the home building industry. The awards are divided into the following categories.

- Leadership In Construction Safety Award
- Single Family Builder Safety Program of the Year:
    - **Less than 10 home starts per year**
    - **Greater than 100 but less than 1000 home stars per year**
    - **Greater than 1000 home starts per year**
- Specialty Trade Contractor Safety Program of the Year:

    - **Less than 500 Employees**
    - **More than 500 Employees**
- Remodeler Safety Program of the Year
- Multi-family Builder Safety Program of the Year
- Associate Safety Program of the Year
- Innovative Safety Program/Idea of the Year
- Home Builder Safety Professional of the Year
- NAHB-Affiliated Association Safety Program of the Year
- Federal and State Plan OSHA Official of the Year

The awards have been presented at the 2007, 2008, and 2009 International Builders Show.

REGULATORY ACTIVITIES

The NAHB staff and members have participated in the rulemaking of proposed OSHA regulations. Several members have served on the Advisory Committee on Safety and Health (ACCSH). The 15 member ACCSH was authorized in the 1969 Construction Safety Act to serve in advisory capacity on OSHA standards and policies. ACCSH holds public meetings and has heard testimony from other NAHB members and staff.

NAHB has also provided input to OSHA on numerous rulemaking activities. In February 2008 NAHB submitted comments about OSHA's proposed Confined Space in Construction Standard. The focus of these comments was what is classified as a confined space in home building and the burden placed on the controlling contractors in residential construction.

The impact of revisions to the Crane and Derrick Standard on the home building industry has also been a point of discussion between NAHB and OSHA. A final report from the negotiated rulemaking advisory committee (A NAHB member served on the committee) was released in July 2004. The revised standard included all cranes that had a minimum lifting capacity of 2000 pounds and required that crane operators must be certified by either an approved crane operator testing organization or the employer's own qualification program that must be audited by an approved testing organization. NAHB has submitted comments to OSHA that the draft of the rule does not consider how small cranes are used on home building sites and that the official estimated cost of compliance is inaccurate.

An NAHB member participated on the Small Business Regulatory Enforcement Fairness Act (SBREFA) panel that recommended to OSHA that it not pursue developing another regulation at this time, but rather the agency focus its efforts on educating the construction workforce about the hazards of airborne silica dust. As a health and safety advocate NAHB has developed and begun distribution of a "Quick Card" on silica hazards at home building sites.

NAHB submitted a negative ballot on the ANSI A10.40 and stated that this standard is of no value to small business in the home building industry because small businesses do not have the resources to conduct risk assessments looking at unknown "risk factors" which could lead to "musculoskeletal problems" (i.e. soft tissue injuries such as sprains and strains). NAHB continues to object to the ANSI A10.40 and has joined a coalition with several other employer-related construction associations to keep this standard from being formally adopted and published. NAHB filed an appeal with the relevant ANSI Board November 9, 2007 and NAHB presented its oral arguments before the ANSI Board of Standards Review (BSR) on February 7, 2007. The appeal was denied and the standard has been adopted.

LANGUAGE BARRIERS

The Home Builders Institute (HBI), the workforce development arm of NAHB in 2008 introduced Sed de Saber™-Construction Edition. This practical and proven system enables Spanish speakers to learn conversational English at their own pace in as little as five months. Sed de Saber™-

Construction Edition was developed by a team of subject matter experts including superintendents, remodelers and builders to ensure that it is the most relevant and impactful product available to break the language barrier that exists within the construction industry – ultimately reducing job site injuries/fatalities and improving quality of construction and boosting your bottom line. The interactive seven book series teaches 500 vocabulary words, 340 phrases and covers job site terminology, tools, equipment and protocol. The entire seventh book focuses on safety and is modeled after the NAHB-OSHA Job Site Safety Handbook.

CONCLUSION

NAHB has developed, published and distributed over 175,000 safety related handbooks and videos. Additionally the NAHB has offered training programs to over 11,000 individuals involved in the residential construction industry. This is further enhanced by the work of the NAHB OSHA Alliance and the involvement of NAHB members and staff in OSHA rulemaking. Through these examples in can be documented that the National Association of Home Builders is an advocate for a safe and healthy workplace.

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OHS WORLD VIEWS: IMPLICATIONS FOR PRACTICE OF OHS IN CONSTRUCTION

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John Barton, John Barton and Associates

ABSTRACT

In Australia there has been a steady decline in the number of construction injuries, but the number never seems to reduce below a certain level. Why are workers still being injured?

One lesson from systems thinking is that the structure of a system is understood from the pattern of observable events, such as injuries or fatalities, which result from that system. However, one's understanding of the pattern of events is influenced by one's world view. This paper advocates the use of Pepper's four world views based on metaphors of similarity, machines, organisms, and systems in environments, as a framework for interpreting a system's patterns of behaviour.

The hypothesis of this paper is that the construction industry needs to recognise the way the different systems approaches associated with these world views provide a systemic approach to managing risk associated with different levels of complexity. In terms of the construction industry this translates into an integrated hierarchy of OHS management approaches ranging from the classification of hazards, to a process view of risk, on to approaches that help conceptualise catastrophes associated with the failure of tightly coupled systems as the result of a small change, and ultimately to an integrated experiential learning approach to risk management.

Keywords: Construction, OHS management systems, Systems approach, Risk management, World views

INTRODUCTION

The construction industry in Australia, as in most countries, is characterised by the speed with which it reflects economic activity, particularly relating to economic outlook, government spending, and interest rates. This volativity is evidenced by the relatively strong deviations around the industry trend line (Figure 1). The Australian Construction industry employed 876 000 people in 2005–06, representing 9% of the Australian workforce (ASCC, 2008). It is characterised by its organisation around a diverse range of housing and infrastructure projects each demanding high standards of construction and timeliness, and by reliance on contractors and a mobile workforce (Lingard and Rowlinson, 2004). To add to this complexity, the industry's industrial relations scene has a history of conflict.

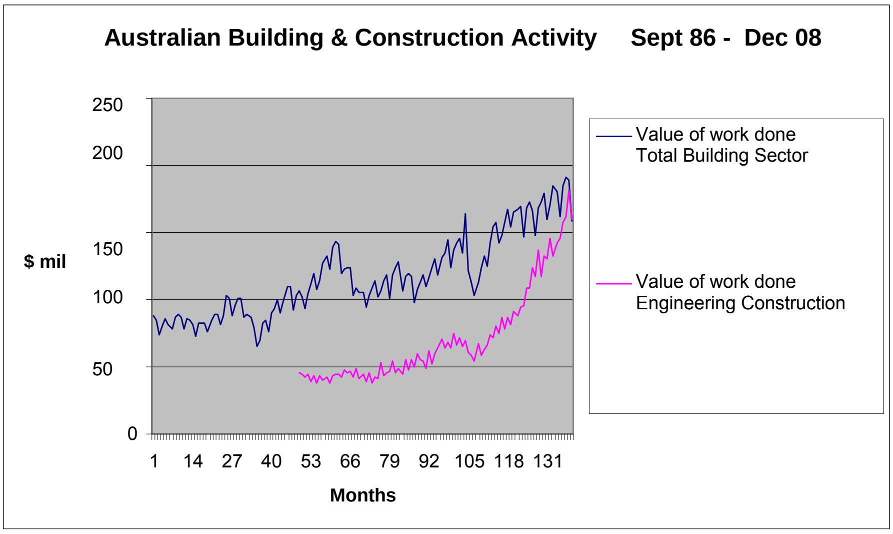

Figure 1. Australian Building & Construction Activity. Sept. 86 – Dec. 08. (Source: ABS, 2009)

On the side of safety, Lingard and Rowlinson (2006) report that in international terms the construction industry "continues to maim more of its workers each year than any other industry" (p.1). Data for Australia shows that in 2005–06, 14 360 claims for compensation were made by employees in the construction industry, accounting for 10% of all serious workers' compensation claims. This equates to 39 employees each day requiring one or more weeks off work because of work-related injury or disease (ASCC, 2008). This incidence rate is significantly worse than the Australian average (Figure 2).

So we are confronted with a significant challenge: how can OH&S effectively be managed in an industry characterised by such complexity?

Lingard and Rowlinson (2006) provide a useful summary of past approaches and some insight into how we may progress into the future. In particular, they stress the importance of design, the need to build OHS standards into competitive tenders, and the importance of understanding safety as a social and moral responsibility. They discuss the perennial question of whether accidents are the result of the worker or the system, and survey a range of modelling approaches that help us to better identify and understand risk. In particular, they comment on "the need to change the culture of the construction industry from one in which risks are regarded as an inherent part of the job to one in which employees at all levels actively care about not only their own OHS, but also the health and safety of others" (p. 318). They argue all levels of managers must demonstrate commitment to OHS, and emphasise that OHS management systems should not be centralised and bureaucratic.

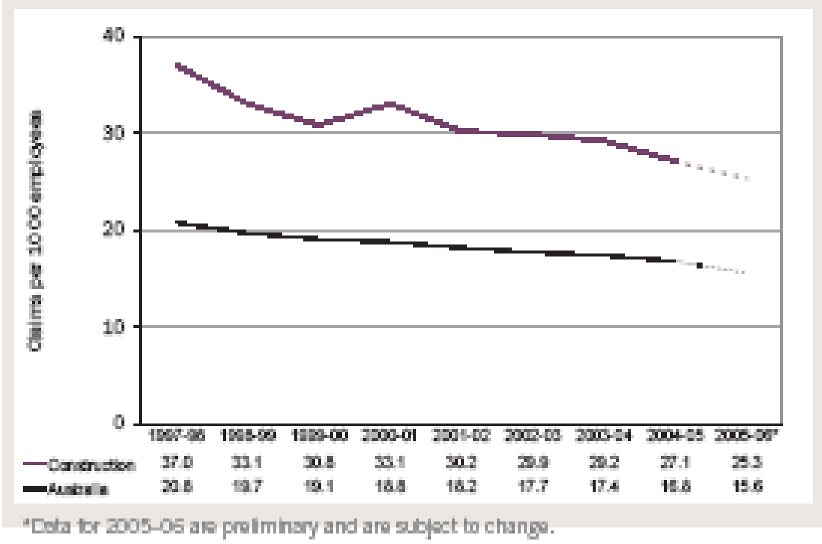

Figure 2. Incidence Rate of Serious Compensated Claims (Source: ASCC, 2008)

But how is this to be achieved? Lingard and Rowlinson (2003) draw on their observation that the construction industry fails to learn from its experience of occupational injuries and illnesses to point the way to the future; they argue the way forward is to apply the principles of "organizational learning" to OHS management.

This paper supports this view and argues that in order to create this future we need to better understand the way OHS management approaches are framed and how these approaches facilitate learning.

To develop this argument, this paper explains the way in which safety and OHS management systems can be framed using different "world views" and corresponding systems approaches and the way in which this relates to learning on the job. In fact, these approaches are not entirely new in the safety industry, but in this paper they are framed as a hierarchy with increasing explanatory power; they provide a *systemic* approach to managing risk and OHS. Failure to recognize the importance of this hierarchy has been revealed in the Victorian Bushfire Royal Commission where it it has been reported (ABC News, 1 July, 2009) that "Counsel assisting the Commission have found Victoria's fire agencies were ill-prepared for Black Saturday"; management, communication, and physical systems with relatively low levels of capability were no match for the catastrophic events of Black Saturday.

FRAMING OHS LEGISLATION AND MANAGEMENT SYSTEMS

Harcourt (1996) identifies four different approaches to OHS:

- The "market" approach in which dangerous work is compensated with wage premiums;
- The "regulatory" approach in which standards are set to limit hazard levels or prescribe safe production methods approach;
- The "accident compensation" approach in which employers are rated on their safety record with consequent effects on insurance premiums; and
- The "workers' rights" approach, in which workers can refuse unsafe work.

Harcourt is critical of the first three approaches; he argues that the market approach can be subjected to employer coercion and the lack of employee power to bargain for appropriate rates; the regulatory approach is hard to enforce and difficult to apply in hazardous situations; and the accident compensation approach fails because it does not link employer costs to unsafe conditions. He favours the fourth approach because it helps detect hazards and provides the incentives for their prevention and rectification. There can be little doubt that workers in the construction industry would support Harcourt's preference. Employers may not be so convinced and would cite cases in which unions are alleged to use this approach to coerce other workers into boycotting sites for political reasons under the aegis of safety.

It is not the purpose in this paper to explore the advantages and disadvantages to these approaches, but to simply point out that each approach adopts a different perspective of the OHS situation and that we learn by debating the differences and adopting one or another approaches as a basis for practice. That is, we recognise the "creative tension" inherent in studying and applying these different approaches.

This is the essence of what is being proposed in this paper: we identify four world views and corresponding systemic ways of approaching OHS, and we debate their advantages and disadvantages and secondly, we learn from our attempts to implement them.

Before detailing the hierarchy of systems approaches being advocated, it will be useful to clarify the usage of the term "system". As Lingard and Rowlinson (2006) explain in reference to their discussion of the "socio-technical approach", AS/NZS 3931:1998 defines a system as:

> [A] composite entity, at any level of complexity, of personnel, procedures, materials, tools, equipment, facilities and software. The elements of this composite entity are used together in the intended operation or support environment to perform a given task or achieve a specific objective (Standards Australia, 1998).

This definition emphasises the notion of physical "parts and wholes", and the way they combine in support of a given outcome, the "systems' purpose". Specifically, parts are identified with tangible entities such as personnel, procedures and materials etc. This definition pretty much aligns with the colloquial use of the term "system" and what systems theorists identify as a "mechanical" view of the universe. But, this definition makes no sense when, for example, you refer to a "system of ideas". This indicates that we need a more general concept of what a system is. One such definition is that a system is a conceptual framework that we use to help make sense of complexity (Lilienfeld, 1978; Barton and Haslett, 2007).

Digging a bit deeper, we learn from cognitive science that conceptual frameworks are essentially metaphorical (Lakoff and Johnson, 1999) and that there are essentially four metaphors that drive our thinking (Pepper, 1942): Formism, a lens through which one sees categories of similar and different events; mechanism, a world view that causes one to see controllable machines with inputs, outputs, processes and feedback; Organicism, a world view sees the world as an organism evolving in response to the environment; and Contextualism, which sees operators in the world who influence the environment and are influenced by it.

Applying this thinking to OHS, depending on your world view, you see different management systems, develop different organisational cultures and use different risk equations to think about risk.

Using Pepper's world views we can establish a hierarchy of systems approaches:

- Classification systems. These systems are based on being able to recognise similarities and to group things accordingly. Common examples include library classifications, accounting systems, and hazard classification systems. Classification systems provide a language which allows us to communicate about systems. They ususally constitute our first mode of thinking when we see something new: the first questions that come to mind are "have we seen this before? "and, "is it like anything else I know about?"
- Mechanistic systems. These systems view things as machines. They can be static or dynamic machines. Examples include thinking about organisations as machines; supply chains; competitive markets; economic systems; process models; and building systems.
- Organic systems. These systems view entities as organisms that go through a life cycle. They exist within an environment and *passively adapt* to environmental change. Examples include

thinking about networks of relations; self-organising systems and emergent systems. An important organic systems perspective that relates to risk is the study of highly interconnected systems that can turn catastrophic as the result of some small change within the system- the "butterfly effect". This framework helps us to understand the dynamics of weather systems, bush-fire behaviour and structural collapses.

- Open systems in which people and organisations form systems that interact with their environments, or contexts; they constitute "social ecologies". Four sets of dynamics interact: internal dynamics of the system; external dynamics in the environment; dynamics in which the system impacts on the environment; and dynamics in which the environment impacts on the system. Such systems allow for the *purposeful adaptation* to and by the environment. They allow for learning and reflection and provide the basic metaphor for understanding human learning and the co-evolution of systems and their environments. Such learning systems lie at the heart of team learning constructs such as those found in quality management (the Deming cycle) and six-sigma processes.

Pepper's world views and their corresponding systems approaches are summarised in Table 1.

Table 1: Relating Pepper's World Hypotheses to Systems Approaches

Pepper's World Hypothesis (Metaphor)	**Systems Approach**
Formism	Classification Systems
Mechanism	Physical/Engineering/Hard Systems
Organicism	Organic/Biological Systems, including complexity and chaos; evolutionary systems
Contextualism	Open/ Purposeful Human Systems; social ecology and co-evolution

While the first two systems approaches emphasise *analysis,* in that you attempt to learn about the whole by studying the parts, the second two emphasise *synthesis* in that you attempt to learn about the parts by looking at properties of the whole. Analytic systems tend to explain *how* something works; synthetic systems help us understand the system's purpose; *why* something exists (Barton and Haslett, 2007).

It is important to understand that these systems frames complement each other. But as you will find, it is sometimes argued that for example, viewing an organisation, as a "machine" is "inappropriate", but viewing an organisation "organically" is acceptable. In fact, both views are important. Overall this hierarchy of systems approaches increases in its power to explain a given situation as we move from classification systems to an open systems viewpoint. For example, while the classification of the sectors within the building and construction industry is very useful as a reference point for classifying data etc, it does not have the explanatory power to help us understand the full dynamics of the industry as it has developed over the past twenty years. A mechanistic interpretation of supply and demand will give us a better understanding, and better still will an organic view of the way the industry has emerged with developments in building technology, for example. But the most complete explanation will be obtained by understanding the way the industry has co-evolved within its socio-technical context, in which certain areas of human enterprise will have transformed the industry by adopting new building practices such as the use of rendered "blue sheet" in house cladding, or prefabricated structures in multi-story buildings, or the use of design construct contractural arrangements.

In general terms we view the first three systems frames as relating to "closed" systems and the fourth as an "open system". In thinking, we use closed systems to form hypotheses as in a laboratory, but we only really understand the implications of our hypothesis when it leads to action in the real world. Consequently, in considering risk, we can make an estimate of the risk based on closed system laboratory tests, but the risks may only be revealed in the longer term as a result of using a material in the open systems context of the actual construction process as we have found with materials such as asbestos.

When developing a more complete approach to OHS we need to apply all these modes of thinking. In fact, as will be discussed below, aspects of each of these approaches have been used in OHS; it is just that the way they complement each other to form a more robust systemic approach is not recognised.

APPLYING SYSTEMIC THINKING TO OHS IN THE CONSTRUCTION INDUSTRY

One of the most significant examples of the application of systemic thinking in OHS in construction relates to the shift from the traditional approach of detailed and prescriptive standards to performance and process-based standards (Johnstone, 1999; Breslin, 2004). The prescriptive approach is based on classification systems and assumes an ability to be able to classify hazards and design corresponding processes for their mitigation and/ or control. For example, we recognise that falling objects represent hazards on a building site so we institute a standard for wearing hard hats and back this with compliance legislation. Such approaches are very beneficial in creating awareness. For example, evidence suggests that regulations (based on classification systems) relating to the handling and storage of hazardous chemicals in the construction industry show promise by increasing awareness of chemicals in the workplace, better control of hazardous substances and improved integration of chemical safety into workplace management (Pearson et al, 1995).

But as Breslin (2004) reminds us, the Cole Royal Commission into the building and construction industry has highlighted the fact that despite the “overabundance of laws and tribunals set up to regulate OHS in this industry in Australia, it has one of the poorest safety records in the country” (p. 563). In the language of systems, it is being suggested that the prescriptive approach does not have the “requisite variety”, that is “the smarts”, with which to adequately manage all aspects of OHS in an industry as complex as construction.

The shift to more process orientated (mechanistic) approaches is usually traced back to the Robens Report 1970-72, which inquired into safety and health at work in the UK (Brooks, 2001). Brooks traces this development over a period of 30 years and attempts to make an assessment of “systems-standard legislation” (p. 363). He concludes that a key benefit of this development has been the ability to link performance measures with systems standard provisions (p.363). Of course, the systems construct that Brooks is referring to is the mechanistic framing of processes that, for example, ignores systems of power, which would be a significant oversight when considering the building industry. In the same vein, Mitchell (2000) considers the importance of both input and output performance measures for the construction industry and proposes a set of 22 “positive performance” measures. Perhaps of greater significance to safety in construction is the attempt to develop safe design guidelines so that upstream hazards can be eliminated (Breslin, 2007) which is clearly using a mechanistic process view of construction.

These process approaches reinforce Reason’s (1997) socio-technical systems-based model of human error. “According to Reason, organisational factors, such as budget allocation, communication, planning, scheduling and unwritten rules about acceptable practices within the company are the starting point for organizational accidents” (Lingard and Rowlinson; 2004, p 25). But, as Emery and Trist (1965) point out, the socio-technical perspective is still essentially mechanistic in nature; it was this realisation that gave birth to the social-ecology perspective (Trist, Emery & Murray, 1997).

It is significant that the majority of OHS thinking applies the first two systemic frameworks-classification systems and process/machines. These presume a relatively clear view of risk, but start to struggle when it comes to incorporating more extreme hazardous situations, for which organacist approaches are more appropriate. Suddenly we are in a sparse landscape where we find an emphasis on approaches such as “crisis management” (Lingard and Rowlinson, 2003). But, despite attempts by Campbell (2004) and others to include processes for the early identification of major hazards and their mitigation, they have an aura about them that suggests we become experts on cleaning up the mess resulting from catastrophes rather than preventing them. Apart from a small number of examples, such as McLucas (2003), where attempts were made to better understand the non-linearities of catastrophes, there appears to be a significant gap in research into catastrophic processes in the building and construction industry. Too often, as McLucus points out, recommendations by inquiries into catastrophes are made within the context of the prevailing world views that are really part of the problem, and so nothing really fundamental changes.

McLucas uses methods such as causal mapping, developed from investigations into aircraft accidents, to describe feedback dynamics; this method may have a significant role to play in understanding the dynamics associated with extreme accidents such as building collapses. In addition, there would appear to be an important opportunity for researchers to consider the role played by "local rules" in establishing what really goes on in managing safety on a construction site (Haslett and Osborne, 2000).

Significantly, there is considerable evidence of attempts to adopt the learning constructs inherent in the fourth approach to systemic framing: the social-ecology or open systems approach. This is the domain of purposeful behaviour and learning, the approach Lingard and Rowlinson (2003) see as the way of the future. An interesting feature of this approach is the way in which it utilises the power of the previous three approaches in support of its learning agenda. In this approach, frameworks using the first three world views can be used within the learning approaches defined by the fourth world view. Although not identified as such, this approach is demonstrated in the Victorian WorkCover Authority's approach to safety management systems (SMS) for major hazard facilities (see Figure 3). This approach advocates a series of SMS tests based on classification, and control measures based on a mechanistic control systems approach as major inputs into a co-evolutionary, open systems, management system which can be described as an action research cycle (Barton and Haslett, 2009; Tepe and Barton, 2009).

Such open systems learning frameworks are also implicit in the discussion of self management and team processes (MacIntosh, 1994); worker participation (Gunninham, 2008) and union participation (Warren-Langford et al, 1993).

Consequently, while we observe that various systems approaches have been applied to OHS management, they have been applied without recognition of the existence of a hierarchy of systems thinking approaches. This hierarchy is based on a number of world views or metaphors that frame complexity and show how we can manage risk within an experiential learning framework (Tepe and Barton, 2009). Indeed, this pluralistic approach constitutes a risk management strategy in itself, hedging against the type of human fallibility evidenced by our continuing difficulties in understanding the nature of systemic risk.

In summary, recognition and understanding the systems hierarchy based on Pepper's world views facilitates a systemic approach to OHS whereby the complexity of individual risk situations can be matched with an appropriate systems approaches and learning frameworks and where the viability of the total risk management system can be understood (see Tepe and Haslett, 2002).

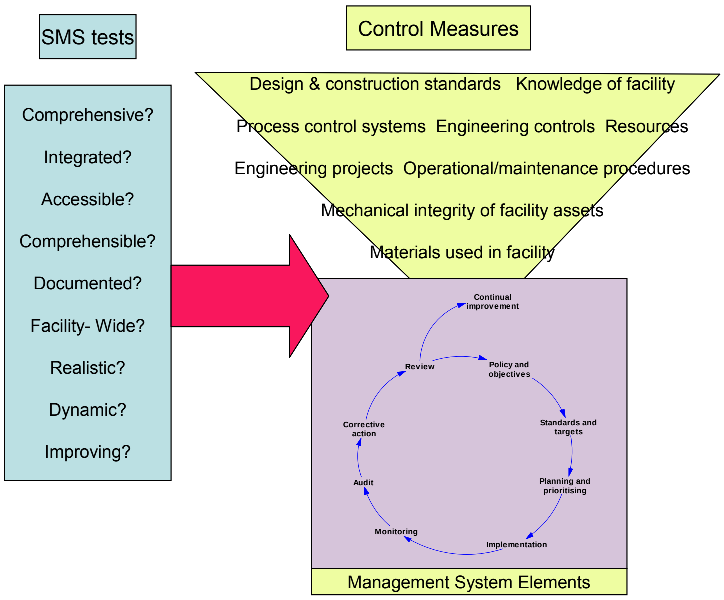

Figure 3. Victorian WorkCover Authority: Safety Management Systems under the OHS (Major Hazard Facilities) Regulations

CONCLUSION

All will agree that the construction industry is complex and, with the increasing rate at which the workplace is being "refashioned" to encompass more flexible work arrangements and increased worker participation (Johnstone et al, 2005), new approaches to OHS need to be developed. This paper supports the contention that on-the-job (experiential) learning will form the core of these new approaches. But for these approaches to work, this paper argues that they need to be linked to a hierarchy of systems approaches that have the intelligence to cope with all forms of hazard that exist on a construction site.

At the present time, while there is significant evidence of experience in applying these approaches in one form or another in the construction industry, but the overall approach is not systematic and is particularly exposed to systemic risk and catastrophic events.

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EVALUATION OF WORKERS' PERCEPTION ABOUT OCCUPATIONAL INJURIES IN WORK ZONES

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ABSTRACT
In the United States occupational fatalities in construction increased on average 0.8% per year from 2003 to 2006, while the fatality occurrences in highway, street, and bridge construction as a segment of the construction industry, increased on average 5.5% per year during the same time frame. Most of these accidents occurred in construction and maintenance work zones. This study analyzed an Occupational Safety and Health Administration (OSHA) database with 202 fatal occupational accidents reported for the 2000 to 2006 period in work zones throughout the United States. New classifications of human-behaviour causes of occupational injuries in work zones were developed to complement those currently used in the construction industry. Surveys were distributed to work zone personnel for evaluating their perceptions of causes of accidents in work zones. In the surveys, workers rated "lack of awareness" as a secondary accident cause, which contradicts the results obtained from the analysis of the accident reports. A binomial logit model was developed to find the factors that influence the perception of workers regarding "lack of awareness" as a primary factor for the cause of accidents. The model revealed that the probability of a worker choosing "lack of awareness" as a primary cause of accidents was reduced when the workers had more than two years of experience, were drivers or equipment operators, or were workers who regularly attended safety meetings.

Keywords: Safety, Accident causes, Human-behaviour, Perception, Occupational injuries, Binomial logit model, Highway, Work zone, Construction, Maintenance.

INTRODUCTION
The interaction between project personnel, passing motorists, and mobile equipment in a restricted area makes a work zone a risky place for construction workers. Highway construction workers are often exposed to fatal injuries involving passing traffic vehicles and construction equipment operating in the work zones (Pratt et al. 2001). Past research efforts have focused mainly on reducing the occurrence of injuries involving passing traffic vehicles. This study focuses on identifying the causes of accidents in work zones and the evaluation of the perception of work zone personnel about accident causes in order to formulate more appropriate safety strategies to reduce the number of serious and fatal occupational injuries in work zones.

PRIOR STUDIES IN IDENTIFICATION OF CAUSES OF ACCIDENTS IN WORK ZONES
Successful safety programs should be focused on addressing the root causes of workplace injuries. Recent efforts have been pursued to identify these root causes of occupational injuries in construction. Table 1 describes key accident causation models that were extensively evaluated in this study, as they consider behavioural causes to be significant in the causation of accidents. This list of accident causation models is not exhaustive. Gibbs et al. (2006) provides a good overview of other accident causation models. None of the prior models that were analyzed in this study were developed for highway construction nor did they evaluate the perception of the construction workers who are the individuals, primarily affected by accidents in work zones.

Table 1 Accident causation models developed to explain construction accidents

Accident Causation Model	Description
Accident Root Causes Tracing Model (ARCTM)	Abdelhamid and Everett (2000) proposed the accident root causes tracing model (ARCTM) which is based on the hypothesis that an occupational injury occurs due to one or more of the following root causes: (1) failing to identify an existing unsafe condition or a unsafe condition that developed after an activity had started, (2) the worker proceeding to work after the unsafe condition was identified, and (3) the decision from the worker to act in an unsafe manner regardless of the initial conditions of the work environment. In the case of a fatal occupational injury, the investigator is not able to determine the injured worker's version. Thus, it is not possible to answer many of the questions that are part of the model
Constraint-Response Model	Suraji et al. (2001) developed a model that takes into account the constraints experienced by and responses used by different parties during pre-construction and the construction phases of a project. The model classifies causal factors in two general types, proximal and distal. The former are factors that directly cause accidents, and the latter are those factors that occur due to inappropriate responses by project participants to constraints and that can cause proximal factors, thereby increasing the likelihood of accident occurrence
Behavioral Root Causes Model	Toole (2002) suggests that all construction accidents result from at least one of eight root behavioural causes. Five of this causes are due to deficient safety management from the employer (i.e., lack of proper training, deficient enforcement of safety, lack of proper safety equipment, unsafe methods and task sequencing, and unsafe site conditions), and the remaining three result from unsafe acts by the injured worker or co-worker (i.e., not using providing safety equipment, poor attitude toward safety, and an isolated freak accident)
Systems Models of Accident Causation	Mitropoulos et al. (2005) developed a conceptual model based on the interactions of production factors, hazardous situations, and the conditions that activate the release of hazards. Hazards in the model are a function of the activity, the context of the activity (physical conditions and surrounding activities), the randomness of the conditions, and task unpredictability (i.e., when an activity cannot be accomplished as expected). Injury incidents are the result of a worker being exposed to a hazard overlapping with an error from any individual involved in the construction activity.

DATA COLLECTION

This study focuses on identifying the causes of accidents in work zones and the evaluation of the perception of work zone personnel about accident causes. The first step was accomplished by analyzing accident reports of fatal incidents that occurred in work zones. The results arising out of this analysis guided the development of surveys which were distributed to work zone personnel who evaluated the likelihood of the occurrence of various causes leading to serious accidents.

Use of Accident Reports for Determination of Causes of Accidents

A database with 202 accident reports involving 213 occupational fatalities that reportedly occurred in work zones during the 2000-2006 timeframe in the United States was obtained from OSHA. The reports in the database contained the following information: date and time of the incident, incident location (state and street), accident event, demographic information of the injured worker, number of employees at the site, the number of total employees, the cost of the project, the identity of the employer, the employer's code for the Standard Industrial Classification (SIC) and the North American Industry Classification System (NAICS), an accident abstract, and a description of the accident. Unfortunately, not all the data was available in each report in the database. The accident descriptions included in the reports were used to classify the data into behavioural causes of the accidents. Table 2 describes the classification of the incidents according to seven behavioural causes groups.

Table 2 Incident classification according to behavioural causes

Behavioural Cause	Description
Negligence of a third party	Associated with individuals not related to the construction/maintenance project, including drivers/owners of intruder vehicles (vehicles without brakes, drunk drivers, a driver who does not follow the orders given by a traffic controller).
Lack of awareness from injured worker	Accidents occur when the worker is not aware of possible hazards (e.g., distracted worker run over by a dump truck backing up).
Unsafe methods or sequencing	The normal sequencing of construction activities does not occur, resulting in an activity being more hazardous than it usually is (Toole 2002); for instance, a worker installing traffic control devices without the appropriate protection, the use of malfunctioning equipment).
Worker misjudgement of a hazardous situation	Accidents occur when a worker does not consider the risk that some circumstances represent (e.g., worker walking along a highway median outside the protection zone, worker stepping into an active lane).
Co-worker lack of awareness and/or misjudgement of a hazardous situation	Accidents occur when a worker does not consider the risk that an activity might represent to a fellow worker or is unaware of the presence of other workers who might be injured while performing usual activities (e.g., a dump truck driver who starts moving his/her vehicle forward without noticing the presence of workers in front of the truck)
Lack of traffic control devices	This behavioural cause is linked directly to the employer and occurs when the employer (e.g., contractor) does not have in place sufficient traffic control devices (e.g., when there are insufficient signs, concrete barriers might be needed but they are not in place).
Not using provided safety equipment	As described in Toole (2002), accidents occur when a worker is provided with safety equipment but does not use it appropriately or simply does not make use of it (e.g., employee working in an elevated bucket not using available fall protection).
Not classifiable	This category is for incidents that could not be classified in any of the above categories due mostly to insufficient description of the events or because the incidents occurred due to isolated circumstances (e.g., suicide)

Use of Surveys for the Identification of Perceptions of Work Zone Personnel

Surveys were distributed to work zone personnel within State Departments of Transportation (DOT), construction companies in the Midwest of the United States, and a County Highway Department in the State of Indiana (USA). These surveys were designed for (1) workers within the three aforementioned sample populations, and (2) personnel with safety managerial roles in DOTs and construction companies (e.g., supervisors, project engineers and safety managers). Some of the questions were identical in the surveys for workers and supervisors in order to address the perspectives of all relevant parties involved in a work zone project on certain subjects; as in the case of the perception of the likelihood of occurrence of different behavioural causes of accidents in work zones. The surveys were distributed between June and September 2007 through e-mail, and during site visits to projects and highway maintenance facilities located in Indiana.

DATA ANALYSIS

Two sets of data analysis were performed in this study: (1) analysis of the reports of fatal accident in workzones and (2) analysis of the surveys distributed to work zone personnel. In the first case, a descriptive analysis was conducted using graphic, tabular and summary statistic descriptors based on the accident cause classifications described in section III, and the characteristics of the injured worker(s) and the project where the accident occurred. For the second phase, a descriptive analysis was performed along with a binomial logit model to statistically analyze the perception of workers of the likelihood of occurrence of one of the major behavioural causes of work zone accidents identified in the first phase of the analysis of this study.

Use of a Binomial Logit Model

When a descriptive analysis of the data obtained from the surveys implemented with workers was performed, it was determined that on average, workers rated the “lack of awareness” as one of the behavioural causes likely to occur in work zones. The authors were interested in identifying what caused the “lack of awareness” to be an important factor in accident causation, as a step towards identifying safety strategies to improve awareness of safety hazards in work zones. A binomial logit model which is a discrete outcome model was chosen to statistically identify and link the factors that influence the perception of workers of the likelihood of occurrence of “lack of awareness” as the primary cause, or one of the major behavioural causes of work zone accidents.

In the survey implemented with workers, the likelihood of occurrence of “lack of awareness’ as a cause of accidents in work zones was rated from one to five, with one and five representing the events with the least and the most likelihood to occur. Since a binomial logit model has only two outcomes, the responses obtained from the survey were converted into one or zeros. The observation was changed into one when the “lack of awareness” score provided by a worker was the highest or tied as the highest score among all behavioural causes of accidents. When this condition was not fulfilled, the observation data point was changed to zero.

The independent variables (or covariates) that were considered for the development of the model can be categorized into two groups: (1) characteristics of the worker and (2) characteristics of the safety orientation received by the worker. In the first group, characteristics such as ethnicity, age, gender, occupation (i.e., construction labourer, flagger or traffic controller, heavy equipment operator, driver, maintenance worker, foreman, survey crew member, inspector, highway technician), and type of employer (i.e., State DOT, construction company, and county highway department) were used for the development of the model. The second group is comprised of the following characteristics: experience time in highway construction or maintenance, knowledge of “Safety and Health” program, whether or not workers’ opinion was requested by their employers for safety improvement, the frequency that employers conduct safety meetings, and the frequency with which workers are assigned to perform activities for which they have not received formal safety training.

According to Washington et al. (2003), the standard multinomial logit formulation is shown in Eq. 1, with I being the total number of outcomes for observation n, P being the probability of observation n having discrete outcome i ($i \in I$), βi as the vector of estimable parameters for discrete outcome i, and Xin is the vector of the observable characteristics (covariates) that determine discrete outcomes for observation n.

$$P_n(i) = \frac{EXP[\beta_i X_{in}]}{\sum_{\forall I} EXP(\beta_I X_{In})} \qquad (1)$$

In the case of this study, the probability had only two outcomes (binomial). So the probability equation is rearranged into:

$$P_n(1) = \frac{EXP[\beta 1X]}{1 + EXP[\beta 1X]} \qquad (2)$$

Washington et al. (2003) states that for estimation of the parameters coefficients (betas), Eq. 3 is solved by maximizing the value of the log likelihood function (LL). In the equation, δin is defined as being equal to 1 if the observed discrete outcome for observation n is i and zero otherwise.

$$LL = \sum_{n=1}^{N} \left(\sum_{i=1}^{I} \delta_{in} \left[\beta_i X_{in} - LN \sum_{\forall I} EXP(\beta_I X_{In}) \right] \right) \qquad (3)$$

RESULTS OF THE STUDY AND IMPLICATIONS

As in the case of the data analysis, the results of this study are structured into two main groups: (1) Determination of human behavioural causes in work zones, and (2) identification of the perception of work zone personnel.

Determination of Causes of Serious and Fatal Accidents in Work Zones

The number of fatalities encountered in the reports was almost similarly distributed during the seven-year period (2000-2006) with the exception of 2004, when there were a maximum of 43 fatalities for the period. Information about gender was available for 209 of the 213 fatally injured workers; ninety percent of them were male. The age of the fatally injured workers varied from 17 to 72 years old. Twenty-seven percent of the victims were between 35 and 44 years old.

Interesting findings encountered from the descriptive analysis of the reports are as follows: (a) Sixty-five percent (131 out of 202) of the incidents were caused by intruder vehicles, and 21% (43) by vehicles that were part of the project (e.g., mobile equipment); (b) Forty four out of the 213 victims were flaggers, which is a significant number considering the low percentage of the workers who are flaggers in regular work zone projects; (c) 22% of the incidents occurred in projects which cost was less than $50,000; (d) eighteen percent of the fatal incidents occurred while workers were setting up, retrieving, or removing traffic control devices (cones, barrels, concrete barriers); (e) the month with the largest number of fatal incidents was October with 22 incidents. This month was also found to be the most significant in number of fatalities by Hinze et al. (1998) and Arboleda (2002) in an analysis of general construction accidents and accidents in trenching construction respectively.

Using the categories listed in Table 2, the accident reports were classified into behavioural causes of work zone accidents as shown in Table 3. The classification of the incidents shows that most of the fatal incidents occurred due to “negligence of a third party” followed by “lack of awareness of the injured worker”, which is the major category relating the cause of the accident to project personnel.

Table 3 Distribution of work zone fatal occupational incidents according to behavioral causes, all U.S., 2000-2006

Behavioural Cause	Number of Incidents	% of Total
Negligence of a third party	52	25.7%
Injured worker’s “lack of awareness”	36	17.8%
Unsafe methods or sequencing	26	12.9%
Misjudgement of a hazardous situation from worker	15	7.4%
Lack of traffic control devices	11	5.4%
Co-worker’s “lack of awareness” and/or misjudgement of a hazardous situation	10	5.0%
Not using provided safety equipment	7	3.5%
Not classifiable	45	22.3%

Identification of the Perception of Work Zone Personnel

Through the implementation of surveys, work zone personnel were asked to evaluate the likelihood of occurrence of the aforementioned behavioural causes. The scale for this evaluation was from one to five, with one and five representing the events with the least and the most likelihood, respectively to occur. The most interesting finding was that workers rated “lack of awareness” as the least likely behavioural cause of accidents to occur, with an average score of 2.9. However, supervisory personnel rated it as the most likely to occur in a work zone tied with “negligence of a third party." Table 4 shows the average scores provided by work zone personnel about the likelihood of the occurrence of each of the causes.

Workers' Perception of "Lack of Awareness" as a Major Behavioural Cause of Accidents

To model the likelihood that a worker considers "lack of awareness" as the primary, or one of the main behavioural causes of work zone accidents, a binomial logit model was developed. The model chosen has the form of Eq. 4 with the utility factor V(la) with the form of Eq. 5.

Table 4 Average scores provided by workers and supervisors for the occurrence likelihood of behavioral causes of accidents

Behavioural Cause	Average Score for Workers	Average Score for Supervisors
Lack of awareness by injured worker	2.94	3.96
Misjudgement of a hazardous situation by injured worker	3.24	3.88
Co-worker lack of awareness and/or misjudgement of a hazardous situation	3.23	3.67
Lack of traffic control devices	2.94	2.75
Negligence of a third party	3.98	4.00
Unsafe methods or sequencing	3.14	2.96
Not using provided safety equipment	3.01	3.17

Ninety-eight observations were used for the model. The model has a log-likelihood function of -57.69 and a chi-square equal to 17.16. This log-likelihood function value was the maximum for the models tried. The chi-square value shows that the goodness of fit for the data is appropriate with a more than 99% confidence interval. All variables included in the model decrease the probability that a worker chooses "lack of awareness" as the primary or one of the major behavioural causes of accidents.

$$P(la) = \frac{e^{V(la)}}{1 + e^{V(la)}} \tag{4}$$

$$\mathrm{V(la)} = 2.48 - 1.24(\mathrm{EXPER}) - 1.64(\mathrm{OFTSM}) - 1.88(\mathrm{HEODRIV}) - 0.99(\mathrm{ASSIG}) \tag{5}$$

Three of the variables in the model were found to be significant at a confidence level of 95%, whereas the remaining variables were found to be significant at a confidence level of 90%. The parameters estimates, the t-statistics, and the p-values for each independent variable are described in Table 5.

Table 5 Description and summary statistics for variables in the binomial logit model

Explanatory Variable	Variable Mnemonic	Estimated Parameter	t-stat	P-value
Constant	ONE	2.48	2.81	0.0050
Worker with more than two years of experience in road construction or maintenance activities	EXPER	-1.24	-2.46	0.0139
Worker employed by a company or state entity that always conducts at least one safety meeting per month	OFTSM	-1.64	-2.31	0.0210
Driver or heavy equipment operator	HEODRIV	-1.88	-2.42	0.0157
Worker assigned to perform an activity without receiving safety training for that activity	ASSIG	-0.99	-1.88	0.0608

The model presented two major groups of workers: safety oriented and non-safety oriented workers. The former consists of workers with two or more years of experience and workers who attended at least one safety meeting per month. The second group consists of workers who perform activities without the appropriate safety training for those activities. For both groups of workers there was a decrease in the probability of choosing "lack of awareness" as a main behavioural cause of accidents in work zones. Table 6 shows the discussion of the outcomes obtained for each independent variable or worker characteristic.

Table 6 Discussion of the influence of the independent variables in the response variable

Worker Characteristic	Influence on the Response Variable	Discussion
More than two years of experience in road construction or maintenance activities	Reduces the Likelihood of choosing "lack of awareness" as the primary, or one of the major behavioural causes of accidents	This group of workers has had the opportunity of observing different situations involving risky situations in work zones and may consider that other behavioural causes are more likely to result in occupational injuries for workers Since experienced workers are likely to have more safety training have when compared with new employees, it is likely that they are more aware of potential hazards; therefore, they might think that they can be injured by other causes not related to their behaviours (factors such as negligence of a third party, contractor not providing sufficient or effective traffic control devices, etc.)
Employed by a company or state entity that always conducts at least one safety meeting per month		Safety meetings are conducted to provide guidance to workers about possible hazards in the work zone and ways to avoid them. Workers who regularly attend safety meetings are frequently advised to be alert in the work zones; As a result, they may believe that they are less likely to be injured due to "lack of awareness"
Worker assigned to perform an activity without receiving safety training for that activity		Workers who perform tasks without adequate safety training may perceive that they are at risk of being injured by causes related to poor safety training.
Driver or heavy equipment operator		This is a concern when workers operate equipment in the work zone, and they perceive that other workers on foot are aware of the risk involved in working in the vicinity of equipment in operation.

Limitations of the Study

A major limitation of using existing accident reports to analyze causes of accidents is the high probability that the accident reports are incomplete and not always accurate. If individuals designing accident report methods or preparing the reports do not appreciate underlying causes then it is unlikely that the appropriate questions will be asked in order to investigate root causality. The reports analyzed in this study were obtained from the OSHA database and they contain the same categories of information. However, the depth of data, particularly as it related to accident description was often subjective.

The authors recognized the potential for bias, when classifying behaviour without observing the context of the situation or conducting interviews. Although accident descriptions were classified using consistent definitions (to ensure internal validity), it is not evident that biases have been completely eliminated. This may have led to the differences in the results obtained from the analysis of the OSHA accident reports and the analysis of the surveys completed by work zone personnel.

CONCLUSIONS

The analysis of accident reports indicated that existing categories for classifying construction accident data into behavioural causes do not entirely describe the work zone accidents. In this study, new behavioural causes, not explored by previous studies, were found to be significant in explaining the causes of injuries. Examples of these classifications are *negligence of a third party*, *lack of traffic control devices*, *and lack of awareness from the worker who was injured*.

The two most relevant behavioural causes of work zone accidents from the accident reports were "*negligence of a third party*" and "*lack of awareness from the workers*." However, in surveys administered to workers, the latter cause was rated as the least likely to occur in work zones. Utilizing the data collected from the worker survey, the binomial logit model revealed that the characteristics of the respondents found to be significant in reducing the likelihood of workers choosing "lack of awareness" as the primary, or one of the major, behavioural causes of accidents were (1) workers with two or more years of experience in road construction or maintenance; (2) workers who attended at least one safety meeting per month; (3) drivers and heavy equipment operators; and (4) workers who were assigned to perform an activity without receiving appropriate safety training for that activity. Injuries related to "lack of awareness" from the workers can be reduced by implementing safety orientations to influence the perception of a specific group of workers. For instance, heavy equipment operators and drivers should be persuaded to be alert of the presence of workers on foot and acknowledge that these workers may not always be aware of the equipment or vehicles operated within the work zone.

ACKNOWLEDGEMENTS

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TRACKING THE CAUSES OF FIRST AID INJURIES

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ABSTRACT
It is common in the U.S. to gauge or monitor safety performance by tracking information related to the incidents in which the injury is sufficiently serious to warrant treatment by a physician. More serious injuries, such as lost workday cases, are commonly monitored, but their frequency is considerably less, making them a less desirable measure for tracking causation. Firms that embrace the zero incidents philosophy regularly report considerable successes in achieving good safety performances. As the number of the injuries decline, there is less injury information by which to develop strategies to make further improvements in safety. The number of minor or first aid injuries, those that are treated on the jobsite with no further treatment being required, occur with considerable frequency on construction sites. One research study showed that 30 first aid injuries were incurred for every injury warranting treatment by a physician. With the higher frequency of first aid injuries, considerable information can be gleaned by assessing the causes of these injuries. The analysis of first aid injuries has shown that accident causation can be more readily identified and preventative programs can be more effectively implemented. Results of the analysis of several thousand first aid injuries has shown that valuable information can be obtained by focusing on these minor injuries. The general understanding is that when sufficient minor injuries occur, that eventually a serious injury will occur. Thus, careful attention should be given to the causes of first aid injuries.

Keywords: Accident causation, First aid, Monitoring incidents

INTRODUCTION
In the United States safety performance of construction projects or construction firms is commonly measured in terms of the number of Occupational Safety and Health Administration (OSHA) recordable injuries sustained per 200,000 hours of worker exposure. OSHA recordable injuries are essentially those which require treatment by a physician. Since the OSHA recordable injury rate is used to evaluate project performance or company performance, the information is widely used to establish general industry-wide information about these injuries. Despite this, little information is gleaned about any specific aspects of OSHA recordable injuries. More attention is generally given to fatality statistics to describe the nature of fatality accidents, along with their causation. For example, an often-cited study concerned the causation of fatalities that occurred during the inclusive years of 1985 to 1989 (U.S. Department of Labor 1990). That study found that 33% of the construction worker fatalities were due to falls, 22% were due to struck-by accidents, 18% were due to caught in/between accidents, 17% were due to electrical shock and 10% were due to other causes (drowning, asphyxiation, poisoning, lightning, explosions, etc.). Such statistics have been used to provide guidance to OSHA in the promulgation of new safety regulations. For example, OSHA emphasized fall safety in several regulatory changes that it made during the 1990s. Thus, the statistics that have been generated have been used to implement changes to improve the safety performance of the construction industry. Since the fatality rates have steadily declined during the past few decades, there is reason to believe that OSHA has been effective in improving the safety performance of the construction industry.

While there has been some success in examining fatality statistics, there are many other accidents that warrant attention. A common analogy that is made is that the more serious accidents (those resulting in fatalities or lost workday injury cases) can be likened to an iceberg, which consists of visible ice above the water surface which conceals the bulk of the mass of ice below the water surface. By focusing on fatalities, a tremendous amount of information is not considered that pertains to the less serious injuries. It is commonly accepted by progressive safety professionals that the focus of attention should be on the causation of minor accidents and close calls. These incidents occur much more frequently than fatalities and serious injuries. It is generally accepted that if a project sustains a large number of minor injuries that a serious injury can be anticipated. The difference between a minor injury and a serious injury is often only a matter of millimetres. As a result, a sustained effort to prevent the occurrence of minor injuries will also prevent the more serious injuries.

Focusing on the analysis of the less serious injuries should provide valuable information by which future injuries can be dramatically reduced. Since this information is not widely publicised, it is felt that such a study might validate the usefulness of such an effort. The intent is to examine information pertaining to the occurrence of first aid injuries and to identify any trends or patterns of injury occurrence that might be illuminated for the construction industry.

LITERATURE REVIEW

One of the early safety professionals in the United States was H.W. Heinrich (1941), an employee of Traveler's Insurance Company who publicized his views on accident causation. He concluded that for every 300 minor injuries there were 29 serious injuries and 1 fatality. In a more recent safety study conducted in cooperation with the Construction Industry Institute it was found that there were approximately 300 first aid injuries (no treatment by a physician being required), for every 10 OSHA recordable injuries, and one lost workday injury (Huang 2003, and Huang and Hinze 2006). While the types of injuries are not that same as in Heinrich's model, the principle of the iceberg is still apparent in both models.

One recent study examined the nature of injury of (first aid) cases that did not warrant attention by a physician. There were injuries sustained on projects where treatment was provided by a clinic. These injuries could be characterized as consisting of primarily first aid cases, but a small portion would also be considered to be OSHA recordable injuries. The data analysis consisted of a broad examination of construction worker injuries, but there was no detailed analysis of the information. For example, the analysis concluded that eye injuries constituted slightly more than 10% of all construction worker injuries (Hinze, et al. 2006).

Numerous studies have been conducted on the analysis of fatality statistics in construction. Since this is not the focus of this paper, these will not be summarized here. Suffice it to say that much research has been conducted with fatality data, but very little data analysis has been conducted with first aid data. The primary reason for this is probably because most companies do not track any information related to first aid injuries. That is, most companies do not document the occurrence of first aid injuries. This lends valued support for the need for further analysis of the numerous, though less serious, first aid injuries.

RESEARCH METHODOLOGY

The objective of this research was to analyze first aid data to identify any patterns or trends that might be apparent. Data were sought from several large construction firms. It was determined that first aid data are not documented by most firms. Presumably, if a worker has a minor injury, that worker simply goes to the nearest first aid kit, quickly treats the injury and returns to work without any record being made of the injury. This seems to be a typical scenario. This is different on many large projects where a nurse's station or emergency medical technician (EMT) station is maintained on the project site. The healthcare professional treats the injured workers who come to the first aid or medic station. The healthcare professional will also make an assessment of the seriousness of the injury. If the injury is deemed serious, the worker will be quickly dispatched to receive medical treatment. Once the injury of a worker has been addressed, the healthcare professional will make a record of the injury. The information is typically documented in an electronic spreadsheet. Three different firms were contacted that provided first aid information from some of their projects. There was considerable similarity between the different records that were received. The first aid injury records contained the following information:

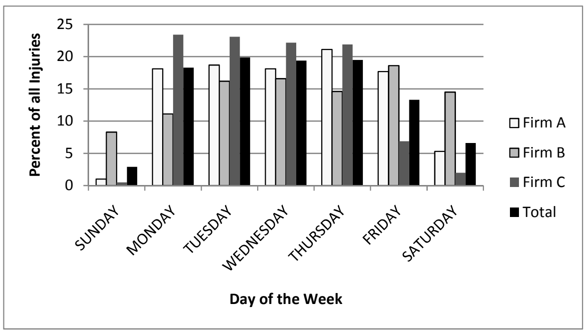
- Time of injury occurrence
- Date of the injury
- Craft of the worker
- Nature of the injury
- Cause of the injury
- Part of the body that was injured

There were 2965 first aid injuries included in the data provided by the three firms. The firms were identified as Firm A, Firm B and Firm C. Firm A was a specialty contractor performing primarily concrete work and the data represented injuries sustained on a number of commercial building projects. Firm B was a large industrial contractor, with the data representing injuries sustained on a series of industrial projects, including shutdown or turnaround projects. Firm C provided data that was accumulated on a single large power plant project. The data were analyzed with the Statistical Package for the Social Sciences (SPSS), version 16.

RESULTS

The analysis of the data was carried out in a straight forward manner. The primary analysis was to examine the frequency distributions of the 2965 first aid injuries for the various factors that were common to the databases. The date of occurrence of the first aid injuries was one of the factors that was defined for each of the cases. The month of the injury occurrence was of interest in this research, this was not examined in this study as some of the project data did not span a full year. From the date of occurrence, the day of the week of injury occurrence was determined. The overall data showed that the frequency of injury occurrence was fairly consistent between Tuesday, Wednesday and Thursday. The occurrence of injuries on Monday was slightly less and the occurrence of injuries on Fridays was considerably less. The lower level of injury occurrence on Monday cannot be readily explained, but the low incidence on Fridays is probably attributed to the practice of industrial and power plant projects not working regular hours on Fridays. When examining the data in terms of the particular firms, it should be noted that Firm A showed no discernable differences for the workdays of the week other than a slight increase in injury occurrence on Thursdays. Firm B statistics were different in that there were significant numbers of injuries on Saturdays and Sundays. These injuries may be associated with shutdown and turnaround projects which typically work around the clock for seven days a week. The occurrence by day of the week showed a slight decline for Firm C from Monday through Thursday with a significant drop on Friday (see Figure 1).

The time of day was examined in two stages. The first was to examine the distribution of injuries by the four six-hour periods in the day, beginning with the six hours between midnight and 6:00 AM. The results show that the greatest number of injuries were concentrated in the period from 6:00 AM to noon, followed by the period from noon to 6:00 PM. When specific companies were considered, it was noted that Firm A had very few injuries between 6:00 PM and 6:00 AM, probably because little concrete work was done during the night time hours. Firm B accrued a significant number of injuries between midnight and 6:00 AM, while Firm C recorded more night time injuries between 6:00 PM and midnight (see Figure 2).



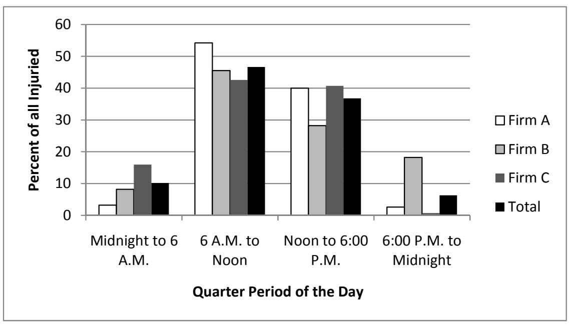
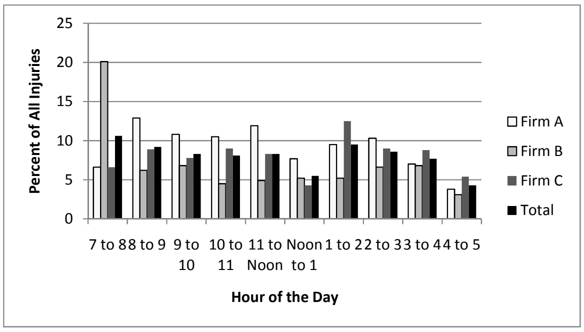


Figure 1. Injury Occurrence by Day of Week   Figure 2 Injury Occurrence by Quarter of the Day

The daytime hours from 7:00 AM to 5:00 PM were examined for the proportion of injuries incurred per hour. The overall data shows a fairly even distribution throughout the day with lower frequencies noted during the noon hour and between 4:00 and 5:00 PM. Firm B showed particularly high injury occurrence between 7:00 and 8:00 AM (see Figure 3).

The data included information on the nature of the injuries. The most common (over 50%) type of injuries were sprains, contusions and lacerations. The category of “other” accounted for over a fourth of the injuries, individually representing less common types of injuries such as insect bites, headaches, etc. The data from the different companies was quite similar, although Firm C showed more abrasions, Firm B recorded more burns, and Firm A recorded more fractures. It should be noted that the fractures would clearly be injuries beyond first aid (see Figure 4). The first aid logs tend to record all injuries, not just first aid injuries. This practice of recording all injuries in the first aid log is apparently common as each of the companies that contributed data for analysis indicated that injuries beyond first aid were commonly included in the logs.



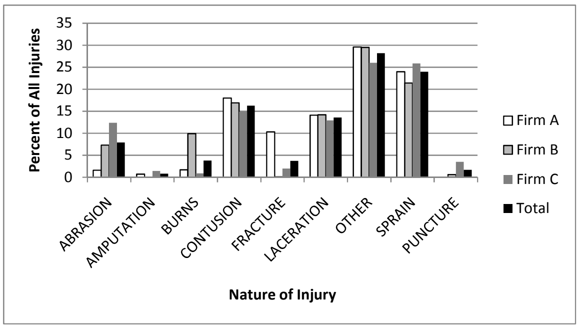
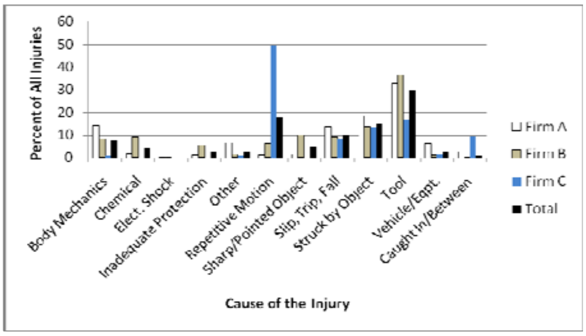


Figure 3. Injury Occurrence by Hour of Day   Figure 4 Nature of Injury

The causes of the first aid injuries were examined. The results showed that approximately 30% of all injuries were caused by tools. This was followed by being struck by objects and by slips, trips and falls. There was a high incidence of repetitive motion injuries, but these were primarily those incurred by the employees of Firm C. Fewer injuries were noted to be caused by body mechanics, chemicals, inadequate protection, pointed objects, equipment and caught in/between incidents. The distribution of the causes of injuries did not vary appreciably between the different companies. The only exceptions appeared to be that Firm A had more injuries associated with body mechanics, struck by objects and slips, trips and falls (see Figure 5).

The part of the body involved in the injuries was examined. These data were not readily retrieved from the data provided by Firm B, so only the data from Firm A and Firm C were examined. The most commonly injured body parts were the arms, hands, back and legs. The employees of Firm A, the concrete workers, sustained significantly more feet and face injuries and significantly fewer arm injuries. It should be noted that in the construction industry eye injuries account for about 10 to 11 % of all injuries. Firm A and Firm C have a policy of wearing safety eyewear at all times and this appears to be reflected in the lower number of eye injuries. Similarly, both companies have policies where workers are always to have gloves with them and to make judicious decisions about their use. In the construction industry hand injuries typically account for about 22 to 25% of all injuries. The policies of Firm A and Firm C regarding hand protection appear to be successful as hand injuries accounted for about 16% of the injuries in these firms (see Figure 6).



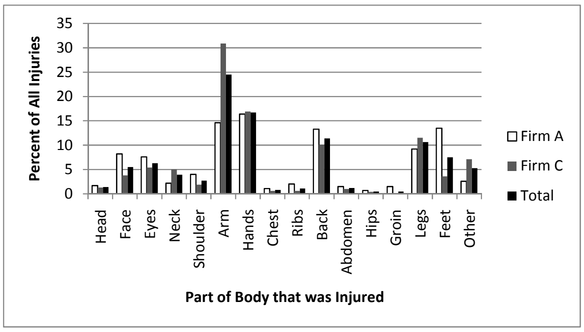
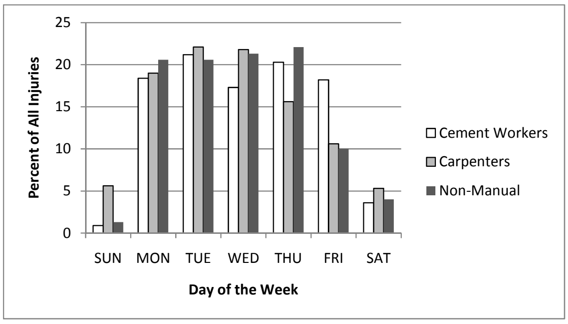


Figure 5. Causes of First Aid Injuries

Figure 6. Part of Body Injured

Additional analysis of the data considered the specific trades of cement workers, carpenters, and non-manual workers, the trades that were most numerous in the database. In the database, there were 467 cement workers, 321 carpenters and 848 non-manual employees. Most cement workers were employed by Firm A, while the carpenters and non-manual employees represented Firms B and Firm C to a greater extent. The analysis of injury occurrence by day of the week showed that cement workers had fewer injuries on Wednesday and Friday. The carpenters had a slightly lower injury frequency on Thursday and even lower on Friday. The injury frequency of carpenters was higher than the other trades on Sunday and non-manual injuries were lower on Friday.

The data were examined in terms of the four quarter periods of the day. The carpenters had fewer injuries during the two daytime periods and decidedly more injuries between midnight and 6:00 AM and between 6:00 PM and midnight. There was essentially no difference in the timing of the injuries of the cement workers and the non-manual workers.



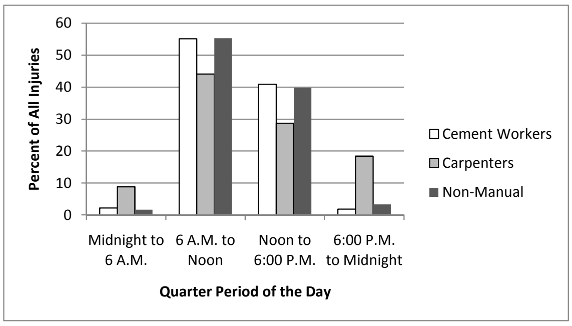
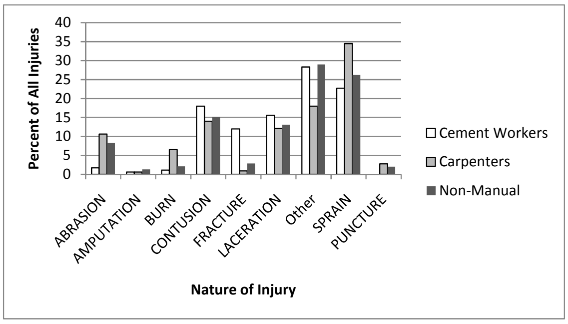


Figure 7. Trade Injuries by Day of Week

Figure 8. Trade Injuries by Time Period

When worker trade was considered in terms of the nature of injury, it was apparent that carpenters had a greater proportion of sprains and cement workers had a greater proportion of fractures. The cement workers sustained a very small proportion of abrasion injuries and burn injuries. The non-manual workers sustained a small proportion of burn injuries. Other injuries were relatively comparable among the different trades (see Figure 9).

The causes of injuries showed that all trades were comparable when the cause of injury was tools or struck by objects. Carpenters had a smaller proportion of body mechanics injuries but a relatively higher proportion of repetitive motion injuries. Non-manual workers sustained a higher proportion of injuries due to sharp or pointed objects and fewer injuries attributed to slips, trips and falls (see Figure 10).



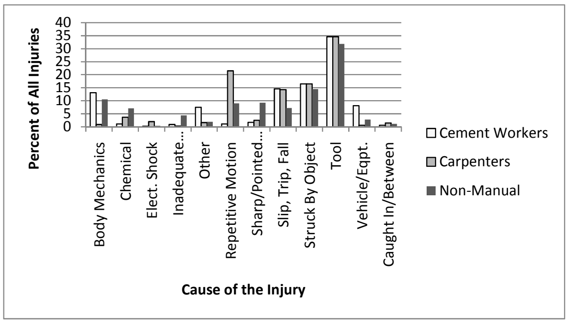


Figure 9. Trade and Nature of Injury

Figure 10. Trade and Cause of Injury

The trade of the workers were examined in terms of the part of the body that was injured. The arms, hands and back were the part of the body most commonly injured. Carpenters had a disproportionately high number of arm injuries, but they had few back injuries. Cement workers had relatively few arm injuries but more injuries to the face, eyes, back, legs and feet (see Figure 11).

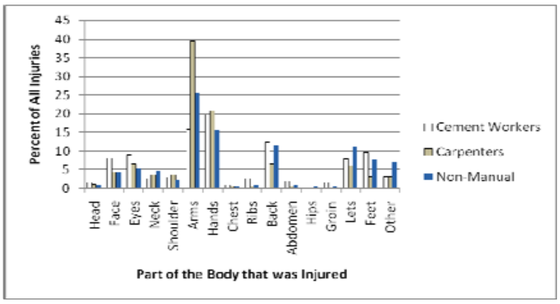


Figure 11. Trade and Body Part Injured

CONCLUSIONS

This research examined first aid injuries that were documented by three different construction companies. A general conclusion that can be drawn from the data is that the distribution of injuries may follow a general pattern but distinct differences were noted between the companies on certain aspects of the injuries. That is, injuries are not random occurrences and their occurrences are not consistent between different companies. As a result, it is concluded that a company would be more successful in developing an effective accident prevention program if it examined the various facets of the injuries of its own employees than those of the construction industry.

Through an examination of the worker trades it can also be concluded that different trades have different types of injuries. This is probably due to the fact that different trades are exposed to different hazards. Different crafts work with different tools, handle different types of building materials, etc. To devise adequate safety programs for a particular trade, it is imperative that an analysis be made of the injuries sustained by that trade. The analysis needs to be trade specific and company specific.

Considerable variability was noted in the injury statistics of the three participating firms. Had additional firms provided data, it is reasonable to assume that the data histories would be unique to each firm. Thus, little would be gleaned if first aid injury statistics were analyzed on an industry-wide basis.

For the firms that provided this information, it can be concluded that safety performance is favourably impacted by the policies of requiring workers to wear eye protection at all times and to always have gloves with them and to use them whenever they are needed. The incidence of eye and hand injuries was clearly below the national average and it is concluded that the company policies directly contributed to reducing these types of injuries.

RECOMMENDATIONS

While a particular construction company would not benefit directly from examining the statistics that were presented, companies should realize that their own injury statistics would provide a wealth of information by which a safety program could be enhanced. First aid statistics are not generally documented on construction sites. Companies are well-advised to consider devising a means of capturing this type of information. Currently, this is most easily accomplished when a healthcare professional is assigned to a project site. Other means might be explored by which first aid injury information might be retrieved on smaller projects where nurse's stations are not utilized.

Additional research should be conducted on the various aspects of first aid injuries. With a sample of three companies, it is difficult to determine if these are truly representative of the construction industry or not. Such added study of first aid injuries should consist of larger numbers of first aid injuries obtained from a larger number of firms. Just as first aid injuries occur more frequently, so too to close call incidents. An effort should also be expended in obtaining information on the incidence of close calls. These would broaden the data base and provide additional information by which to better understand the causes and other factors associated with the large numbers of minor incidents in the construction industry.

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THE ORGANIZATIONAL CULTURE OF SAFETY

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ABSTRACT

Major accidents are frequently traced to failures in the safety management system, and investigations sometimes reveal that safety management systems bear little relation to what goes on at the workplace. Safety management systems virtually exist in theory and not in practice. For a number of years, safety professionals, regulators and others have argued that safety is not simply a matter of compliance with externally imposed regulations. Instead, Hopkins (2006b) argues that organizations need to manage safety proactively in the same way as the organization to manage their production activities. Hence, a cultural approach to enhancing the safety of organizations is now receiving attention.

The cultural approach to safety means that safety cannot be assured simply by introducing a safety management system alone. The cultural approach to safety suggested by Reason (2000) is something to bring safety management to life. This means that the right organizational culture is necessary to make safety systems work. When talking about organizational culture, organizational behaviour and, hence, some relevant organizational factors will come into play.

Schein (1992) provides a useful summary of the concept of culture as observed behavioural regularities, group norms, climate, habits of thinking and shared meanings. He also emphasizes the behavioural element in culture by defining it as "the way we do things around here". This phrase carries with it the connotation that this is the right, or appropriate or accepted way to do such things in this organization. Cooper (2000) develops a three aspect approaches model for evaluation of safety culture in an organization. The model consists of: psychological aspects; behavioural aspects; and situational aspects of the safety culture. Cooper (2000) describes these aspects as organizational factors.

In the paper, a new model of organizational culture of safety is being proposed based on the theory of planned behaviour with organizational commitment serving as the attitude element, organizational citizenship behaviour serving as the behavioural element and the organizational culture of safety as the outcome.

Key words: safety management systems, safety culture, organizational commitment, organizational citizenship behaviour, three aspects of safety culture

ORGANIZATIONAL CITIZENSHIP BEHAVIOUR

Previous research on organizational citizenship behaviour indicates that such behaviour is critical for organizational effectiveness, but little theoretical work details how it might contribute to enhance organizational functioning of safety. It is suggested that citizenship behaviours enhance the functioning of the organization by contributing to the development of safety climate; collective mindfulness and risk awareness for the creation of organizational behaviour of safety.

Organizational citizenship behaviours (OCB) can be defined that employee behaviours that go beyond role requirements, that are not directly or explicitly recognized by the formal reward system, and that facilitate organizational functioning (Organ, 1988). Podsakoff, MacKenzie, Paine,

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and Bachrach (2000) concluded that citizenship behaviours typically stem from positive job attitudes, task characteristics, and leadership behaviours. Thus prior research indicates that individuals are most likely to go beyond their formal job requirements when they are satisfied with their jobs or committed to their organizations, when they are given intrinsically satisfying tasks to complete, and /or when they have supportive or inspirational leaders.

In 1991 Graham proposed a conceptualization of organizational citizenship grounded in political philosophy and modern political theory (e.g., Cary, 1977; Inkeles, 1969; Rossiter, 1950). Graham (1991) suggested that there are three forms of organizational citizenship. Obedience describes employees' willingness to accept and abide by the organization's rules, regulations, and procedures. Loyalty describes the willingness of employees to subordinate their personal interests for the benefit of the organization and to promote and defend the organization. Finally, participation describes the willingness of employees to be actively involved in all aspects of organizational life.

In subsequent empirical work Van Dyne, Graham, and Dienesch (1994) indicated that participation actually takes three forms. Social participation actually takes three forms. Social participation describes employees' active involvement in company affairs (e.g., keeping up with organizational issues or attending non-mandatory meetings) and participation in social activities within the organization. Advocacy participation describes the willingness of employees to be controversial in order to improver the organization by making suggestions, innovating, and encouraging other employees to speak up. Functional participation describes employee contributions that exceed required work standards (e.g., volunteering to take on extra assignments, working late to finish important projects, or pursuing additional training and staying abreast of new developments).

Generally speaking, it has been argued that OCBs facilitate organizational performance by "lubricating" the social machinery of organizations (Borman & Motowidlo, 1993; Smith et al., 1983). Organ, 1988; Podsakoff & MacKenzie, 1997 have discussed some more specific ways in which OCBs might positively influence organizational performance by: OCBs may enhance coworker or managerial productivity; OCBs may free up resources for more productive purposes; OCBs may reduce the need to devote scarce resources to purely maintenance functions; OCBs may facilitate the coordination of activities between team members and across workgroups; OCBs may enable organizations to attract and retain high-quality employees by making the work environment a more pleasant place to work; OCBs may enhance the stability of organizational performance by reducing the variability in a work unit's performance; and OCBs may enhance an organization's ability to adapt to environmental change.

Loyalty
Employees demonstrate loyalty when they are willing to sacrifice their own interests for the good of the company. According to prior research, an essential component of trust is the willingness to be vulnerable to the actions of another party (Bhattacharya, Devinney, & Pillutla, 1998; Mayer et al., 1995). Not surprisingly, then, individuals are most likely to trust those who are pursuing common goals and whom they perceive as not purely self-interested (Lewicki, McAllister, & Bies, 1998). When employees demonstrate their loyalty to the organization, it is likely that such behaviour will convey to managers and peers that these individuals are not looking out simply for them-selves and that they value the well being of their colleagues and the organization as a whole. Logically, then, individuals who are loyal should not only tend to be considered likable by their colleagues but trustworthy as well. In this way, loyalty should contribute to the development of strong relational ties between employees to establish the unify view on organizational climate particular in safety climate and collective mindfulness.

Obedience
Employees demonstrate obedience through their willingness to respect and comply with the rules, regulations, and procedures of the organization. Rules, regulations, and procedures are important in organizations because they facilitate the organization's ability to control the execution of its many activities (Katz & Kahn, 1978). Rules also make organizational behaviour more predictable, and thereby serve to reduce uncertainty (Katz & Kahn, 1978). A key component of trust is the

ability to predict the actions of others. In other words, when employees are able to anticipate each other's actions, they are more likely to trust one another. Their peers, then, should see employees who are obedient, as more trustworthy.

Previous research indicates that obedience should also increase the degree of liking among employees. For example, social psychological research on conformity has shown that individuals who are compliant are typically seen as more likable than individuals who are considered deviant or noncompliant (Schachter, 1951). As in other studies, this research indicates that managers and individuals in general tend to avoid uncertainty (March & Simon, 1958). Thus, when employees can be counted on to play by the rules, they are more likely to be trusted and liked by their managers and colleagues. For this reason, obedience should contribute to safety climate and collectively mindfulness of the organization.

Functional participation

Functional participation is behaviour that goes above and beyond the call of duty in the execution of one's job. As noted by Van Dyne et al. (1994), relative to the other forms of participation, functional participation behaviours are employee contributions that are more individually focused. That is, these types of behaviours are less likely to involve direct contact with other individuals; they consist, rather, of participatory behaviours like taking on additional work activities or volunteering for special projects.

Nevertheless, these self-focused behaviours are likely to foster trust, liking, and identification among employees in an organization. For example, in a study of citizenship behaviour in student workgroups, Nguyen and Seers (2000) found that individuals were most satisfied with their team members and most likely to enjoy being a part of the team when their teammates were willing to execute their task-related duties at extremely high levels. Thus, employees who are highly committed, hardworking, and willing to develop themselves are likely to be highly valued and well liked by their peers. Moreover, other research has shown that individuals who do more than is required of them tend to be viewed as competent, reliable, and trustworthy (Mishira, 1996). Finally, employees are more likely to identify with groups composed of individuals whom they like or view as reliable and competent (Hogg & Terry, 2000). Therefore, when employees demonstrate functional participation, this is likely to bring individuals closer together and this should be attributing to the creation of safety climate, collective mindfulness and risk awareness.

Social participation

It suggests that by engaging in social participation (e.g., by participating in voluntary meetings and organization-sponsored social events), individuals are likely to make important contacts with other employees in the organization. Employee social participation is also likely to help build relational capital in organizations. To begin with, social psychologists indicate that social interaction tends to lead to interpersonal attraction (Insko & Wilson, 1977)—that is, the degree of liking among individuals is typically higher when those individuals have had the opportunity to interact with one another socially.

Consistent with this idea, studies of groups and teams have shown that social interaction is an important determinant of group cohesion (Mullen & Copper, 1994). Hogg and Terry's (2000) research suggests, too, tha6t individuals tend to like and identify with individuals with whom they interact. Moreover, social activities in organizations (e.g., company picnics) are often explicitly designed to encourage the development of relationships or friendships among employees and to increase the extent to which employees identify with one another in respects of organizational climate and collective mindfulness and risk awareness.

Advocacy participation

The citizenship behaviours also may contribute to speak up with constructive suggestions and to encourage their colleagues to do so as well. However, if employees are unwilling to communicate or share their ideas and thoughts with their colleagues, it is less likely that a shared language and shared narratives will develop among them. In contrast, when employees present their ideas and openly share their true opinions with their coworkers, such actions are likely to facilitate the creation of shared language and narratives within the organization. In other words, when employees are willing to voice their opinions and encourage their colleagues to express themselves, this contributes to a work environment in which employees are comfortable sharing ideas and knowledge (Van Dyne et al., 1994). Advocacy participation, then, should facilitate the creation of collective mindfulness and risk awareness in organizations.

Three Aspects of Safety Culture

Cooper (2000) develops a three aspect approaches model for evaluation of safety culture in an organization. The model consists of: psychological aspects, behavioural aspects and situational aspects of the safety culture. Cooper describes these aspects as organizational factors. The behavioural aspect is concerned with "what people do" within the organization which includes the safety-related activities, actions and behaviours exhibited by employees. Situation aspects describe, "what the organization has for its policies, operating procedures, management systems, control systems, communication flows and workflow systems". The psychological aspects can be described as how employees see and feel their organization in the aspect of safety. This aspect is concerned with individual and group values, attitudes and perception.

Safety climate

Psychological climate has been defined as referring to individuals cognitively based descriptions of situational characteristics (Jones & James, 1979). Koys and DeCotiis (1991) defined psychological climate as an experiential-based, multidimensional, and enduring perceptual phenomenon which is widely shared by the members of a given organizational unit. Psychological climate, according to Furnham (1997), is the intervening psychological process whereby the individual translates the interaction between the perceived organizational attributes and individual characteristics into a set of expectancies, attitudes and behaviours.

Parker and colleagues (2003) concluded that psychological climate is a property of the individual and that the individual is the appropriate level of theory, measurement, and analysis. Parker adhered to the psychological climate areas; job characteristics, role characteristics, workgroup characteristics, leadership characteristics and organizational attributes.

The value of the climate construct in safety research rests on its ability to predict behavioural consequences. Climate has been considered to be an important behavioural antecedent. Reichers and Schneider (1990) stated that organizational climate seemed to be a natural concept stemming from the desire to specify environmental influences on motivation and behaviour. Glendon and McKenna (1995) expressed that perceptions are a critical behavioural antecedent. Zohar (2000), in his study regarding safety performance, stated that climate perceptions inform employees of desired role behaviour and to practices-as-pattern. Zohar (2003) proposed, that climate perceptions affect safety records as follows: climate perceptions influence behaviour-outcome expectancies; expectancies influence prevalence of safety behaviour; and behavioural and safety influences company safety records.

Risk Management

The second element in Cooper's model (2000) is on situation aspects. The situation aspects described by Cooper as "what the organization has" in respects of policies, procedures, regulation and the management. Apart from the documents and procedures, Weick and Sutcliffe (2001) see that a highly reliable organization should have collective mindfulness of danger. The collective mindfulness is a characteristic of the organization where employees will organize themselves in such a way that they are better able to notice the unexpected in the making and halt its development. They also advocate that mindfulness organizations should have a commitment to resilience by which organizations are not disabled by errors or crises. Reason (1997) sees the collective mindfulness organizations should have a well developed reporting culture where employees would hurt for lapses and errors and the employees recognizing that lapses and errors would lead to larger failures. Weick and Sutcliffe (2001) also advocate that mindfulness organizations are reluctant to discard information as simplifications increase the likelihood of surprise. Hopkins (2006) sees that the mindfulness organization should sensitive to the organizational operations. This is not only applicable to the frontline operators who maintain situational awareness but the managers also are sensitive to the experience of the frontline operators.

Risk awareness

Cooper (2000) defines behaviour aspects are concerned with “what people do” within the organization, which includes the safety related activities, action and behaviours exhibited by employees. Hopkins (2006) advocated that the rationale for encourage risk awareness among employees is that it is impossible to devising a set of safety rules to cover every situations. Hale (2003) states that rules are essential but it can never be complete bring us to something of an impasse and he continues that one way to move beyond this impasse is to abandon the idea where a set of rules can ever be determined once and for all and to recognize that a regime of rules is necessarily a dynamic one which needs to be managed. He advocates for a self corrective mechanism to obsolete safety rules owning to change of situation. Hopkins (2006) also states that risk awareness will lead to group thinking, will not downgrading of intermittent warnings of dangers and will not normalizing the evidence of hazardous.

Organizational Commitment

The definition of organizational commitment is that it is the worker’s attitudes about the entire work organization. The concept of organizational commitment has been taken to imply worker attitudes and the concept of organizational citizenship behaviours (OCB) refers to commitment-related behaviors (Organ, 1990). Organizational commitment views it as composed of three dimensions: affective commitment, which is the employee’s emotional attachment to the organization; continuance commitment, which refers to commitment to continue with the organization because there are costs associating with leaving; and normative commitment, which is like a sense of duty or obligation to stay with the company (Meyer & Allen, 1997).

In another word, affective commitment occurs when the employee wishes to remain with the organization because of an emotional attachment. Meyer et al (1993) states that affective commitment arises from job conditions and job expectations are met. This means that the job provides the rewards that employee expected. By this projection, the employee can develop royalty to the organization and; hence, to develop collective mindfulness and to develop a good safety climate within the organization.

Continuance commitment exists when a person must remain with the organization because he or she needs the benefits and salary or cannot find another job. Meyer, Stanley, Herscovitch and Topolnytsky (2002) state that continuance commitment correlates with low commitment. The continuance commitment findings suggest that individuals who believe they must keep their jobs tend to perform more poorly than individuals who believe they are free to quit. It is also possible that people who feel trapped in their jobs respond with reduced effort. However, previous research has also suggested that different parts of the world have different self–centered value. Employees from China can be more abide by the group norm. This is because of group cohesiveness. Spector P. (2004) suggests that if group continuation is virtually important to group members, the conformity to norms will be a critical issue. When in the workplace, people are often dependent on their jobs for their economic survival, and the work group can be as important as their family. Threats to the well being of group are taken seriously. Hence, the continuance commitment may be correlated to the elements of obedience and formal participation, as these two elements are to ensure the group survival within the organization.

Normative commitment comes from employee’s personal values and from the obligations that the person feels toward the employer. These obligations toward the employer come from benefit or the identity that the organization has done for them (Meyer et al 1993). In Meyer et al 2002 study, it is found that normative commitment correlated positively with job satisfaction. This means that employees are having higher commitment and higher satisfaction to the organization itself. It can be said that normative commitment is related to royalty, obedience, functional participation, social participation and advocacy participation. Hence, it can be foreseen that employees who have normative commitment may also attribute to the organizational safety climate, collective mindfulness and risk awareness.

Conceptual Model

A useful model known as the theory of planned behaviour was developed by Icek Ajzen and his colleagues (1986). The graphical representation of the theory is shown in Figure 1. This theory is to the view that people consider the implications of their action before deciding to engage or not engage in a particular behaviour. A meta-analysis reported that normative commitment was related to OCB (Organ & Ryan 1995). It should be noted that organizational commitment is contributing to the contextual performance of employees. The organizational commitment is linked with employee's attitude. Attitude can be defined as the degree of positive and negative feeling of a person toward a particular person, place and thing. (Fishbein & Ajzen 1975). A subjective norm is an individual's perception of the social pressures to perform or not perform a particular behaviour. Perceived behaviour control is the individual's brief as to how easy or difficult performance of the behaviour is likely to be.

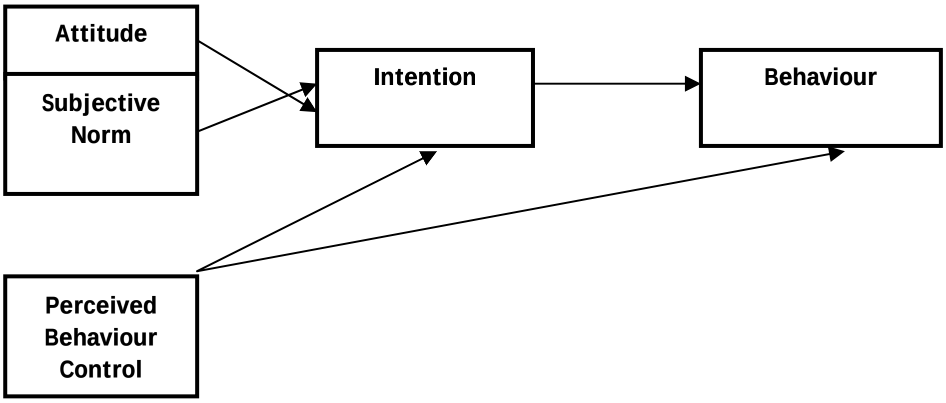

Figure 1: Theory of Planned Behaviour

From the aforementioned, the theory of planned behaviour emerges as an appropriate framework to relate the process of organization commitment; OCB; and three aspects of safety culture. Incorporating the above elements into the theory, behaviour becomes synonymous with three aspects of safety culture; OCB serves as the perceived behaviour control; and organizational commitment then becomes the factor representing the attitude. Thus, a new model is being formed with the interactions as shown in Figure 2 below:

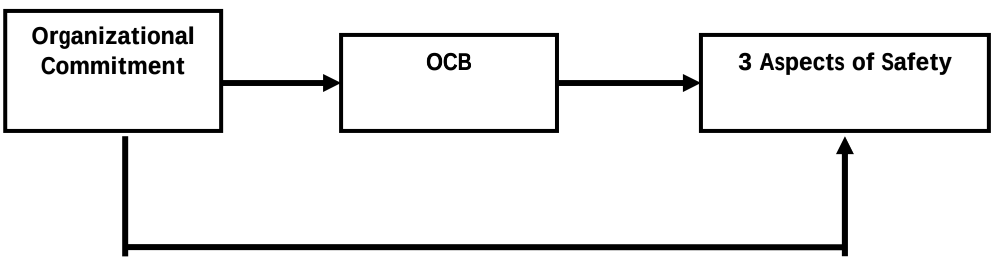

Figure 2: Model of the Organizational Culture of Safety

A research agenda with the above model can then be used to help illuminate a better understanding the organizational culture of safety on sites. A multi-discipline research design on construction sites has been formulated by using the above model to test out the organizational cultural safety among the site management; site supervisory staff and the workers. Another, function of testing out the model is with the hope to determine the motivation factors of assisting to achieve better organizational cultural safety. Owing to the construction of the model, the mediation effect of OCB will be tested. Preliminary interviews were conducted among various groups of respondents with the aim of identifying of key elements to be used in the main questionnaires. An industry wide questionnaire survey with then is carried out to measure variables as listed in the aforementioned as outlined in the proposed research framework above. Subsequent, interviews will be carried out to confirm the findings of the questionnaire results.

CONCLUSION

A conceptual framework of organizational culture of safety that advances the understanding of the organizational commitment; OCB; and safety culture has been developed. Thus, a more explanation of organizational culture of safety influenced by other type behaviour and motivation factors can be offered. After testing and refining, the proposed framework can be served as a diagnostic mode, by providing the organization with targets of interventions to the behaviour and motivation factor for enhancement of the organizational culture of safety.

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SAFETY INVESTMENT AND SAFETY PERFORMANCE OF BUILDING PROJECTS IN SINGAPORE

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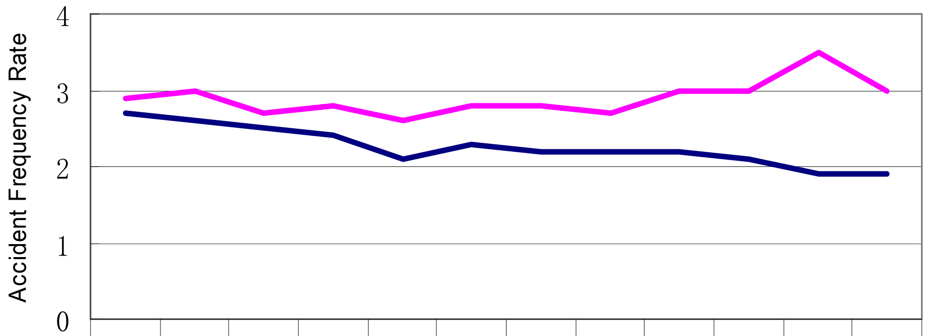
ABSTRACT
Safety investment is aimed at protecting the health and physical integrity of workers and the material assets of a contractor. A popular assumption holds that increased investment in safety produces improved safety performance. However, close examination of previous studies on safety investment reveals that the relationship between the level of safety investment and safety performance remains debatable. The purposes of this study are therefore to: (1) investigate the relationship between safety investment and safety performance in the context of building construction in Singapore; and (2) identify factors influencing the relationship between safety investment and safety performance of building projects. Data were collected by means of conducting a survey. The population of the survey consists of all building contractors in Singapore and the sampling frame is a list of 234 large and medium general registered building contractors with the Building Construction Authority (BCA) of Singapore. Moderated regression is used to analyze the data and describe the relationship between safety investment and safety performance. The findings indicate that the strength /or direction of the relationship between safety investment and safety performance may be influenced by factors, such as safety culture, hazard level, and complexity of a project. Additionally, their relationship might vary under different project conditions. With the establishment of the relationship between safety investment and safety performance, the research can be used as a basis for assisting building contractors to determine a budget for safety management of a building project.

Keywords: Occupational health and safety, Safety performance, Safety investment, Project hazard level, Building projects

INTRODUCTION
For the past few decades, efforts have been made by the government and industries in Singapore to address the problems of workplace safety and health. Safety performance of all industries has experienced a continuous improvement from 1996 (the accident frequency rate was 2.7 accidents per million man-hours worked) to 2007 (the accident frequency rate was 1.9 accidents per million man-hours worked) (MOM, 2008). Conversely, there is no apparent improvement in the construction safety performance. As shown in Figure 1, the accident frequency rate of construction industry has been stagnating at around 3 accidents per million man-hours worked since 1996 (MOM, 2008). Moreover, the collapse of Nicoll Highway along with two other major accidents in 2004, which claimed a total of 13 lives, was a stern reminder that more needs to be done to protect workers on sites (Teo and Ong, 2005; MOM, 2007). Such high fatal rate had prompted the government to examine various strategies for enhancing construction site safety performance.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
All Factories	2.7	2.6	2.5	2.4	2.1	2.3	2.2	2.2	2.2	2.1	1.9	1.9
Construction	2.9	3	2.7	2.8	2.6	2.8	2.8	2.7	3	3	3.5	3

Figure1: Industrial Accidents by Frequency Rate and Industry
(Source: Occupational safety and health division, MOM (2008))

In 2005, the government undertook a fundamental reform in the WSH framework in order to achieve a quantum improvement in the safety and health for workers. The target was set to halve the occupational fatality rate from 4.9 fatalities per 100,000 workers in 2004 to 2.5 by 2015 so as to attain standards of the top ten good safety records developed countries (MOM, 2007). The new framework is guided by three principles as shown in Table 1.

The reform in the WSH framework suggests that if the prescriptive rules and enforcement procedures do not produce desired results, attention should be directed toward a self-motivating or self-regulating approach to this problem. The Robens Report, *Safety and Health at Work* (1972) takes the view that too much law encourages apathy and apathy is what causes accidents at work. Therefore, voluntary, self-generating effort is the only way to reduce accidents in industry (Nichols, 1997). One way in which such a self-motivating solution could occur would be if decision makers of a business had in-depth understanding of the financial cost and its implications of WSH issues. The main driving force behind the industrial safety movement is the fact that accidents are expensive, and substantial savings can be made by preventing them (U.S. Department of labor, 1955). ‘Safety pays’ is regularly used by government as a way of motivating employers to attend to occupational health and safety (Hopkins, 1999). Brody et al. (1990) pointed out that when prevention activities are perceived as sufficiently profitable, the investor will be likely to undertake the investments voluntarily.

Table 1: Principles of the New WSH Framework

Three Principles	Desired Mindset Change	
	From	To
Reduce risk at source by requiring all stakeholders to eliminated or minimize the risks they created	Managing risks	Identifying and eliminating risks before they are created
Greater industry ownership of WSH outcomes	Compliance with “Letter of the law”	Proactive planning to achieve a safe workplace
Prevent accidents through higher penalties for poor safety management	Accidents are costly	Poor safety management is costlier

(Source: Occupational safety and health division, MOM (2007))

However, there remain many debates in the literature on whether the increase of investment in construction safety can result in the improvement of safety performance of building projects. Safety investment was assumed by many researchers (Levitt, 1975; Laufer, 1987; Brody et al. 1990) to have positive impact on the safety performance without the support of empirical evidence. The decision tree developed by Hinze (2000) indicates that this impact is largely a game of probabilities, as there might be no injuries even if there is no investment in safety. Recognizing the potential of safety investment to reduce the risk of work injuries, researchers become more concerned about the empirical examinations on the relationship between safety investment and safety performance. Crites (1995) compared safety performance with the size and funding of formal safety programs over an 11-year period (1980-1990). However, it was found that safety performance was independent of – or even inversely related to – safety investment. Tang et al. (1997) examined the function of the relationship between safety investment and safety performance of building projects in Hong Kong and found a weak correlation coefficient (0.25) between safety investment and safety performance. They assumed that the low coefficient of correlation (0.25) might be due to the difference in safety culture of the different companies. However, Tan (2007) gave another possible explanation for the low coefficient of correlation that there might be no relationship between safety investment and safety performance. Therefore, the purposes of this study are therefore to (1) test the relationship between safety investment and safety performance, and (2) identify factors influencing the relationship between them for building projects.

LITERATURE REVIEW

Safety investment for building projects

Safety investment is defined as the costs which are incurred as a result of an emphasis being placed on safety control, whether it be in the form of safety training, safety incentives, staffing for safety, Personal Protective Equipment (PPE), safety programs, or other activities (Hinze, 2000). The components of safety investments have been discussed in some previous studies (e.g., Laufer, 1987; Brody et al., 1990; Tang et al., 1997; Hinze, 2000). Accident prevention cost comprises expenses for safety planning, acquisition of equipment and protective installations, personnel training, salaries for safety staff, safety measurement and accident investigations (Laufer, 1987). Brody et al. (1990) classified safety investments into three types: (1) Fixed prevention costs (FPCs); (2) Variable prevention costs (VPCs); and (3) Unexpected prevention costs (UPCs). FPCs are incurred before production takes place and exist regardless of the accident rate. Examples of FPCs include human resources allocated to safety. VPCs are proportional to accident frequency and severity. They include time taken by accident analysis specialists attempting to identify causes and to prescribe corrective measures. UPCs relate to measures initially unforeseen when a production procedure is originally conceived or when machinery is designed or purchased.

In an attempt to optimize construction safety cost, Tang et al. (1997) collected the data on the investments in safety of building projects in Hong Kong. The information on safety investments was divided into three major investments components, namely (1) safety administration personnel, (2) safety equipment, and (3) safety training and promotion. Investments in safety administration personnel comprise the salaries of these personnel, such as safety officers, safety supervisors, or safety managers in some large companies, and their supporting staff such as clerks and typists. Investments in safety equipment include the expenditure on personal protection equipment and other equipment that involve the provision of safety on building sites. Expenditures on safety training and promotion are also part of safety investments.

Hinze (2000) discussed the most salient components of a safety program for the construction industry while numerous experts were consulted about the costs of the various components of a safety program primarily associated with the petro-chemical and industrial sectors. These safety program elements include: (1) substance abuse testing, (2) staffing, (3) training, (4) personal protective equipment, (5) safety committees, (6) investigations, (7) preparation and implementation of safety program, and (8) safety incentives.

Factors affecting safety performance of building projects

Hazard has been defined as a real or potential situation that may cause unintentional injuries or fatalities to people or damage to, or loss of, an item or belongs (Asfahl, 1990). Therefore, the assessment of safety performance can be conducted by evaluating all on-site hazard elements. With the decrease of its potential hazard, its safety performance improves (Fang et al., 2004). According to the abovementioned definition of hazard, factors determining hazard level of construction sites can be classified by referring to the classification of accident causes (Fang et al., 2004). DeReamer (1980) has grouped the causes of accidents into two categories: immediate causes of accidents and contributing causes of accidents. The former includes unsafe acts and unsafe conditions, while the latter includes mental and physical conditions of the workers and the management policies. In construction industry, Abdelhamid and Everett (2000) have grouped all unsafe conditions on construction sites into four categories: management actions/inactions, unsafe acts of worker or coworker, non-human-related events and an unsafe condition that is a natural part of the initial construction site conditions.

Fang et al. (2004) divided hazard factors into two categories: (1) factors outside the construction site, such as the safety involvement of the employer, designer, subcontractor, consultant, insurer and the public demand and concern on occupational health and safety; and (2) on-site hazards, including the physical conditions and all on-site activities of managers, workers and other organizations, which are then grouped into two categories: immediate factors and contributing factors. An immediate hazard factor is a factor that can cause an accident physically and directly, whether the accident happens or not, including unsafe acts and unsafe conditions. A contributing hazard factor is a factor that can further explain immediate hazard factor, including safety management policy, manager and worker's mental or physical conditions, initial construction site conditions, and so on. Heinrich's accident causation theory (1941) was summarized into two main points: (1) people are the fundamental reason behind accidents; and (2) management is responsible for the prevention of accidents (Peterson, 1982). It is suggested that accidents could be somewhat prevented through endeavors of management.

Therefore, based on the review of causes of accidents on construction site, two hypotheses are postulated as (1) Safety investment has positive effect on safety performance of building projects, and (2) The relationship between safety investment and safety performance of building projects is affected by project hazard level.

RESEARCH METHOD

Instrument

A questionnaire was designed with the objective of examining the relationship between safety investment and safety performance of building projects. The questionnaire consists of four major parts as described below:

- The first part collects the information about the general characteristics of the project, e.g. company size, project size, duration, man-days worked, height of building, type of the project, type of client, and so on.
- The second part asks the respondents to provide information about the safety performance of the project, which is measured by the Accident Severity Rate (ASR). ASR is derived by the following formula:

$$\textit{Accident Severity Rate (ASR)} = \frac{\textit{No. of Mandays Lost to Workplace Accidents}}{\textit{No. of Man-hours Worked}} \times 1{,}000{,}000$$

- The third part aims to collect costs information about safety control activities of the project. Based on the review of previous studies on safety investment, safety investment comprises expenses for all kinds of accident prevention activities. The tangible part of safety investment consists of dollars spent on the accident prevention activities. There is, however, another part of safety investment, namely intangible safety investment, taking the form of time invested in the accident prevention activities, e.g. the time invested in safety training and orientation, the time invested in emergency response drills, the time invested in safety meetings and inspections, and other activities. This part of safety investment is always unobservable, and therefore tend to be neglected by practitioners. With consideration of both tangible and intangible safety investments, the costs items consist of staffing costs, training costs (including formal training courses and in-house safety training and orientation programs), safety facilities costs, personal protective equipments costs, safety committees costs, safety promotion and incentive costs, costs of new technologies, methods or tools designed for workplace safety, and others. A dimensionless quantity, the Safety Investment Ratio (SIR) was used to enable the comparison of the level of safety investment among projects of different sizes. SIR is therefore defined as follows:

$$\textit{Safety Investment Ratio (SIR)} = \frac{\textit{Total Safety Investment}}{\textit{Contract Sum}} \times 100\%$$

- The fourth part scrutinizes the hazard level of the project by assessing each the project scope and the vicinity/location. The framework for estimating the Project Hazard Index (PHI) developed by Imriyas et al. (2008) was adopted for this study. Eleven hazardous trades in building projects and their respective attributes for assessing each trade's hazard were listed in the questionnaire. However, not every hazardous trade may be applicable to a given projects. Thus, applicable trades need to be selected and rated. Respondents were required to rank the attributes on a 5-point Likert-type scale between 1 = "low level" and 5 = "high level" to each of the statements found in this part. The PHI is derived by the following formula:

$$PHI = \frac{1}{m} \bullet \sum_{i=1}^{11} H_i$$

Where $0<m\leqslant 11$; H_1 = degree of hazard contributed by demolition works; H_2 = degree of hazard contributed by excavation works; H_3 = degree of hazard contributed by scaffolding and ladder use; H_4 = degree of hazard contributed by false works; H_5 = degree of hazard contributed by roof works; H_6 = degree of hazard contributed by erection works; H_7 = degree of hazard contributed by crane use; H_8 = degree of hazard contributed by machinery and tools use; H_9 = degree of hazard contributed by works on contaminated sites; H_{10} = degree of hazard contributed by welding and cutting works; H_{11} = degree of hazard contributed by works in confined spaces. The formula for calculating the individual scores is described below:

$$H_i = \frac{1}{n_i} \bullet \sum_{j=1}^{n_i} AS_{ij}$$

Where n_i = number of hazard attributes for i^{th} hazard trade; AS_{ij} = j^{th} hazard attribute score of i^{th} hazard trade.

Data collection

Personal interviews with a questionnaire were used to collect data for this study. The population consists of all building contractors in Singapore. The sampling frame is a list of 234 large and medium general building contractors (A1, A2, B1, and B2) who were registered with the Building Construction Authority (BCA) of Singapore. The reason why small general building contractors (C1, C2, and C3) are excluded from the sampling frame of this study is that, according to practices of Singapore construction industry, small general building contractors (C1, C2, and C3) usually perform as sub-contractors of building projects and it is not possible to acquire complete information about the whole building project from sub-contractors. The building contractors from the sampling frame were contacted via Email or telephone to request them to participate in this study and the contractors whom were interviewed so far (this study is at the initial stage of a three-year research project) are as shown in Table 2. The contact persons (project managers or safety officers) were then interviewed with the questionnaire after he or she agrees to accept the interview. The interviewees were requested to provide information for their project/s that has/have been completed within the past three years. The project managers of these projects were required to review the historical records about the cost information of safety related activities and safety performance of the projects that they had managed.

Table 2: Distribution of Sample Contractors

BCA Grade	*A1*	*A2*	*B1*	*B2*
Population	35	27	57	115
Sample	3	3	3	2

For a single project, three members of site management staff comprising project managers, construction managers, site engineers, safety officers, and safety supervisors were requested to complete the project hazard assessment form, which is the fourth part of the interview questionnaire. The average of PHI value derived from the three questionnaires was used to gauge the project hazard level.

The characteristics of the sample projects were given in Table 3. It was shown that the data were collected from a wide range of building projects in terms of firm's BCA grade, project size, type of project, type of client, percentage of work completed by sub-contractors, and height of building.

Table 3: Sample Profile

Profile	*Number*	*Percent*
Project Type		
Commercial building	2	9.52
Residential building	12	57.14
Office building	5	23.81
Industrial building	2	9.52
Project Size (Singapore Dollars)		
Up to $10 mil	2	9.52
> $10 mil ≤ $50 mil	11	52.38
> $50 mil ≤ $100 mil	6	28.57
> $100 mil	2	9.52
Type of Client		
Private	16	76.19
Public	5	23.81
Height of Building		
Up to 5 stories	7	33.33
> 5 ≤ 10 stories	5	23.81
> 10 ≤ 15 stories	4	19.05
More than 15 stories	5	23.81
Firm's BCA grade		
A1	6	28.57
A2	5	23.81
B1	5	23.81
B2	5	23.81

RESULTS AND DISCUSSION

Relationship between safety investment and safety performance

The data were analyzed using the Statistical Package for Social Sciences (SPSS) software. Pearson's Correlation Coefficient was used to test the relationship between variables and safety performance of building projects. The purpose of performing a correlational analysis is to discover whether there is a relationship between variables, which is unlikely to occur by sampling error (assuming the null hypothesis to be true) (Dancey & Reidy, 2004). The null hypothesis is that there is no real relationship between the variables. The results of correlational analysis between safety investment, project hazard level, and safety performance were reported in Table 4. Safety performance and safety investment were weakly related (r = -0.339, p = 0.133 > 0.05). The negative correlation can be interpreted as meaning that an increase in safety investment correlates to an improvement in the safety performance as measured through a decreased ASR value. The correlation between project hazard level and safety performance was also found to be weak and not significant (r = 0.365, p = 0.104 > 0.05). The positive correlation can be interpreted as meaning that an increase in project hazard level correlates to an increase in ASR value. This finding does not support the commonly held assumptions that safety investment is positively correlated to the safety performance of building projects. The low correlation coefficient for safety investment and safety performance is perhaps due to the difference in project and company characteristics, e.g. firm's BCA Grade, project size, project duration, percentage of work completed by subcontractors, height of building, type of project, type of client, and project hazard level.

Table 4: Correlation among variables

Variables		*ASR*	*SIR*	*PHI*
ASR	Pearson (r) Correlation	1.000	-	-
	Sig. (2-tailed)	-	-	-
SIR	Pearson (r) Correlation	-0.339	1.000	-
	Sig. (2-tailed)	0.133	-	-
PHI	Pearson (r) Correlation	0.365	0.355	1.000
	Sig. (2-tailed)	0.104	0.114	-

To ascertain the association between safety investment and safety performance of building projects without the effect of other factors related to project characteristics, partial correlations were applied in this study. Partial correlation is a method used to describe the relationship between two variables whilst taking away the effects of another variable, or several other variables, on this relationship (Dancey & Reidy, 2004). This type of analysis helps spot spurious correlations (i.e. correlations explained by the effect of other variables) as well as to reveal hidden correlations (i.e. correlations masked by the effect of other variables). The effects of other factors on the relationship between safety investment and safety performance were get rid of by 'partialling out' other factors, by statistical means. This is also known as 'holding other factors constant' (Dancey & Reidy, 2004). The control variables in partial correlation are the variables which extract the variance which is obtained from the initial correlated variables.

Partial correlation can be computed using SPSS software. The results of partial correlations were presented in Table 5. The coefficient of correlation r would then be showing us the correlation between safety investment and safety performance when the influence of other factors related to the project and company characteristics was removed. As indicated in Table 5, the correlation between safety investment and safety performance was not significantly changed by partialling out the factors such as firm's BCA grade, project size, project duration, percentage of work by subcontractors, height of building, type of project, and type of client. Project hazard level was found to be the only factor that may influence the relationship between safety investment and safety performance. A moderate correlation (r = -0.538, p = 0.014 < 0.05) was found between safety investment and safety performance for building projects, with project hazard level partialled out. The associated p value was 0.014, which means that there is only a small chance (0.14%) that this correlation has arisen by sampling error. Thus it suggests that, in this small sample (n = 21), the association between safety investment and safety performance was partially due to the project hazard level. Similarly, the correlation between safety performance and project hazard level was significantly increased from 0.365 (p = 0.104) to 0.552 (p = 0.012 < 0.05), with the effect of safety investment removed. The findings indicate that the relationship between safety performance and safety investment is affected by project hazard level. Safety investment has positive effect on safety performance of building projects, when holding the project hazard level constant.

Table 5: Partial correlation between SIR and ASR

Control Variables			*ASR*
Firm's BCA Grade	*SIR*	Pearson (*r*) Correlation	-0.362
Project size	*SIR*	Pearson (*r*) Correlation	-0.363
Project duration	*SIR*	Pearson (*r*) Correlation	-0.322
Percentage of work by subcontractors	*SIR*	Pearson (*r*) Correlation	-0.377
Height of Building	*SIR*	Pearson (*r*) Correlation	-0.379
Project Type	*SIR*	Pearson (*r*) Correlation	-0.259
Type of Client	*SIR*	Pearson (*r*) Correlation	-0.343
Project hazard level	*SIR*	Pearson (*r*) Correlation	-0.538(*)

** Correlation is significant at 0.05 level (two-tailed)*

Curves for the relationship between safety investment and safety performance

Based on the above analysis, the relationship between safety investment and safety performance of building projects is found to be affected by the project hazard level. According to the definition of the rating scale for assessing the project hazard attributes and the formulas for calculating the PHI, the value of PHI ranges from 1 to 5, where "1" represents the lowest project hazard level and "5" represents the highest project hazard level. Therefore, the critical value of PHI was set as "3". The 21 projects were divided into four groups based on the project hazard level (see Table 6). About 90 percent of projects fall into the category of low hazard projects (2≤PHI<3) and category of high hazard projects (3≤PHI<4).

To facilitate the comparison of the relationship between safety performance and safety investment under various project hazard conditions, two curves were plotted based on the abovementioned classification of projects. The first curve described the relationship between safety performance and safety investment under low project hazard level (2≤PHI<3); and the second curve described the relationship between safety performance and safety investment under high project hazard level (3≤PHI<4). Since there are only two projects belong to the categories of extremely low hazard projects (1≤PHI<2) and extremely high hazard projects (4≤PHI≤5), the curves for the relationship between safety performance and safety investment under extremely low or high project hazard level will not be discussed in this paper.

Table 6: Classification of Projects based on PHI Value

Category	*PHI range*	*Number*	*Percent*
Extremely low hazard projects	1≤PHI<2	1	4.8%
Low hazard projects	2≤PHI<3	10	47.6%
High hazard projects	3≤PHI<4	9	42.8%
Extremely high hazard projects	4≤PHI≤5	1	4.8%

Regression techniques were used to plot the curves of the relationship between safety performance and safety investment. Through the review of previous studies on the relationship between safety investment and safety performance, two types of regression models, including

Inverse model (Laufer, 1987) and Exponential model (Tang *et al.*, 1997) were used to determine which model provides the best fit. Table 7 summarized the regression models and parameter estimates for low hazard projects (2≤PHI<3). Both Inverse model and Exponential model provide moderate R square value (0.541 and 0.567 respectively). This indicates that, with Exponential model, 56.7% of the variance in safety performance can be accounted for by changes of safety investment. The chance of the obtained results having been obtained by sampling error, assuming the null hypothesis to be true, is only 0.012 (<0.05). The plot of safety performance against safety investment was shown in Figure 2. Thus, both regression models are suitable to describe the relationship between safety performance and safety investment of building projects when the project hazard level is low *(2≤PHI<3)*.

Table 7: Model Summary and Parameter Estimates (2≤PHI<3)

Equation	Model Summary					Parameter Estimates	
	R^2	F	df1	df2	Sig.	Constant	b1
Inverse	0.541	9.438	1	8	0.015*	-846.424	1827.659
Exponential	0.567	10.469	1	8	0.012*	1875.615	-3.146

** Correlation is significant at 0.05 level (two-tailed)*

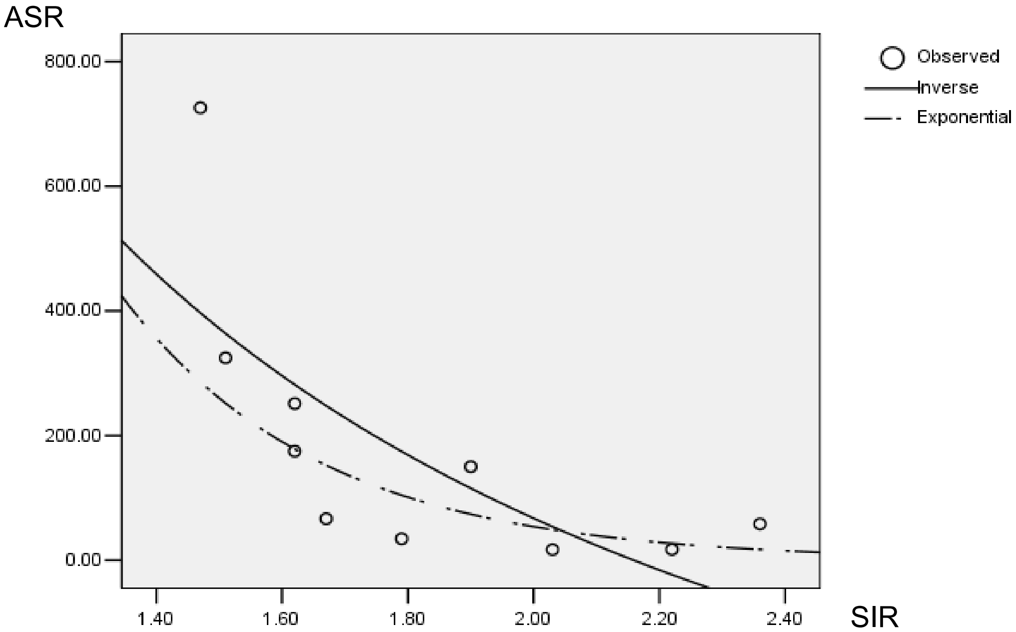


Figure 2: Plot of SIR against ASR under Low Project Hazard Conditions

Similarly, regression analysis was carried out to plot the curve of safety performance against safety investment under high project hazard conditions (3≤PHI<4). The regression models and parameter estimates were presented in Table 8 and the plot of safety performance against safety investment was shown in Figure 3. The R square values for both models were found to be high (0.722 and 0.834 respectively), which indicates a high correlation between the dependent variable and independent variable. Both the two model have an associated probability level of $p<0.05$, showing that the results are unlikely to have arisen by sampling error, assuming the null hypothesis to be true. The exponential model provides a higher R square value (0.834) than the Inverse model (0.722), which means that the exponential model is more suitable to describe the relationship between safety performance and safety investment under high project hazard conditions. 83.4% of the variance in safety performance can be explained by the variance in safety investment for projects with high hazard level.

Table 8: Model Summary and Parameter Estimates (3≤PHI<4)

Equation	Model Summary					Parameter Estimates	
	R^2	F	df1	df2	Sig.	Constant	b1
Inverse	0. 722	18.151	1	7	0.004**	-2950.164	7364.810
Exponential	0.834	35.229	1	7	0.001**	160985.759	-2.984

*** Correlation is significant at 0.05 level (two-tailed)*

The comparison of the curves for the relationship under various project hazard conditions further illustrates the interactive effects of safety investment and project hazard level on the safety performance of building projects. The relatively higher R square value, which represents the higher correlation between dependent and independent variables for the curve under high project hazard conditions, suggests that the effect of safety investment on safety performance is more significant for projects with high hazard level than those with low hazard level. The results of this study provide empirical evidence to support the suggested hypotheses 1 and 2. Safety performance of building projects is positively related to safety investments when holding the project hazard level constant. Furthermore, there is stronger positive relationship between safety performance and safety investments under high project hazard level. The interactive effects of safety investment and project hazard level on safety performance imply that in order to achieve good safety performance, different investment decisions in workplace safety need to be made under different project conditions. The same level of safety investment for different building projects does not necessarily produce the similar safety performance. To achieve a certain level of safety performance, more expenditure on safety is required for those projects with higher project hazard level than those with lower project hazard level.

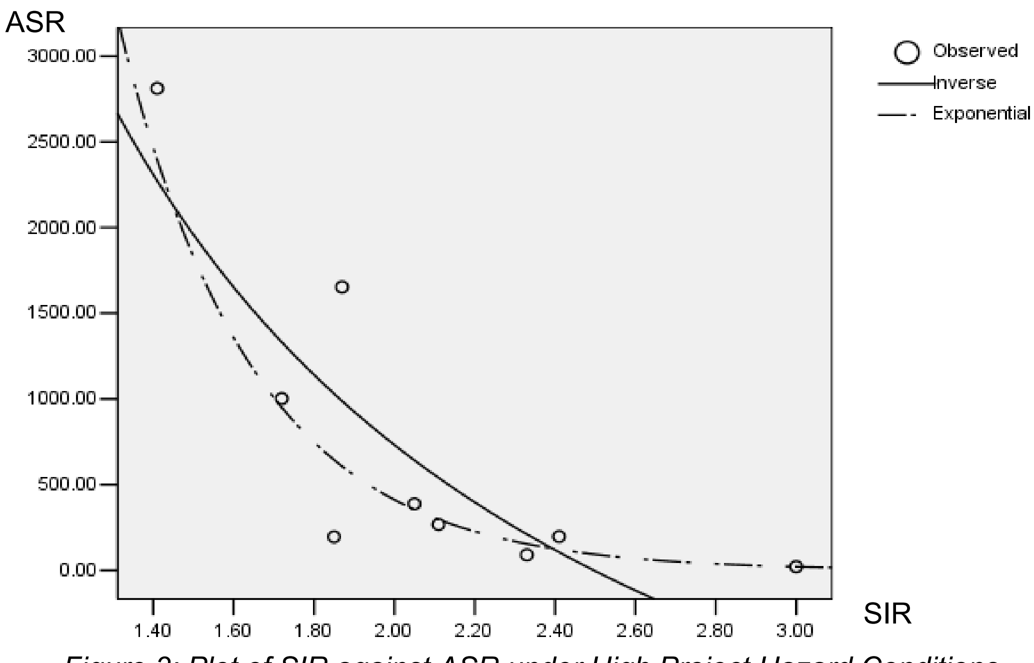


Figure 3: Plot of SIR against ASR under High Project Hazard Conditions

CONCLUSION

This study was focused on the empirical investigation into the relationship between safety performance and safety investment for building projects. The results of correlational analysis and partial correlational analysis indicate that safety performance is positively related to safety investments when removing the influence of project hazard level. Curves for the relationship between safety performance and safety investment were estimated using Regression methods. Comparison of the curves under various project hazard conditions further demonstrates the influence of project hazard level on the relationship between safety performance and safety investment. The curve of their relationship under high project hazard conditions has a relatively higher R square value than that under low project hazard conditions, showing that safety investments have a stronger positive impact on safety performance under high project hazard conditions. The role of safety investment in improving safety performance is more important for projects with high hazard level than those with low hazard level.

The findings of this study can partly explain the low correlation coefficient (0.25) between safety investment and safety performance obtained by Tang et al. (1997), and then may contribute to resolve the debates of researchers on the relationship between safety investment and safety performance. The interactive effects of safety investment and project hazard level on safety performance imply that in order to achieve good safety performance, different investment decisions in workplace safety need to be made under different project conditions. To achieve a certain level of safety performance, more expenditure on safety is required for those projects with higher project hazard level than those with lower project hazard level.

However, project hazard level may not be the only factor influencing the relationship between safety investment and safety performance of building projects. The next stage of this study will examine the effects of other factors, e.g. safety culture, on the relationship between safety investment and safety performance. More rigorous function of the relationship between safety investment and safety performance could be developed with integration of all possible influencing factors.

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PARTNERING: BETTER BUSINESS IMPERATIVES

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ABSTRACT

Since May 2005, The Australian Reinforcing Company and Baulderstone Pty Ltd have worked collaboratively to initiate, implement and evolve a partnering approach in Queensland. Together, they developed the Better Business Group

Meeting monthly, the Better Business Group is comprised of equal representation from both companies, plus an external facilitator. To sharpen strategic intent and ensure productive initiatives, the group identified three critical areas of focus: safety, efficiencies and business development. Each stream is responsible for designing, rolling out, monitoring and refining initiatives that will maximise sustainable growth for both partners. Streams report to the Steering Committee at the monthly meetings for management sign-off and resourcing of initiatives. In addition, to accelerate personal development, all participants receive best business practices and techniques, such as communication excellence and cross-industry case studies.

Initiatives implemented by the Better Business Group Safety Stream include Sharp Bar Awareness Program, alternative packaging and delivery methods, and a focus on site personal protective equipment (PPE). Currently this stream is working on joint site safety audits, to learn from each other and adapt the most useful safety processes. The results speak for themselves. The Better Business Group safety innovations have greatly contributed to the steep decline of reinforcement related injuries on Baulderstone sites from 17% to 0.68% of total site injuries.

The success of the Better Business Group is clearly based on the strong relationships within the group. Open, transparent and honest communication has been the key since the group's inception. Issues can be raised quickly, examined critically and resolved collaboratively. This group is challenging and changing the way we do business. It prides itself on a quest for continual improvement, so that initiatives remain relevant and significant. Its legacy will be business growth, propelled by an empowered workforce.

Keywords: Partnering, Supply chain, Collaboration, Safety improvements

LITERATURE REVIEW

"Partnering is a management approach ……. based on mutual objectives, an agreed method of problem resolution, and an active search for continuous measurable improvements" (Bennett & Jayes 1995). The Australian Reinforcing Company (ARC) and Baulderstone embarked on a partnering program in 2005 as both companies realised that the results that could be achieved by working together would far outweigh the results achieved by working independently.

According to Lendrum (2003) strategic partnering is the "effective bringing together of environment, process and people", and it is to this definition that ARC and Baulderstone have endeavoured to work towards. This process has been encouraged via senior management support from both companies, a practice that is supported by Lendrum (2003) as he indicated the importance of the "unconditional support and active participation from senior management".

"There is …. a range of other potentially positive outcomes with partnering such as learning, improved quality, end-user satisfaction, safety, cost control, and improved working environment" (Atkin *et al* 2003) The partnering process that exists between ARC and Baulderstone have given rise to positive outcomes. Examples of these outcomes, particularly in the field of safety, are contained within this report.

INTRODUCTION

The Australian Reinforcing Company (ARC) has had a proud history of supplying reinforcing and fencing products throughout Australia since 1920. With over 40 locations across Australia, including 5 main manufacturing sites, ARC employees over 900 people.

ARC is committed to delivering quality products to Infrastructure, Residential and Commercial construction, Concreting and Mining markets. ARC's products include standard reinforcing, special reinforcing, mining products, tools and accessories, general purpose mesh and residential and commercial fencing

Baulderstone has been "Creating what matters" in Australian building and infrastructure for over 80 years. Formerly known as Baulderstone Hornibrook, the company represents a merger between two prominent construction businesses founded by Sir Manuel Hornibrook and Bert Baulderstone.

Today, Baulderstone is one of the largest Building and Engineering companies in Australia, employing over 1200 people across the country. Baulderstone's record of achievement continues to develop through the construction of specialist medical and educational facilities, commercial and residential developments, bridges, road and rail infrastructure, tunnels, water treatment plants, and power stations. With its Corporate Head Office in Sydney, Baulderstone also has offices located in all capital cities in mainland Australia (except Darwin) as well as a regional office in Townsville

The Australian Reinforcing Company (ARC) and Baulderstone have worked collaboratively in Queensland to initiate, implement and evolve a partnering approach. The formulation of the Better Business Group is a result of the decision to work together in this way.

With the aid of an external facilitator, formal monthly meetings of equal representation from both companies have been conducted since May 2005 to develop this relationship.

It was recognised strategically within the Better Business Group that there should be initiatives developed in the areas of Safety, Efficiencies and Business Development. As such, these areas became the streams within which the Better Business Group operates.

This report will identify the basis of partnering and provide examples of some of the initiatives developed within the Better Business Group that have contributed to an improved safety record.

PARTNERING AND THE BETTER BUSINESS GROUP

We can identify many examples of partnerships in our daily lives such as in the form of the union of the husband and wife, and in the form of a team of sportspeople striving for the ultimate goal. These examples indicate the importance of partnerships and how they strive to get the best out of the individual as well as the partnership group as a whole.

In a business sense, the overall goal of partnering by the Better Business Group is the realisation of a safer and more efficient commercial arrangement between client and supplier.

Lendrum (2003) maintains that partnering is about a paradigm shift. It is about changing the way we do things, and the way we think, to enable us to achieve greater results together. A basis of partnering is that the collective results of the partnering companies are greater than what each company can achieve independently.

"Successful partnerships are based on trust, shared information and the long term" (Lendrum 2003). The Better Business Group has taken a long term view in its development. For the benefit of the partnership, both companies share information within any probity requirements by either company's clients. The group's value is continually verified, particularly at the end of year meeting where there is a focus on results achieved and the direction for the following year.

It is important to the group that there is equal representation from both ARC and Baulderstone. The Better Business Group has evolved to have all the work conducted within the three working streams; Safety, Efficiencies, and Business Development. With the intention of maximising sustainable growth for both ARC and Baulderstone, each stream is responsible for the designing, rolling out, monitoring and refining of initiatives.

The active participation from senior management from both companies is considered vital to the group. Within the Better Business Group, this participation is via their involvement in the Steering Committee. As part of the conclusion to each monthly meeting, the senior managers from both companies sign off and resource the initiatives presented in the Stream Leaders' reports back to the Steering Committee.

A further part of the Better Business Group partnering process is the external facilitators deliver of best business practices and techniques, such as communication excellence and cross-industry case studies. This is designed to accelerate personal development within the workforce of both companies.

SAFETY INITITATIVES

A number of the initiatives that have been developed within the Better Business Group have shown to improve both efficiencies and safety records for both companies in Queensland. The following initiatives are some examples of those that have been shown to affect the safety on Baulderstone construction sites, as well as within the ARC processing sites. These initiatives range from the more basic initiatives to the more detailed.

The Sharp Bar Awareness Program

This program began with the view to investigate the causes of workplace injury due to sharp bar cuts and to recommend improvements to reduce or eliminate such injuries. At one stage, reinforcement related injuries represented nearly one-fifth of all injuries on Baulderstone sites, so this was seen as critical to understand and act upon.

Of all the reinforcement injuries on site, it was found that the majority of these were caused by the dags on the ends of reinforcement bars. These dags posed a risk for all handlers of the reinforcement, from the factory processors through the delivery and final users on site.

PICTURE ONE: DAGS ON ENDS OF REINFORCEMENT BARS AFTER PROCESSING

PICTURE TWO: DAGS ON ENDS OF REINFORCEMENT BARS ON SITE

It was identified that the dags were the result of a number of circumstances that occurred during the processing stage:

- Infrequent replacement of the blades on the fixed cutting machines
- The wiping the bottom section of the bar downwards by the mobile cutting machines
- If a shear is through the rib of the bar, a dag will tend to form.

As part of the sharp bar awareness program, a number of improvements were introduced, including:

- Setting up a blade maintenance program
- Improving the bundling and loading regime
- Improving sharp bar awareness
- Installing site safety champions
- Segregating storage and prefabrication areas for reinforcement on site
- The use of gloves, long sleeved shirts and long trousers on site
- Raising awareness by presenting workshops to the sites
- Compiling a safety information pack

PICTURE THREE: EXAMPLE OF SAFETY ALERT POSTER

As part of the program, and to ensure clarity of information from sites, greater detailed definition of site injury reports was implemented to specifically differentiate between bar, mesh and wire cuts; identify the diameter of the bar that caused any cut, and; to differentiate between handling and "walk past" injuries.

Further initiatives implemented under this program include the awareness made to all sites via safety alert posters, toolbox training and Site Safety Committee advice. At the time, segregation of reinforcement on site was not a common practice, so reinforcement storage away from access ways was ensured via the inclusion of this on the Site Safety Audit Checklists.

Within ARC, initiatives under this program started with the clear definition of what is considered to be a sharp bar. The awareness of potential injury to the end user was then raised via Tool Box Talks. The placement of safety alert posters at every cutting machine was also introduced to encourage operators to report sharp bars. Additionally, maintenance checks are now carried out at the end of each shift by the operator to check the sharpness of the shear cutting blade.

It is now planned to roll out the Sharp Bar Awareness Program to other ARC sites nationally.

Alternative Packaging

It was recorded that cuts were occurring on site due to the standard packaging of reinforcement with tie wire.

As a result, ARC introduced alternative bundle tying options providing not only significant safety improvements, but also efficiency savings.

These alternative options included the use of heavy-duty plastic Zip-ties in lieu of the traditional tie wire and the use of disposable industrial bags on pallets, enclosed in a brick cage, for large loads of reinforcement "smalls".

Furthermore, the use of Zip-ties has been identified as a potential use to tie reinforcement together on site in place of tie wire, to further enhance on-site safety.

Modular Construction – Prefabrication and Rollmaster Slabs Innovation

As early as possible in the project construction life, the partnership provides the ability to confirm the feasibility of using modular construction methods for the rapid positioning of reinforcement on site. Whilst the efficiency of placement of the reinforcement is a high motivator in the use of these modular methods, a safer method of working is enabled by using such methods. The modular construction methods revolve around the welded reinforcement in ARC's yard to be essentially be directly installed on site. These methods can be in the form of column cages, modular form culvert bases and ARC's Rollmaster system

PICTURE FOUR: MODULAR FORM CULVERT BASES

PICTURE FIVE: ROLLMASTER ON-SITE

As an example of a modular construction method, Rollmaster is essentially reinforcing bar welded to straps and rolled up. Once on site, the mat is rolled out either manually or by using a compressed air hose. Much of the standard industry practice of manual steel fixing is removed by using Rollmaster as reinforcement for concrete slabs and decks.

Whilst these modular construction methods provide gains in efficiencies, there are clear safety benefits, including the removal of manual "hazard" lifts. For each tonne of reinforcement sent prefabricated, there is a substantial reduction (up to 90%) of manual lifting of reinforcing bar. Furthermore, given that there is less on-site handling by the end user, potential cut hazards are also minimized.

Alternative Delivery Methods
In an endeavour to reduce top of truck (working at heights) safety issues, alternative delivery methods have been devised within the Better Business Group. Whilst not all of these delivery methods are suitable for all construction sites, the requirement of personnel on the top of the trailer for unloading has been reduced where these initiatives have been able to be applied.

One example of an alternative delivery method is the use of a side-loader to deliver reinforcement. This method has been trialed on one site, with further trials due on the next appropriate construction site.

In this case, the fact that the load was lifted from the truck to a segregated lay-down area at ground level ensured that there was no need to have any person climbing over the reinforcement on whilst still on the truck trailer. The reinforcement, once laid down was also in a clearly defined segregated area.

Even though this initiative started within the efficiency stream, it wasn't long before the safety benefits of this delivery method were realised.

Site Focus on Personal Protective Equipment via Champions
In the warmer, more humid climate of Queensland, it is often the case still to have site workers not wearing the appropriate Personal Protective Equipment (PPE).

The Better Business Group identified the safety improvement in ARC factories was a result of their making certain that the correct PPE was used by personnel within the factory setting. Consequently, it was agreed between the partner companies that with the support of site champions, there would be a greater focus on the use of gloves, long trousers and long sleeved shirts on sites.

The development of this initiative had to include a heat stress policy and the extensive review of light-weight gloves and clothing to suit the hot and humid Queensland climate.

Whilst this initiative could be seen as arguably the easiest to implement, it is one that still requires constant reviewing on the construction sites.

Joint Safety Audits
Currently the Safety Stream within the Better Business Group is working on joint site safety audits. The expected outcome is to learn from each other and adapt the most useful safety processes

RECORDED RESULTS
The results that have been achieved on Baulderstone sites have been significant. According to statistics provided by Baulderstone, it has been found that the Better Business Group safety innovations have greatly contributed to the steep decline of reinforcement related injuries on Baulderstone construction sites in Queensland from 17% to 0.68% of total site injuries.

With reinforcement injuries on site representing 17% of all site injuries in 2002, Baulderstone (Queensland) management implemented a focus on safety for their sites. By 2004, this figure had dropped and settled at around 6.3%.

From 2004 onwards, the only consistent and monitored change was the rigorous approach by ARC and Baulderstone via the Sharp Bar Awareness program. Understanding that it is impossible to hold all variables consistent, it appears that this program contributed to further improvements in safety, resulting in the reinforcement injuries on site representing 0.68% of total site injuries in 2006.

Further, it has been identified that as at July 2009, there has been zero Lost Time Injuries (LTIs) based on reinforcement injuries on Baulderstone construction sites since June 2006.

CONCLUSION

Strong relationships formed within the Better Business Group have clearly assisted in the successes of the Group itself. The open, transparent and honest communication has and will always be the key to its striving for continual improvement. The personnel within the Better Business Group enjoy challenging and changing the way we do business, and ensure that all initiatives remain relevant and significant. Propelled by an empowered workforce, the legacy of the Better Business Group will be business growth.

The innovation and implementation of any of the Better Business Group initiatives would have been almost impossible without the visible support of senior management from both companies. Ensuring their understanding of all initiatives through their involvement in the Steering Committee has built the confidence of the workforce to follow through with improved methods of performance, and enables the resourcing of such things as funds and time.

The safety statistical results mainly due to the safety initiatives developed within the Better Business Group speak for themselves insofar as the success of the group is concerned. Furthermore, the efforts of the group were rewarded with the receiving of the High Commendation Award in the Research, Development and Innovation category at the 2008 Engineers Australia Engineering Excellence Awards (Queensland Division).

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IMPLEMENTING OCCUPATIONAL HEALTH AND SAFETY IN SMALL CONSTRUCTION ENTERPRISES

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ABSTRACT
This research is based on a benchmarking study of occupational health and safety (OHS) management practices of construction companies in Australia. It is mandatory for Australian construction firms to provide a safe working environment for their workers and sub-contractors. However, many small to medium enterprises that are not in a position of financial strength, struggle to provide adequate levels of OHS.

The results show that the size of the company is a major contributing factor to their OHS performance. Small enterprises employing less than 25 employees have comparatively low levels of management performance compared to larger enterprises. Company size is a limiting factor that impacts on the ability of small firms to implement comprehensive OHS plans. Nevertheless, some firms seem to be able to provide better OHS management practices than their size would suggest.

This research analyses a group of good and 'mediocre' performers across a range of OHS management criteria, in order to identify benchmarks that lead to best practice. The results show that a variety of risk management practices, particularly design control and health and safety review, were used by the better performing contractors. The paper concludes with the implications of the study for small to medium enterprises in the construction industry.

Keywords: Occupational health and safety, Construction management, Small to medium enterprises, Australia

INTRODUCTION
While it is well understood that the building and construction industry is inherently dangerous, increased emphasis needs to be placed on occupational health and safety management (OHS) both on and off site. There is a large body of evidence to show that construction is amongst the most dangerous industries in the economy (Champoux & Brun 2003). There is also a lesser amount of research that indicates that smaller firms have greater difficulty in ensuring the safety of their workforce compared to larger firms (Holmes, 1999, Champoux, D, et al 2003; McVittie, D et al 1997). These two issues significantly impact the construction industry, making the improvement of OHS a difficult task. This research is based on a benchmarking survey of small and medium sized construction firms to measure their capacity to implement comprehensive OHS management systems.

SMALL FIRM AND SUBCONTRACTING
A significant problem within the construction industry is the disorganisation and subcontracting and its effects on OHS. The growing dependence on subcontracting work has significant implications on the management of safety and is "an important source of injury at work" (Mayhew et al. 1997). Loosemore and Andonakis (2007) highlight the "complex web of constantly changing contractual relationships" as significant influences on the OHS performance of the construction industry. Loosemore and Andonakis (2007) further highlight the propensity of principal contractors to transfer risk onto subcontractors that lack the knowledge and resources needed to properly

address OHS. In addition, Mayhew et al. (1997) state that organisations consisting of "self employed workers, teams or small employers do not have the resources to devote to OHS that is the case with larger organisations". This ultimately creates a gap in the knowledge and understanding about OHS.

Holmes (1999) conducted research from a sample of Australian companies and found that small construction firms did not manage OHS risks as effectively as larger firms. Data from the Australian Bureau of Statistics shows that the majority of Australian construction firms were small businesses, 97% of general construction businesses employ less than 20 employees, and 85% employing less than five people (VWA 1998). Holmes commented that, small businesses did not feel the need to focus on OHS in their management systems and believed that the control of risk is the responsibility of employees. This was contrasted with the attitude of large businesses that indicated that OHS should be integrated into their entire management system across all projects within the company.

A similar study conducted by Wilson (2000) found that safety attitudes varied by the size of the company. He suggested that there is some doubt whether smaller companies can benefit from higher standards of OHS practice, due to the implementation costs involved. Other research (Lingard & Rowlinson 1994) showed that firms having more resources and experience tend to deal with health and safety issues more effectively. Therefore in a relative sense, larger companies tend to be more committed to safety. It is also possible that OHS regulations which require formal documentation procedures do not fit the traditions, competence and needs of very small companies (Hale 1998).

Mayhew (1997) states that industries where subcontracting is common, often has a higher incidence of serious injuries and fatalities. In his analysis of the United States census data, the research suggests that self-employed workers were more than twice as likely to be killed at work. Subcontractors are generally much smaller companies than main contractors, hence are less well organized and have fewer resources to implement proper OHS systems. According to Holmes (1999) they are also less committed, because of their smaller involvement on the project as a whole.

THE COST OF IMPLEMENTING OCCUPATIONAL HEALTH AND SAFETY

Cost has a role in reducing accidents and improving efficiency. According to Hinze (1988) safety is an important issue, but many people do not feel it is vital to the success of projects. Research by Tang (1997) into the injuries on 18 construction projects suggested that the higher the investment in safety, the better the safety performance. However, Holmes (1999) points out that, time and economic constraints appear to influence the way that individuals perceive risks and consequently risks should be identified prior to construction.

Hinze (1988) has found that injury rate tends to be higher where those projects were competitively bid. It is common practice for the contractors to discount their jobs just to win the tender, and as the result OHS suffers. Safety is often found to be the first item to face cost cutting, as the employers often believe that implementing a safety system will cost more. In addition, managerial focus tends to concentrate on production 'at cost' and safety does not help production therefore it suffers when a project runs over budget (Hinze 1988).

On the other hand Wilson (2000) suggested that the main contractors should have a good working knowledge of safety procedures. However, the main contractor often leave the responsibility of safety to the individual subcontractors and may never take an active part in ensuring that the subcontractor are taking all measures necessary to provide a safe working environment. Lingard and Rowlinson (1994) found that very few contractors take safety performances into account when selecting a subcontractor. Her research results suggest that by screening suppliers and contractors, accidents are reduced and OHS standards improved.

In order for this study to be effective a method was required to standardize the measurement of Construction Company's safety performance. A number of previous researchers have considered this issue. Research by Jaselskis (1996) recommended that companies should set OHS benchmarks, his methodology was based on collecting, both qualitative and quantitative information about the company's safety performance to determine OHS.

The next section of the research outlines the model used to benchmark OHS performance using a Capability Maturity Matrix which was created by an industry think tank, known as the Construction Industry development Agency (CIDA) In 1994 Monk performed a similar questionnaire in New South Wales using the CIDA matrix system. Her results showed a large difference between the OHS performance for small contractors (10-19 employees) compared to large companies (150 plus employees). The study concluded that on average, smaller contractors did not perform up to level 2 of the matrix, which is below the minimum required to meet legislative compliance. The results of this survey were then compared to Monk (1994) and some conclusions are drawn.

METHODOLOGY

The Health and Safety Continuous Improvement Matrix developed by CIDA (1995) is a benchmarking system for the comparison of OHS performance across the Australian construction industry. The CIDA system allows a company's occupational health and safety performance to be measured against the OHS criteria for contractors and sub-contractors (CIDA 1995). The CIDA matrix contained 16 criteria however the final survey removed 3 criteria from the questionnaire due to lack of relevance to the study and to reduce the length of the questionnaire. This framework does not conflict with current industry standards (i.e. National Construction Standard, Guide to Best Practice, etc.) and was utilized as a benchmarking tool.

The system allows the grading of companies' occupational health and safety between 0 and 5 against OHS system elements that are set out on the CIDA matrix. Level 0 was disregarded in the author's questionnaire. It was assumed that the contractors who responded have a least some appreciation and awareness of OHS.The system elements are matched to quality assurance standard AS 3901. The questionnaire requires the respondents to subjectively assess their own OHS management within the system.

A questionnaire was developed based on the CIDA's Health and Safety Continuous Improvement Matrix, also included questions relating to the type of companies, and the type of projects that they undertake. Initially a pilot study was conducted to examine the ability of the questionnaire to obtain the information necessary for the research. Pilot studies are an effective way of improving question wording and avoid mistakes in the questionnaires. They allow researchers to identify potential problems and errors, including improvement of wording for a better understanding of the questions. The pilot study showed that the questionnaire was too long. The final questionnaire was reduced in size to approximately half of the original pilot study questionnaire.

A total of 230 questionnaires were sent to Victorian construction companies by post. The sample of companies was obtained from the author's own private contacts and from the Yellow Pages listing of the Melbourne telephone directory.

The questionnaire comprised two parts: **Part A,** demographic of the company, their characteristics, in relation to contract size, contract duration, number of employees and other factors found in the literature review which has an influence on the company's OHS mangement. Also there were other questions relating to; attitude of the company management, OHS tender costs, and the effectiveness of safety committees. These results were compared with scores obtained from Part B of the questionnaire. **Part B,** comprises the CIDA's the Health and Safety Continuous Improvement Matrix using the original 13 elements, 3 were deleted due to a lack of relevance and only a brief description of the element was given.

In essence the survey required firms to rate their existing performance against the criteria shown in the CIDA matrix. The survey design used randomized questioning so the level of the matrix was not immediately obvious. This was done to reduce the effect of firms exaggerating their performance against the matrix. Responses were received from 44 organisations, the range of companies was considered to be representative of the construction firms in Victoria, Australia. Of the 44 organisations represented in the data, 21 were classified as small with less than 25 employees with the remainder classified as medium to large comprising at least 26 employees and included firms up to 150 employees. The survey was not designed to be an exhaustive study but instead is only indicative of the trends within the Victorian industry. The data from each response was entered onto SPSS, and used for analysis of the survey data.

The results were presented in two ways. Firstly a set of descriptive statistics showing the average scores for each factor was undertaken. This was followed by a Discriminant Analysis (DA), which is a form of MANOVA; to distinguished between groups of firms the each displayed similar characteristics. Discriminant analysis involves deriving a variate, the linear combination of the two (or more) independent variables that discriminate best between a *priori* defined groups. Discrimination is achieved by setting the variate's weights for each variable to maximize the between-group variance relative to the within-group variance. The linear combination for discriminant analysis, also known as the discriminant function

Discriminant analysis is the appropriate statistical technique for testing the hypothesis that the group means of a set of independent variables for two or more groups are equal. To do so, discriminant analysis multiplies each independent variable by its corresponding weight and adds these products together. The result is a single composite discriminant score for each individual in the analysis.

The following section present the results of 44 survey responses involving self-rating against the CIDA OHS capability maturity matrix The next section commences with a brief set of descriptive statistics, and then uses discriminant analysis (DA) as the main analytical instrument.

RESULTS

The DA was undertaken to determine if CIDA matrix criteria could be used to identify the differences between firms that did and did not make specific allowance for OHS in their bid prices. The results showed that the DA was effective at identifying such contractors. The Eigenvalue was high (0.51) indicating that the DA is a good discriminator. The DA function is a simple linear equation that can be used to investigate the relative impact of each of the independent variables contained in the function. It is often tempting to use the unstandardized weight to interpret the function but it is better to use the standardized weights (Table 4).

The major finding of this research (Table 1) was that *company size* had a significant influence on a company's OHS performance. The score was lower for small firms compared to large firms for all of the critter in the CIDA matrix. This result was consistent with research by, Wilson (2000) and Holmes (1999). The study shows that there were important differences between the larger and smaller contractors on all CIDA elements (Figure 1). This is not a surprising finding because smaller companies' lack the resources to perform at a high level of OHS management performance.

Table 1 Average OHS matrix score by company size

	Small contractors (0-25 Employees)			Large contractors (26-100+ Employee)		
	Mean	Std. Dev	Valid N	Mean	Std. Dev	Valid N
B1-Management Responsibility	3.05	0.97	21	4.04	0.98	23
B2-Health & Safety System	2.86	1.06	21	4.22	0.80	23
B3-Contract Review	2.05	1.12	21	3.22	1.78	23
B4-Design Control	2.57	1.16	21	3.61	1.41	23
B5-Purchasing	2.76	1.04	21	3.39	1.20	23

B6-Work Method Control	2.76	0.89	21	3.87	0.87	23
B7-Inspection & Testing	1.67	1.11	21	2.87	1.39	23
B8-Control of Non-conformance	2.29	1.35	21	3.65	1.15	23
B9-Corrective & Preventative Action	2.81	1.03	21	3.91	1.04	23
B10-Health & Safety Records	2.86	1.01	21	3.87	0.92	23
B11-Health & safety Auditing	2.24	1.04	21	3.43	1.44	23
B12-Training	2.71	0.78	21	3.57	1.12	23
B13-Statistical Techniques	1.95	0.97	21	3.35	1.37	23

Firms were then classified as “actively” planning their future OHS if they specifically included cost in their tenders, firms that did not make a plan to allocate cost in their tenders were classified in this research as be “reactive” (Table 2). In other words, those firms that responded in the positive to the question, Do you include the cost of OHS in tenders, were classified as “Active”, and the negative were classified “reactive”. This was used as the basis for determining the difference between the firms using discriminant analysis (DA).

Tables 2 – Number of employees in firms by whether OHS cost are included in tenders

Cost inc. in Bid	0 – 25 Emp	25 – 50 Emp	50 – 75 Emp	75 – 100 Emp	100 + Emp	Total	%
Reactive (No)	6	2	1		2	10	25%
Active Yes	15	5	3	2	8	33	75%

The next phase of the research considered the question of scores for firms that indicated that they did plan for the cost of OHS in their tenders. A Discrininamt Analysis (DA) was undertaken using the responses to the question about whether OHS costs were included with the bid price. It was speculated that firms that recognized the importance of OHS cost in advance, and made specific allowance for it, should have better OHS management practices.

It can be clearly seen (Table 3) that the most significant discriminator is *Design Control (0.777)*, which relates to criteria about how the risk assessments are carried out prior to the commencement of the project. Firms that rated themselves low on the matrix indicated that they do not undertake a formal risk management process, and instead rely mainly on *past experience of staff*. This approach was contrasted with firms that rated themselves more highly; in those cases firms indicated that used a *Formal review process based on well establish procedures*.

The results of the DA also show (Table 3) that the next significant discriminator is *Health & Safety System (-0.615)*, which relates to criteria about how the OHS policy is embedded in the firm’s organisational procedures Firms that rated themselves low on the matrix indicated that they do not have formal and comprehensive OHS policies in place and instead have *Little or no obvious policy* and rely mainly on *ad-hoc procedur*es. This approach was contrasted with firms that rated themselves more highly; in those cases firms indicated that used a *Continuous improvement plans, fully resourced OHS and consultative processes for all system components.*

Table 3 – Standardized Canonical Discriminant Function Coefficients

Benchmark Criteria	Function
B1-Management Responsibility	.217
B2-Health & Safety System	-.615
B3-Contract Review	-.059
B4-Design Control	.777
B5-Purchasing	.019
B6-Work Method Control	.471
B7-Inspection & Testing	-.028
B8-Control of Non-conformance	.320
B9-Corrective & Preventative Action	-.235
B10-Health & Safety Records	.435
B11-Health & safety Auditing	-.559
B12-Training	.308
B13-Statistical Techniques	.081

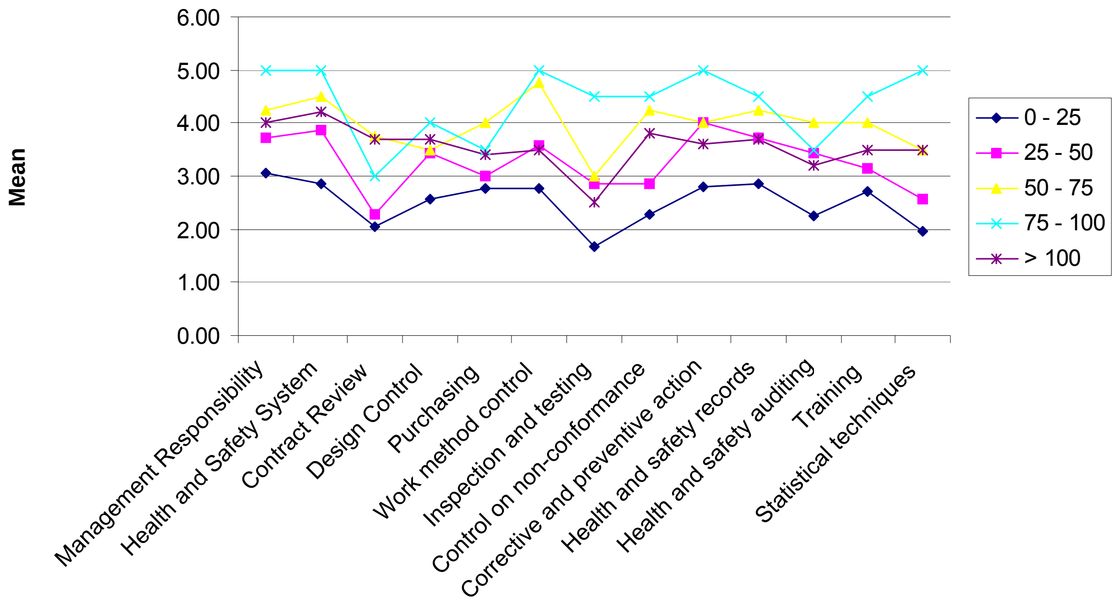
In other words, firms that took the time to specifically identify OHS risks associated with upcoming projects were more highly rated on the CIDA matrix. It was not surprising to find that the majority of firms that do <u>not</u> allow for OHS cost in their bids were the small firms (Table 2). This seems to suggest that these firms will find it difficult to implement the most to effective of OHS during the construction phase of their projects. It is more likely that these firms have an *adhoc* approach to the OHS that leads overtime to greater risks of serious injury, and a lower overall performance.

DISCUSSIONS

The major finding of this research was that *company size* had a significant influence on a company's OHS managment. (Figure 1) According to (Monk 1994) many occupational accidents and injuries are due to a breakdowns in the existing OHS management systems. The result shown in was found to be consistent with this research.

The construction industry contains a very large proportion of small firms that may not be in a strong position to implement good OHS systems. However, firms that want to improve their OHS performance should become more strategic about their actions. This research has shown that small contractors tend not to include OHS costs in their tenders reducing their ability to deal with potential problems. Contractors that have more formal process for identifying their OHS costs prior to bid, tend to become higher rated on the CIDA matrix.

Figure 1-Average OHS performance by company size



The next part of the research investigated whether it is possible to improve safety performance without the need to increase the size of the firm. The matrix scores were interrogated based on the notion that firms that it may be possible for a firm to increase it's OHS performance by strategically addressing only a few of the criteria.

The DA (Table 3) showed that the most significant differences in the OHS matrix score occurred in the *Design Control* and *Health and safety System* elements. This indicates that contractors that scored highly in these criteria tended to be higher on the matrix. These two elements have an important impact on safety performance and it is likely that many of the respondents recognised their importance.

One of the unexpected findings in this research was that all the companies' scores for *Inspection and Testing* were the poorest amongst all the other elements regardless of the size. The results of the research found that smaller companies perform poorer in this element compared to larger companies. However, it does not seem to be a major factor that influences the overall safety performance.

Hinze (1988) found that injury rate tends to be higher when projects were competitively bid. Although competitive bidding alone should not affect OHS performance, the research suggested that cost pressures tended to reduce the commitment to safety. This research questioned contractors about how they allow for the cost of implementing OHS plans on their projects. The results below (Table 2) shows the there were 10 *Reactive* firms and 33 *Active* firms. As previously mentioned this was based on whether they included costs in their tender prior to construction. Holmes (1999) suggested that OHS risk should be identified prior to construction and the costs of OHS should be included in the tender. Companies that allow OHS costs in their tenders seem to have a much higher performance in all elements, on average one standard level higher (Figure 1).

CONCLUSION

As expected the major factor affecting the OHS management practices was found to be the *company's size*. This research found that larger contractors tend to have better management structures compared to smaller companies because they have greater resources to do so. Large firms' generally do larger projects with more risks and so are required to implement better OHS planning. This research supports previous work conducted by Wilson (2000) that found that it was difficult for smaller companies to benefit from higher standards of OHS practice, due to the implementation costs involved.

Small contractors and sub-contractors on the other hand, generally perform poorly for similar reasons; their projects are generally smaller and have lesser OHS risks. Many occupational health and safety professionals believe that the application of effective occupational health and safety management systems will lead to a better OHS performance.

Firms that identified that they actively plan for OHS in advance seem to perform better against the CIDA matrix. *Design Control and Health and Safety Systems* are two of the criteria that appear to discriminate the practices of “active” and “inactive” firms, regardless of size. These two criteria play a major role in OHS management and this research suggests that any could improve OHS performance by concentrating in those areas.

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DEVELOPMENT OF SAFETY EFFECTIVENESS INDICATORS FOR USE IN THE CONSTRUCTION SECTOR

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ABSTRACT

This research outlines the development of a set of Safety Effectiveness Indicators (SEI's) which are derived from previously mapped Safety Management Tasks (SMT's) which in turn are constituents of a Construction Safety Competency Framework. Due to resource constraints, 13 only of the original 39 SMT's were selected for detailed examination and development into effectiveness Indicators

Initially six SMT's were developed to collect both quantitative and qualitative data on the effectiveness of the undertaken process. A number of formats and data collection options were prepared. This pilot process was trialled at construction sites of three major Australian construction companies. Feedback via structured interview and focus groups enabled the development of an additional number of SEI's to 13 in total.

This process resulted in the development of 13 SEI's which included both qualitative and quantitative data collections and further developed the SEI's as multi user instruments for ease of use on construction sites

The initial development of this set of SEI's is a positive step towards more clearly defining and measuring lead indicators. Further research is planned to explore the utility of these instruments with an additional number of construction companies.

Keywords: Lead indicators, Safety management tasks, safety effectiveness indicators

1. INTRODUCTION

Cohen (1977) reviewed the then current research on occupational safety, and stated that both strong company commitment to safety, and communication between all levels of a company are the most influential factors to improving safety. Other factors included careful selection of staff, and early and continuous training throughout the lifetime of the company. In 2009 these factors remain vital in Occupational Health and Safety (OHS).

Since Cohen's review there has been a continued decrease in the injury rates within the Australian construction industry. However this sector suffers from far more injuries and ill-health than the Australian average, with one fatality occurring on average per week and pays one of the highest workers' compensation premium rates in Australia. The fatality rate is three times higher than the national average, and 15% of all industry fatalities are in the building and construction sector. Notwithstanding some improvement in their rates, fatalities are too high. Other than lost time injuries (LTIs) or similar 'negative' 'lag' performance indicators, reliable, comparable and easily undertaken performance indicators are not available. An evaluation of Positive Performance Indicators (PPIs) as an OHS performance measuring tool, based on a brief overview of its limited uptake in Australian industry, suggests that it does not reliably measure OHS performance. There is a clear need to accurately measure safety performance on construction sites in order to improve industry performance. Likewise, in the pre-construction design and scoping phase, as well as in the post-construction facility management stage of completed projects, there is a need for reliable safety performance measurement. These issues of safety performance measurement have been addressed in part through a matrix of safety cultural competencies determined by identified safe behaviours and safety management tasks (SMTs) for the Australian construction industry (Biggs, Sheahan & Dingsdag, 2006; Dingsdag, Biggs, Sheahan & Cipolla, 2006)

1.1 Current methods of measurements

The main purpose of measuring safety is to develop strategies that will eliminate future incidents. Measurement and evaluation of OHS continues to be predominately by lag indicators, which include fatalities, compensation, Lost Time Indicators (LTIs). These measurements have the obvious inherent problem in that they can only be compiled after something has gone wrong, thus a negative measure – one of failure, rather than performance. Another contributing factor to poor OHS in the construction industry is the various State and Federal laws that govern OHS throughout Australia. These can be confusing and lead to inconsistencies between the safety regimes between states, and between and within construction companies.

Establishing a credible, accurate and timely standard for allowing industry-wide measurement of OHS performance remains the key to moving forward in improving OHS by the Australian Government (Federal Safety Commissioner's 2005-2006 Progress Report, 2006). Referred to as lead indicators, they aim to recognise signals **before** an incident happens. This would give a way to improve safety before an event occurs, thus reducing the lag indicator rates. At present the only tool actively used to measure lead indicators are Positive Performance Indicators (PPIs). PPIs measure the actions an organisation has taken to manage and improve OHS performance (Comcare 2004).

In 1999 the National Occupational Health & Safety Commission (NOHSC) gave the construction industry a guide to the development of performance indicators. From the areas idenitified, key indicaors were designed, most focusing on the numbers of, for example, OHS audits, OHS training, OHS plans, etc. Views on the effectiveness of PPIs have varied, but there has been limited uptake by industry, which suggests they do not reliably measure OHS performance (Dingsdag, Biggs and Cipolla, 2008). A major problem with PPIs is they measure how often an event occurs, rather than how effectively it is undertaken. There has been a general lack of consistent uptake in the industry as a whole, and lack of convergence and guidance in the literature.

1.2 Future methods of measurement

During the NOHSC (1999) safety culture was identified as a potential performance indicator, but not considered other than in a remote reference. Improving the safety culture has been the used the in the nuclear power industry, where there is an environment of planning for anticipated and unexpected events (Rochlin, 1999). There exists an ingrained culture of learning, communication, and locus of responsibility. These perceptions, attitudes and behaviours are created and maintained by management, and passed to employees in what actions will be rewarded, tolerated or punished (Aitken & Driscoll, 1998). Safety then must be personalized to the individual, and be allowed to challenge unsafe behaviour. It is at this level that safety could, and should, be measured, and used to as a lead indicator of effective safe behaviours. This as yet underveloped tool would be a means to assess an organisations sense of "how things are actually done around here", the direction in which Guldenmund (2000) concluded was the best way for measuring safety climate.

Recent research by Dingsdag, Biggs, Sheahan and Cipolla (2006) has developed a matrix of cultural competencies, developed through extensive consultation with industry, government and unions. 39 Safety Management Tasks (SMTs) were developed, which have definable activities, actions and processes associated. These activities, actions and processes need to be undertaken to manage workplace safety, and can be formatted into a tool to measure how effectively a task is being performed.

2. AIMS

The challenge for the current project is to develop reliable, comparable and constant indicators that measure safety performance without the drawbacks commonly attributed to PPIs: The indicators must be easily measured, comparable for benchmarking purposes within sections of an organization and across industries without being subject to random variation. For the construction industry specifically, they must be able to be implemented uniformly from project site to project site notwithstanding the disparate sectors of the industry, the variability of the work undertaken and the diverse risk contexts these generate. Further, they must be simple to implement so that they are not capital and human resource intensive: They must not be so complex that they are time-consuming to administer and collate and they must measure effectiveness instead of simply measuring a number of event s which have no demonstrated effect on safety performance.

This paper looks at the pilot development of 6 effectiveness indicators drawn from 13 of the original 39 SMTs. It is further planned to extend the pilot investigation to an overall 13 of the original 39 measures which have been selected for their relative importance. Resource constraints have restricted both the pilot study and the follow on planned field trials to a total of 13 SMT's

The 6 SMTs were then trialed on various sites throughout Australia. It will then be discussed on how to refine the tool through the results, comments and suggestions from industry. This tool will then be developed into a workbook to be published and distributed to the construction sector.

3. METHODS

13 SMTs were developed to collect both quantitative and qualitative data on the effectiveness of the task on the investigated sites (See table 1). As discussed, 6 of these SMT's were previously involved in a pilot (see table 1), were each tool was given to a construction site and over a period of 6 weeks the workforce was asked to complete each task when it arose on site. The results and feedback given from the pilot assisted in the development of the tool to be used in the field trial.

Table 1: List of all 13 SMT's across Pilot and planned additional field trials.(*SMTs used in pilot)

SMT Number	SMT Title
1*	Carry out project risk assessment
6*	Carry out workplace and task hazard identification, risk assements and control (JSAs/SWMSs)
13*	Plan and deliver toolbox talks
16	Consult on and resolve OHS issues
18*	Challenge unsafe behaviour/attitude at any level when encountered
20	Recognise and reward people who have positively impacted on OHS
21	Deliver OHS training in the workplace
22	Carry out formal incident investigations
24	Carry out formal inspections of workplace and work tasks
25	Evaluation research and prepare reports on OHS issues, performance and improvement strategies
26*	Monitor sub-contractors activities
28	Evaluate OHS performance of subcontractors
36*	Work with staff to solve safety problems

A Workbook was distributed for the Pilot. The first section contained information on the history of the project and instructions on how to use the Workbook, the final page was a feedback form that allowed users to return information on either the whole booklet, or an individual SMT in a structured format. The following pages were the 6 SMTs. Each SMT page was composed of the SMT title, spaces for name of evaluator, date and which status the evaluator considered him, or herself. This was followed by a description of the SMT and why it should be undertaken. Below this was the measurement scale, which was broken into different elements. The number of elements used ranged from 2 to 5. Each element was constructed of 2 statements on the extremities of a 4 point Likert scale. A negative descriptor of the element was anchored to the lowest number on the Likert Scale (1), and a 'best practice' descriptor was anchored to the highest number (4). The 2 and 3 point scale had no descriptors associated with them. The user was instructed to read the element and then mark the scale that best reflected where the felt their site lay on the scale – either poor practice (1), best practice (4), or somewhere in between (2 or 3). Each SMT was to be done separately to the others, as and when they arose on site.

The pilot trial began mid 2008 and was conducted on a number of sites suggested by the Industry members of the research group. The three companies are large 1st tier construction companies in Australasia.

Following completion of the pilot trial, debriefing meetings took place to receive any comments users had on the ease of use of the workbook. During the meetings and focus groups different scales were presented to the groups to see which scale would most relevant and easily used by sites. The scales presented were:

1. 4 point likert scale (as used in field trial and pilot).
2. 0 Point Likert scale.
3. Yes/No/Not Applicable boxes for each whole element.
4. Yes/No/Not Applicable boxes for each element description sentence.

4. RESULTS

Feedback was provided to the team by the forms contained in the workbook, which were collated. Focus groups were conducted to receive feedback from all participants in the pilot trials.

Of the comments received back via the feedback from, the changes requested were:

- Language/wording too complicated make simpler
- Repetition between elements
- Scale confusing

Of the focus groups held the major changes requested were:

- Language made more comprehensible
- More room for comments
- Ensure users of the workbook realize that each SMT is filled out separately from the rest

Other factors discussed in the focus groups that could potentially impede the uptake of the workbook are that it could simply add, or be seen to add, another layer of complexity to safety requirements.

Of the six SMT's used in the Pilot to develop SEI's, two are reproduced here (Figures 1 &2). The six SEI's developed in the Pilot take into account the comments and feedback described above. Once the follow on field trials are completed, it is anticipated that all thirteen SEI's will be developed and produced in a similar manner.

Figure 1. Plan and deliver toolbox talks

SAFETY EFFECTIVENESS INDICATOR FOR SAFETY MANAGEMENT

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TASK 13: PLAN AND DELIVER TOOLBOX TALKS

Job title	
Date of evaluation	
Evaluator status (CIRCLE ONLY ONE)	Independent observer **OR** Leader/facilitator **OR** Participant
Evaluator role	
Workplace name and company	

SEI 13 description	This SEI measures how to plan and hold a successful, value adding toolbox talk that achieves involvement and awareness.
Why SMT 13 is undertaken	Toolbox talks are held as one way of ensuring effective consultation, exchange of ideas and information between work crews and their supervisors leading to increased awareness of safety issues, hazards and safety actions on site.

Element 1	**Facilitator/leader encourages and gets participation, listens, and provides opportunities for input from all participants.**	
Descriptors	• Participants are actively encouraged to participate and to provide input.	Yes ☐ No ☐ Not applicable ☐
	• Facilitator is open to feedback, encouraging discussion that increases the level of risk awareness relevant to the team and site.	Yes ☐ No ☐ Not applicable ☐
Comments		

Element 2	**Facilitator/leader organises actions arising from toolbox talk and allocates responsibilities.**	
Descriptors	• Action owners are consulted by facilitator/leader before task allocation.	Yes ☐ No ☐ Not applicable ☐
	• Facilitator/leader confirms understanding of individual responsibilities, milestones and timeframes, and any other action owners involved.	Yes ☐ No ☐ Not applicable ☐
	• Action owners recognise and support the need for change and the outcomes wanted from the actions.	Yes ☐ No ☐ Not applicable ☐
Comments		

Element 3	**Facilitator/leader records relevant toolbox meeting discussion, awareness points, actions and action owners.**	
Descriptors	• Toolbox talk is accurately documented and distribution process agreed.	Yes ☐ No ☐ Not applicable ☐
	• Awareness strategies, opportunities and any improvements or requests raised or identified are accurately captured.	Yes ☐ No ☐ Not applicable ☐
	• Agreed action owners, activities and time frames are recorded and allocated.	Yes ☐ No ☐ Not applicable ☐
Comments		

Figure 2. Work with people to solve safety problems

SAFETY EFFECTIVENESS INDICATOR FOR SAFETY MANAGEMENT

CRC Construction Innovation
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TASK 36: WORK WITH PEOPLE TO SOLVE SAFETY PROBLEMS

Job title	
Date of evaluation	
Evaluator status (CIRCLE ONLY ONE)	Independent observer **OR** Leader/facilitator **OR** Participant
Evaluator role	
Workplace name and company	

SEI 36 description	Display and use of an effective process that actively involves all relevant people in problem solving.
Why SMT 36 is undertaken	To ensure interactive workforce engagement and collaboration in interventions before risk exposure occurs.

Element 1	Collaborative and proactive approach to identifying hazards and issues.	
Descriptors	• • Consultation process is understood and applied.	Yes ☐ No ☐ Not applicable ☐
	• Inspections identify hazards for routine work and planned high risk tasks.	Yes ☐ No ☐ Not applicable ☐
	• Inspections are conducted by a range of trained relevant site people.	Yes ☐ No ☐ Not applicable ☐
Comments		

Element 2	Seek input from all relevant people.	
Descriptors	• Input is encouraged, constructive, clear and non-biased.	Yes ☐ No ☐ Not applicable ☐
	• Issues are elevated to the appropriate levels for input from anyone, or all affected.	Yes ☐ No ☐ Not applicable ☐
Comments		

Element 3	Collaboratively develop and implement solutions.	
Descriptors	• Interactive stakeholder engagement and collaboration in interventions or solutions before risk exposure occurs.	Yes ☐ No ☐ Not applicable ☐
	• Issues are resolved with shared consensus.	Yes ☐ No ☐ Not applicable ☐
	• Solutions communicated to those impacted.	Yes ☐ No ☐ Not applicable ☐
Comments		

5. CONCLUSIONS

The initial reaction by participant organizations was favourable to the use of the SEI process. The pilot SEI workbook was considered by all participants as an excellent tool as it “offers consistency across the industry”, and they would like to see it “applied across industry” The researchers intend to expand the study form pilot to field trial and include a number of organisations both at 1st and 2nd tier level across several States and develop a further 7 SEI’s to a total of 13. This trial is expected to complete in late 2009. The final SEI measures are anticipated to be simple to use and robust in their applicability across the sector. The overall aim is to meet Cole’s (2003) proposition of a uniform series of measures across Australia and across construction environments.

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SAFETY CULTURE AMONG SUBCONTRACTORS IN THE DOMESTIC HOUSING CONSTRUCTION INDUSTRY

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ABSTRACT

Research suggests that subcontracting precipitates negative occupational health and safety (OHS) outcomes. This article sketches a portrait of the safety culture of subcontractors who work in the domestic housing industry in Australia to better understand them and inform policy decisions. Ethnographic data was gathered from a short survey of 150 subcontractors, in depth interviews with 11 subcontractors from various trades, document analysis, OHS course evaluations, informal conversations and investigator diaries. Despite the high rates of injury and disease in the construction industry, construction workers want to be safe at work and they trust their own safety knowledge developed over years of involvement in the industry. They have a poor understanding and appreciation of OHS legal requirements and accept that construction work is dangerous. They tend to think of safety as common sense and often blame the injured worker for not being careful enough. Safe behaviours are constrained by a competitive industry that puts costs before safety. Enforcement strategies fail to take the culture of the industry into account and are being met with a form of passive resistance. Three main areas that subcontractors believe need addressing are the critically important role the builder plays in Organizing the construction process, the interdependence of the different trades, and manual handling. An attempt is made to deconstruct the elements that constitute subcontractor safety culture in an effort to determine possible purchase points that, if systematically addressed, may lead to OHS best practice, rather than minimum compliance.

Keywords: Subcontracting, Housing construction, Safety culture

INTRODUCTION

This paper presents an analysis of some aspects of a research project that explored attitudes to OHS held by subcontractors in the domestic building industry. It was conducted because a large amount of anecdotal evidence gathered by the researcher strongly suggested that there was a growing culture of resistance to modern OHS legislation among subcontractors in that industry. The discussion examines the OHS situation in the construction industry and the influence of workplace culture on safe working. The evidence suggests that improved OHS outcomes may be compromised if the cultural values, norms and social structure of the industry are either ignored or marginalised.

The ‘problem of subcontractors’ in house construction in Australia is then examined using an approach inspired by root cause analysis techniques. The author probes beyond the obvious by picking apart and identifying the factors that contribute to poor OHS practices of subcontractors identified in safety literature. Understanding the influences on subcontractors will help develop targeted intervention strategies to improve their OHS performance. Enforcement strategies that purely target behaviours will have limited long term effectiveness if they fail to address the reasons why those behaviours occur.

SETTING THE SCENE

Construction is a high-risk industry (Stromm, 2001) with a high incidence of workplace deaths, injuries and diseases (WorkCover NSW, 2001) and a poor safety record (Safe Work Australia, 2008). According to Worker’s Compensation statistics, the construction industry of NSW has the fourth highest incidence of employment injuries (ASCC, 2009) and the highest number of work-related fatalities (ASCC, 2009) of all industries in NSW. The incidence of injury in the construction industry throughout Australia is 50% higher than the all industry rate (Breslin, 2004). Hence, OHS laws in Australia target the construction industry.

Subcontracting has become a major feature of the construction industry and Silberberg (Silberberg, 1991) asserts that subcontractors make up about 90 % of workers in the domestic housing segment of the industry. There is mounting evidence that this shift to subcontracting is having negative health and safety effects on these types of workers (Quinlan, 2003). Monitoring and enforcement of OHS is more difficult at workplaces such as building sites that have multiple subcontractors, and it increases the risk of instances of 'paper compliance' escaping undetected (Quinlan, 2003: 6). Hence, management of subcontractors is a key feature in the success of any OHS management system in this industry (WorkCover NSW, 2001), yet subcontractors have received little OHS research despite their importance to the construction industry and the Australian economy (Mayhew et al., 1996).

Johnstone (1999) found that subcontractors who work in domestic housing had poor understanding and awareness of OHS requirements. The National Occupational Health and Safety Commission (NOHSC) concluded that the domestic housing segment was not introducing OHS as effectively as other sectors of the industry (NOHSC, 1999). However, there appears to be very limited research targeting OHS in the domestic housing industry, which can mean poor policy (ACIL, 1996): 'Redressing this situation should be a matter of priority' (ACIL, 1996).

METHODOLOGY

This research has been designed to increase understanding of construction industry safety. The literature review revealed that there has been very little research conducted to gain insight into how subcontractors understand OHS and what it means for them. The aim was to talk to and listen to subcontractors from the domestic housing industry with the objective of finding out what they think, feel and do about safety at work to deconstruct subcontractors' subjective experiences and how they give meaning to their own situation. The desired outcome was to find some way of addressing the safety situation in the building industry. The main purpose of this study was exploratory. Therefore, it was thought best to use a qualitative theoretical framework on which to base the research methodology. The quantitative perspective may have difficulty in allowing for attitudes to be made explicit, especially in the absence of current substantive research that describes those attitudes.

The principle methodology employed for this research was ethnography. Ethnography is an act of sense making in which the researcher attempts to uncover multiple layers of meaning held by the group being studied (Barab et al., 2003), capture the personal experiences of participants and explore their complex social situations (Punch, 1994). The ethnographic approach allowed for the subjective understandings of the realities of the subcontractors to emerge, and for a cultural analysis to be applied to their words.

Somerville and Lloyd (2005) have suggested that ethnographic methods are extremely suitable for research into workplace cultures. In her study of learning safety in the mining industry she found that 'cultural analysis can explain how worker subjectivities, including learning and practising safety, are constituted within these workplace cultures' (Somerville and Lloyd, 2005). She believes that cultural analysis can help identify a 'potential locus of change' (Somerville and Lloyd, 2005) that one can use to mobilise workers to 'intervene in their own workplace practices' (Somerville and Lloyd, 2005). Eales and Spence (2005) suggest that the ability to identify and manage these 'cultural levers' will help facilitate ongoing change. It is proposed here that more effective intervention strategies can be developed by understanding exactly what the subcontractors perceive as their meaningful safety concerns.

The data was collected through a combination of a short oral survey of 158 subcontractors, participant observation, in depth semi structured interviews with 11 subcontractors from 6 different trades, document analysis, discussions in hundreds of OHS induction courses, course evaluations, informal conversations with subcontractors over a 9 year period and investigator diaries. It was simultaneously and iteratively recorded, analysed and coded into emergent themes.

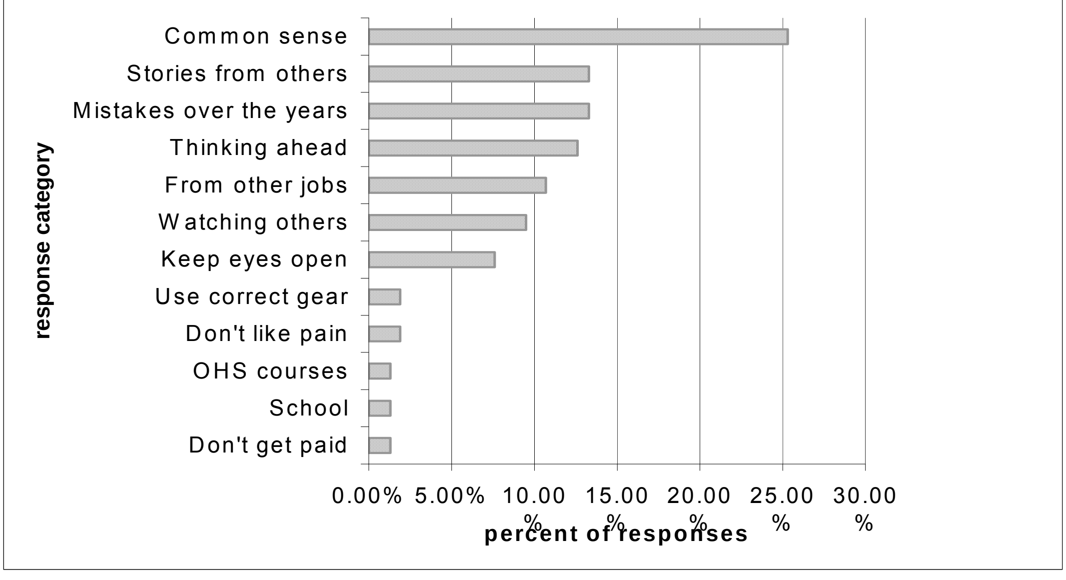
Reliability of results was enhanced through triangulation, and validity was strengthened by the author's emic connection with the industry that made it difficult for the participants to mislead him, deceive him, or gloss over things. His working relationship of equality with many of the interviewees helped to address issues of power and perspective, which is essential when determining what version of culture is written (Barab et al, 2003: 3).

FINDINGS AND DISCUSSION

This section of the paper is grounded in the data gathered for this research. Statements made represent perceptions enunciated by the research participants. A complex picture emerged of the subcontractors' workplace culture, and in particular, their safety culture. Three macro themes were evident: the subcontractors' need for independence and autonomy, their need and desire for personal safety, and their opinions of WorkCover's enforcement strategies.

In response to the open-ended oral survey question 'How did you learn to work safely?', the most often cited response was 'Common sense' (25%), followed by 'Mistakes over the years' (13.3%), 'Stories from others' (13%), 'Thinking ahead' (12.6%), 'From other jobs (10.7%) and 'Watching others' (9.5%). Low response rates were for 'Use correct gear' (1.9%), 'OHS courses' (1.3%) and 'School' (1.3%). Their learning was specific to the tasks they perform and the tools they use. It was not generic, but trade specific. That is, they have learned to work safely through involvement with their trade in the construction industry.

Table 1. Responses to the question: 'How did you learn to work safely?'



Subcontractors place an enormous amount of trust in their own common sense to help inform their safety judgements and decisions. This trust in their own decision making is fundamental to their success as subcontractors because they are constantly required to make accurate practical judgements in the specific contexts of ever changing workplaces. It seems that common sense is related to reflective practice, and the decisions reached through common sense very often come from critical reflection. It is developed and informed through participation in the process of performing construction work, which means common sense is learned, is not fixed and is amenable to change as new circumstances challenge previously held conceptions. Locating the exact sites for this learning is imperative if changes are sought to the way construction workers manage safety.

Appropriate information informs their common sense. Subcontractors are intelligent, motivated, industrious and innovative people. If they know something is going to hurt them they will mostly try to devise a practical and effective method of either eliminating the hazard, or minimising the harm it can cause. They consider this as 'using your common sense'. It may indicate that appropriate, relevant, timely and context specific information will help them make safety related judgements.

Throughout the history of the building industry, safety has been part of and integrated into subcontractors' core business activities, but not necessarily enunciated or defined anywhere. Safety knowledge is often tacit knowledge and is learned as part of learning how to perform the job properly. Most of the safety learning that subcontractors value has occurred informally as part of performing construction work. Their safety behaviour is a result of heuristically making iterative judgements about the hazards and risks they face. Historically, the construction workers have defined this process for themselves and have developed a culture that integrates safety and work. Now, government has legislated what risks are permissible and what risks are not.

Subcontractors have a deep respect and trust for the safety knowledge gained from years of practice, and a distrust of safety courses that attempt to privilege paper/procedural knowledge over practical, embedded and embodied safety knowledge. They rely on this personally created safety knowledge and distrust the paperwork knowledge of WorkCover, which is often perceived as irrelevant, costly and ineffective. WorkCover inspectors are perceived as authoritarian, dogmatic, petty and unfair. It is thought that they are more interested in fining people than creating a safer workplace. The resulting situation is that enforcement strategies are tending to not necessarily produce safer workplaces, as was intended, but paperwork compliance: that is, minimum compliance rather than best practice.

Most subcontractors feel that the hazards and risks they face are mostly predictable within their own trade, yet many concede that the interrelationships between the trades often pose safety concerns. The construction of a house means more than each subcontractor performing their own work skilfully – it requires all trades to work together cooperatively throughout the whole life cycle of the project. However, the structure of the industry favours a culture of independence and individual resourcefulness at the expense of interdependence and consideration for others. Many subcontractors are in such a hurry to get in, finish, and get out, that they may not consider other people who depend on them. If subcontractors are not genuinely thoughtful of others on site they may leave invisible dangers for unsuspecting workers. The findings demonstrate that OHS is often compromised by the thoughtlessness of some people for others on building sites. Examples include the plumbers use temporary taps that hurt the tiler; the carpenters leave loose floor boards for the unsuspecting person to fall through; people leave their mess for others to either clean up or trip on; the builder leaves piles of dirt for the brickie to stumble over.

A very strong theme that emerged from the data was the central role that the builder plays in helping to create a safer workplace. A safe construction site is one in which the builder is well organised, plans ahead, and communicates effectively with all parties. It is the builder who is the one constant throughout the construction process and it is he (or she) who has the power and position to foster positive interfacing between trades who rely on each other but who often are not on site with each other.

The people who constitute the construction industry culture share some common perceptions of risk. They believe that construction sites are safe for them, but not for outsiders like owner builders, women or children, who do not understand the construction site. They are unanimous about not liking the paperwork requirements that are reifying OHS. They seem to perceive financial risk as more important than personal safety. They all accept that building work degrades the body, but continue with it because it pays the bills. They often view the financial risks represented by WorkCover's enforcement as more hazardous than continuing with their present work procedures. Their reluctance to spend money on OHS is related to the fact that they have very tight profit margins resulting from the competitive tendering process that sets prices at a minimum. Subcontractors' subjectivities and actions are constituted within and influenced by the 'latent conditions' (Reason, 1997) created by the history and culture of the industry that favours costs and production over worker safety.

There are many hazards in the building industry that are not prescriptively addressed by legislation and enforcement and which are often seen by the subcontractors as more important to them. For example, manual handling injuries constitute about 55% of all compensable injuries in the construction industry (WorkCover NSW, 1998) but enforcement strategies do not address the large amount of manual handling in the industry.

Manual handling is a major cause for concern because it is an intrinsic part of work as a subcontractor. Mayhew et al (1996) found that not only did self employed subcontractors take less time off work if injured, about half of all subcontractor builders interviewed had chronic back pain and few worked in the industry after aged 50. James et al (1992 in Mayhew et al, 1996) found that injured self employed workers frequently tried to 'soldier on', particularly after cuts, abrasions, sprains or strains, which contributed to a greater incidence of chronic disability among self employed workers and earlier retirement. All of the interviewees in this current research project who were over 40 years old have some kind of chronic injury from excessive and/or repetitive manual handling activities, and 6 of the 11 interviewees are trying to find a new career because *this job is killing me*. The fact that there is very little room for vertical career advancement (Mayhew et al, 1996) means that they must face the unrelenting hard physical labour for their whole working life and this necessarily degrades the body.

Workers who participated in this research do not respect OHS legislation that does not address things that matter to them. The technical approach taken by enforcement agencies alienates many small businesses and can be a barrier to their participation in OHS best practice initiatives (Caple, 2005). They are suspicious of rules that do not seem to help their lot, and they wonder how legislation is going to reduce the amount of manual handling they perform that is ruining their bodies. They believe that many of the rules do not actually address their real safety concerns, such as repetitive movements, constant manual handling, poor organisation of the construction process, poor coordination and communication between trades, unclear areas of responsibility, and the noisy/dusty working environment.

OHS is becoming a sphere of tension that is at the intersection of subjectivities, power, and the production of knowledge. The subcontractors' self concept of being a competent worker is threatened by WorkCover's disempowering enforcement strategies that devalue their knowledge born of practice. Many workers in the building industry feel as though WorkCover would have a better chance of creating a change in both behaviours and attitudes if they took on more of an educative role rather than the strict disciplinarian role that now seems to be their reputation. A common theme to appear is the opinion that WorkCover inspectors are behaving like Gestapo, or, as some have put it *frustrated would-be police. They are out to really get people and not there to help.* Perceptions are that enforcement strategies are *putting people off side* and *giving safety a bad name.* They feel that it would work much better if the inspectors were not so authoritarian, and came on site to talk to people. Subcontractors feel that they would be able to negotiate an OHS compliant workplace if they were treated with respect, consulted, and their knowledge, opinions and experiences validated.

SUBCONTRACTOR SAFETY CULTURE

In the following sections the author has used a system of root cause analysis to help deconstruct the safety culture of subcontractors in an effort to understand both their meta narrative and micro concerns. It is only by understanding these that they can be adequately addressed. The ensuing discussion is informed by ongoing qualitative research conducted by the author. Where possible it is supported by literature. However, owing to the dearth of literature exploring subcontractor safety culture some of the points raised may appear novel and unsubstantiated. This is to be expected when forging new knowledge and provides suggestions for further research.

The construction site

Construction sites are the environment in which subcontractors work, they belong to this cultural space and place (Wadick, 2007). They are dusty, noisy and messy; the ground is often uneven, with trenches, piles of dirt and material offcuts around the site; there is often poor access such as long muddy driveways on a hill; people frequently work outdoors in the elements; much work is performed on temporary surfaces and it is not always easy to distinguish between precarious and safe (Bentley et al., 2004). Construction sites continuously change so it is difficult to predict what it will be like at any point in the future.

Work methods

Most subcontractors are specialist trades people who perform a limited range of activities. Construction work is usually heavy and repetitive; people use their body to use tools to dig, cut, grind, nail, screw, place, fix, apply, climb, and so on. They rarely use paper (Wadick, 2005) – most writing performed on construction sites is rough sketching and calculations done with a builder's pencil on disposable surfaces such as a timber/plaster offcut or a scrap of cardboard torn from a packaging box. These are dispensed with after use. Written safe work method statements (swms) are regarded as an unhelpful burden on their limited resources, as they do not easily allow for constant problem solving in unique situations. Safe working is further compromised because OHS is not always a high priority when planning a job, but is seen as an add-on cost that impinges on their already slim profit margins (Hager et al., 2001).

The subcontracting system

Subcontracting is favoured in the house building industry because it offers builders flexibility and cost efficiencies (Ireland, 1988). However, its very nature poses challenges for OHS management. At its core are the competitive tendering process and the piecework nature in which subcontractors get paid for how much they produce, which encourages them to take shortcuts (Breslin, 2004). Compounding this is the fact that subcontractors receive no workers compensation coverage, no holiday or sick pay and no superannuation; they must pay for insurances such as accident, public and products liability, and workers compensation for their own employees. They also provide at least one vehicle and all the tools of their trade; very often they even supply the materials to be installed in the construction process; they must pay for all the training they and their employees undertake. No workers compensation, paid holidays or sick leave means that they take few breaks and often work with injuries that other employees would normally get paid recuperation time for, while there are very few 'light duties' for the injured building worker to perform under any rehabilitation programme. There is very little opportunity for career advancement, which means they labour for their whole working life; they often change careers by age 50 due to their body wearing out. With no other qualifications, they usually must accept a job with lower wages, although with better working conditions that may help their body recover. It is hard to find reliable data on the extent of injuries and diseases among subcontractors because there is no systematic method for collecting and/or collating such information: there are no official injury or incident reporting mechanisms (Mitchell and Boufous, 2005). We simply don't know the extent of the problem and its costs to them, their families and society.

Many different subcontractors are involved in the building of a house and research has identified at least three widespread implications for health and safety:

1. There is poor communication between the trades which means subcontractors often leave unsuspected hazards for the tradespeople following on from them (Bentley et al., 2004).
2. There are few structured systems for OHS consultation and people are often tarnished with the label 'whinger' if they speak up or make suggestions (Wadick, 2005).
3. The builder has enormous power and influence over the construction process, and the leadership and people management skills of the builder can be the difference between a safe and unsafe workplace (Biggs et al., 2005, Wadick, 2007, Biggs et al., 2006).

In fact, subcontractors are the last in a long chain of circumstances and events over which they have very little control (Williams et al., 2005). They do not feel cared for, so why should they care (Geller, 1994, Sirota et al., 2005): just make as much money in as little time as possible and move to the next job.

People/construction personnel

The builder is the glue that holds together this fragmented and sometimes chaotic process (Hager et al., 2002). However, the builder is not always present, and even when he is, may lack in the soft people skills to make it cohesive (Wadick, 2005). Builders are specialists at process control, but not communication, consultation, conflict resolution, negotiation, and listening – they pay more attention to getting the job done rather than worker safety. The subcontractor is essentially a disposable item, and they will be dispensed with if they complain (Wadick, 2005).

Time/cost pressures and discontinuous activities tend to make the needs of the tradespeople following each trade in the construction process invisible. Therefore many subcontractors take a self-preservation approach and do the minimum amount of work to satisfy the job requirements. This can mean that, for example, the plasterers don't mark the plasterboard where the electrician has left a bracket for the power point or light switch so the electrician has difficulty locating these. This creates animosity and spirals into a situation where subcontractors often do not look after anyone's interests except their own (Wadick, 2007). The builder has the power (but perhaps not the skills) to ameliorate this: if he cares for them, they are more likely to care for others; if he seems not to care for them by screwing their price down to a bare survival minimum, they don't have time to care for anyone else, and it is very difficult to quantify 'caring' in financial terms.

Workplace culture and safety culture

It is difficult to separate out the safety culture from the workplace culture as they are historically integrated. It has always been a male dominated masculine culture of toughness, risk taking and 'can do' attitude (Hayes, 2002, Agapiou, 2002). Being a good tradesperson is synonymous with knowing how to use your tools properly and safely, and how to be careful in such a dangerous industry (Wadick, 2007). If you get hurt, it is your own fault (Wadick, 2007), and everyone knows their body is deteriorating because of their job. It is a practical industry with relatively no history of the written word (ACIL, 1996): it is based on doing and not writing about doing. The construction industry has a high percentage of people with poor literacy skills (Construction Training Australia, 2001, Kelly and Searle, 2000), who are successful if they possess good trade skills. Even though much of the work is repetitive, most subcontractors are fiercely independent business managers who constantly make decisions that affect the success of their business. They carefully balance the tension between costs, production and their safety (Hager et al., 2001) – they see safety as largely common sense and rely on not being hurt, because an injured worker cannot earn money. Many resist modern safety rules because they do not perceive them to be making their life better, just more complex. Safety has been given a bad name by all the negative rumours that are now restorying OHS. Safety is now the demon that will punish you if you are caught (Biggs et al., 2006), and the worst thing is that the rules of engagement are not always clearly understood (Wadick, 2005).

Equipment and Materials

Subcontractors use tools, equipment and materials with their bodies all of the time they are at work. Many of these things are heavy, awkward, toxic or with poor ergonomic design. They are put in and taken out of vehicles, moved and carried around the site, up/down ladders or scaffold, and gradually wear the body out. Many subcontractors do not even know what poisons they are exposed to in the materials they or other workers on site use: they will often prejudice perceived quality of the product over their own health and safety as they will pay a bit extra for quality, but not for safety (Wadick, 2005).

Training

Subcontractors place an extremely low priority on off-the-job training (ACIL, 1996), as it is perceived to be a cost rather than investment. Anything they need to learn they'd rather learn on the job from other trusted workers (Wadick, 2007). Builders and supervisors have very little training in people skills, which is not really considered as one of their core competencies. OHS training is generally perceived as a waste of time and money as it doesn't address their real concerns (Wadick, 2005).

OHS knowledge

Subcontractors are happy to have safer workplaces. However, they are unhappy if they have to pay for safety from their slim profit margins (Hager et al., 2000). They complain that OHS compliance costs them more but they can't charge more (e.g. compulsory training, PPE, harnesses, scaffolding, tagging electrical equipment, & paperwork), and it often makes the job slower. They believe that OHS legislation does not address their main concerns of the interrelationships between the trades, the poor organisational skills of the builder, and the constant and repetitive manual handling (Wadick, 2005). There is also confusion over what is actually required by OHS legislation. They are confused because legislation espouses a performance approach based on risk management, but WorkCover inspectors often take a prescriptive and random/inconsistent approach that depends on the mood of the inspector (Wadick, 2005). Not knowing what the rules are creates a deep sense of insecurity and dissatisfaction, and feeds into the negative storying of OHS. There is also a lack of trust in the voluminous Codes of Practice that do not clarify how to behave safely in each circumstance, and are perceived to deny the realities of construction work.

RECOMMENDATIONS

It is believed by the author that the following recommendations may be possible to implement in the current state of subcontracting in the domestic house building industry. These are organised in relation to the previous categories used for the root cause analysis of the subcontractor safety culture.

Recommendations:

1. Integrate OHS at the design stage of every building and at every step along the way; this will help with many things, including manual handling because materials will be delivered where and when they are needed to prevent double or even triple handling. *(Construction site and equipment/materials).*
2. Provide free training for subcontractors in the skills of filling out paperwork such as safe work method statements, and allow this to attract professional development points. *(Work methods and training).*
3. Facilitate inter-trade site meetings with action plans and follow up to clarify what they need to work safely. *(Personnel and subcontracting system)*
4. Ensure that all quotations for work include how the people are going to work safely. This will include how they perceive that they will be effected by other trades. *(Subcontracting system).*
5. Create a broader workers compensation system that includes subcontractors. This will have the dual advantage of giving subcontractors paid and managed recuperation time for injuries and allow for the collection of meaningful injury statistics that can inform planning. It will also allow for a system to be developed that will help retrain workers whose body won't permit them to stay in the industry. *(Subcontracting system).*
6. Provide free training for builders in people skills such as communication/consultation, conflict resolution, negotiation and leadership. Ensure this is a key component of all building courses. *(People and construction personnel).*
7. Pressure toolmakers to design safer tools that are more ergonomic, less noisy and light weight. *(Materials and equipment).*
8. Substitute the number of toxic chemicals in construction products with harmless ones. Educate people who use toxic products of their dangers and methods of safe use. *(Materials and equipment).*
9. Assess how OHS is included in all trade and building courses to ensure it is core, not just add on. (*Training).*
10. Reinvigorate the apprenticeship system to increase funding to help small businesses train apprentices. This will have the dual advantages of securing the future skill needs of the country and providing help for the overstretched workers. *(Training).*
11. Train WorkCover inspectors in people and education skills so that they can visit sites as educators more than enforcers. *(OHS knowledge).*

12. Create and circulate a detailed list of the prescriptive aspects of OHS legislation as applied by inspectors. This will help the subcontractors at least define the goals and will squash the negative OHS rumours. *(OHS knowledge)*

CONCLUSION

This paper has discussed a research project that deconstructed subcontractors and working safely in the building industry. It was found that the construction workplace culture influences the work practices of the subcontractors who work in the industry. Subcontractors want to be safe at work, but working safely is compromised by such competing forces as time/money pressures, the nature of the work, the power and position of the builder, and the interrelationships between the trades. OHS reform will not create a best practice safety culture unless it addresses these cultural imperatives of the industry.

A system of root cause analysis helped describe subcontractor safety culture in terms of seven categories: the construction site, work methods, the subcontracting system, people/construction personnel, workplace and safety culture, equipment and materials, training, and OHS legislation. Recommendations were offered that may help improve the safety culture of subcontractors and these were referenced to the seven categories.

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IMPROVING ETHICAL STANDARDS AND SAFETY IN THE CONSTRUCTION AND ENGINEERING INDUSTRY

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ABSTRACT
Standards of ethical behaviour directly affect standards of safety and the construction industry has an unenviable reputation of unethical business practice due to poor public perceptions of its record in managing the environment, workers' health, welfare and safety, lawlessness and corruption in general. This paper does not question the validity of these perceptions but reports the results of a survey of 129 construction professionals which identified three main factors as particularly influential in determining ethical behaviour in the construction industry, namely: (i) the absence of ethics training programs; (ii) the absence of reward systems for those who act ethically within the industry; and (iii) the low level of 'visibility' that exists within the industry. These findings are important for an industry that has become increasingly negatively stigmatized in recent years. The paper concludes with a series of organizational and contractual recommendations to help the industry achieve higher standards of ethical conduct and in doing so, improve standards of safety.

KEYWORDS: Ethical standards, Public perceptions, Ethics training programmes

INTRODUCTION
The links between ethical management practices and safe working environments are well established. For example, Krause (2007) argues that organizational cultures driven by a deep sense of commitment to ethical principles such as value for human life, integrity and justice, tend to lead to safer work environments through more effective and communications, more openness to sensitive issues and a greater sense of personal responsibility by employees and managers. However, unfortunately in Australia Loosemore and Chau (2002), Loosemore et al. (2003) and Vee and Skitmore (2003) found that the industry is generally seen as unsafe, unethical and insensitive to the needs of minority groups such as women and migrants. Similarly, in the UK Wood et al. (2002:4) found that "…the industry has a reputation for poor quality and service, a bad safety record, and a history of broken promises and sharp practice." In the US, Doran (2004) found that 84% of American owners, architects, construction managers, contractors and subcontractors had witnessed some sort of unethical behaviour in their contact with the construction industry. In Africa, Alutu (2007) revealed an alarming amount of unethical behaviour in the Nigerian Construction Industry where there was 89% agreement between respondents that contract officers negotiate their own percentage share of the contract before a bid is prepared. There are also many examples of Japan, Hong Kong, Singapore and China's industries being plagued by unethical practices such as illegal land grabs, immoral employment practices, bribery, the omission and use of unsafe building materials to maximise profit margins, embezzlement, unethical bidding practices etc (Debrah and Ofori,1997; Ho, 2003; Transparency International, 2005).
The aim of this paper is to explore the organizational factors that may contribute to this poor ethical record. While the issue of ethics in construction has received some attention in recent years, the literature is highly fragmented and anecdotal and we have very little understanding of the organizational factors that may contribute to unethical behavior. It is the aim of this paper to explore these factors in more detail and to determine which are most relevant to the construction industry.

POTENTIAL CAUSES OF UNETHICAL BEHAVIOR

While there has been little research into the causes of unethical behavior in construction, there have been many studies outside the industry. For example, numerous studies have identified that a code of ethics is associated with positive ethical behaviour (Trevino et al., 1999). This was a causal factor explored in the construction industry by Ho (2003) who found that the best method of implementation is by the employee's immediate supervisor. Similarly, Delaney and Sockell (1992) found that the existence of a formal ethics training program in the workplace is essential to implement an ethics code and promote 'ethics awareness'. Furthermore, Kaptein and Wempe (2002) found that ethical behavior is more likely if it is underpinned by a formal process and a single clear point of contact for raising and discussing ethical dilemmas. This supports an abundance of evidence which points to the importance of rewarding ethical behaviour and punishing unethical behaviour (Kaptein and Wempe, 2002). For example, Hegarty and Sims (1978) found that when unethical behaviour is indirectly rewarded by management or other external sources, the individual becomes inclined to become a repeat offender. Rewards can come in many guises including tolerance and protection of unethical behavior etc.

Moving beyond the issue of codes and the way they are communicated and enforced, Akaah (1992) found that the strength of employee identity with an organisation and their commitment to its goals and vision is associated with more ethical behaviour. Perceived fairness of treatment between employees and management is also particularly important and companies which avoid special treatment of higher level managers provide an environment which is more conducive to ethical company culture (Kaptein and Wempe, 2002). Linked to this is the importance of fair performance review processes which in turn is linked to clarity of employer's expectations. It also relates to the important issue of leadership which has also emerged as an important factor in encouraging ethical behavior. As Jennings (2006) point out, managers that demonstrate what is expected of employees through their own actions are more likely to encourage ethical practice in their subordinates. Trevino et al. (1998) found that if an employee feels that he is merely following the instructions of a supervisor, then he will not feel responsible for the consequences of his actions. The relationship also works the other way so that if both supervisor and worker consider the other to be responsible for unethical actions, then ethical responsibility is undermined. Jennings (2006) also found that ethical standards can also suffer when management is not receptive to bad news and places too much pressure on its employees to provide consistently positive results. For example, Jennings (2006) explains that in Sunbeam's collapse, the hiring of a new CEO, Al Dunlap led to the setting of unrealistic profit goals. In order to meet these goals, employees documented false sales transactions, reduced company inventory to inflate profit numbers and organised premature shipping of products to make sales numbers look better. Furthermore, Trevino et al. (1999) found that companies which were perceived by employees as focusing on personal gain rather than benefitting external stakeholders such as customers and the public were generally less ethical than other companies. Finally, related to the issue of leadership is governance. For example, Jennings (2006) describes the ethical collapse of numerous companies which were led by a dominant Chief Executive Offices (CEO) who are seen as unapproachable and unchallengeable with respect to legal and ethical concerns. Related to this issue of governance is the impact of a weak and ineffectual board of directors which cannot challenge the CEO (Jennings, 2006).

Finally, according to Kaptein and Wempe (2002) ethical behaviour is influenced by the level of visibility (likelihood of getting caught). For example, if the workplace does not have a system to control internet use or private telephone calls, visibility would be considered low in administrative terms. In contrast, an open plan office where an employees actions are more obvious would have a high level of physical visibility. 'Visibility' can also be classified as vertical or horizontal. Vertical visibility is concerned with management being able to track employee conduct while horizontal visibility is concerned with peers and colleagues being able to monitor each other's ethical conduct.

METHOD

In order to determine the extent to which the organisational factors discussed above are influential in the construction industry we undertook a web-based survey of construction professionals. A web-based survey was used because of the confidentiality it provided to respondents. To maximize the response rate we also depersonalized the questions and rather than approaching respondents individually we worked through the HR departments of their employing firms. Following this strategy we distributed 723 surveys and obtained a useable response of 129 (17.8%). Our sampling strategy was deliberately very broad. The survey was distributed to employees in construction firms which ranged in size from small residential builders with only 15 employees and a turnover of $5m to large international firms with over a thousand employees and a turnover of $6.6bn. Thus the work undertaken by our respondents' employers covered a broad range of disciplines and areas including residential, commercial, civil, retail construction and refurbishment.

ANALYSIS OF RESULTS

77.2% of our sample reported that ethics training programs are either seldom or never organised by employers to educate employees (Figure 1).

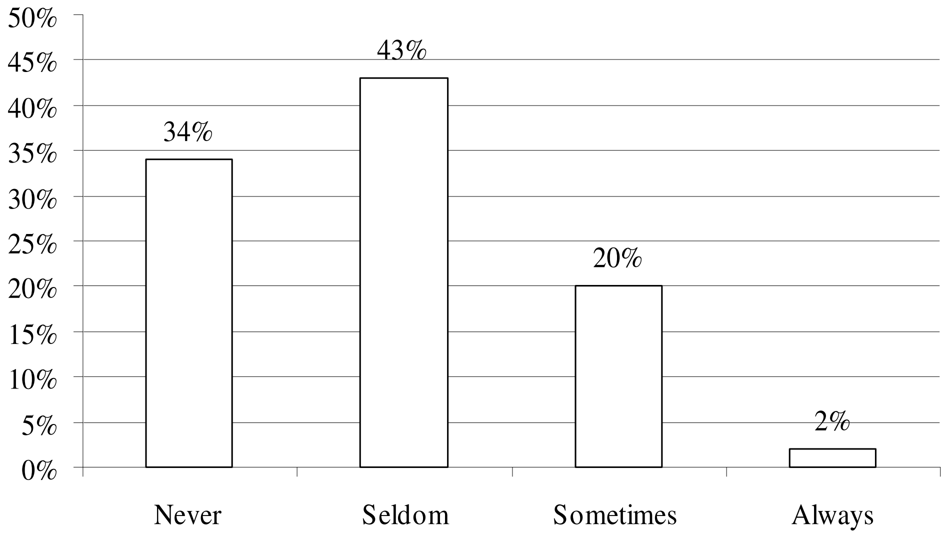

Figure 1: Ethics training programs in construction.

72.88% indicated that ethical behaviour is never or seldom rewarded (Figure 2) although 59.69% indicated that there is sometimes or always a sanction imposed for acting unethically (Figure 3). This suggests that unethical behavior is positively discouraged but is not positively encouraged.

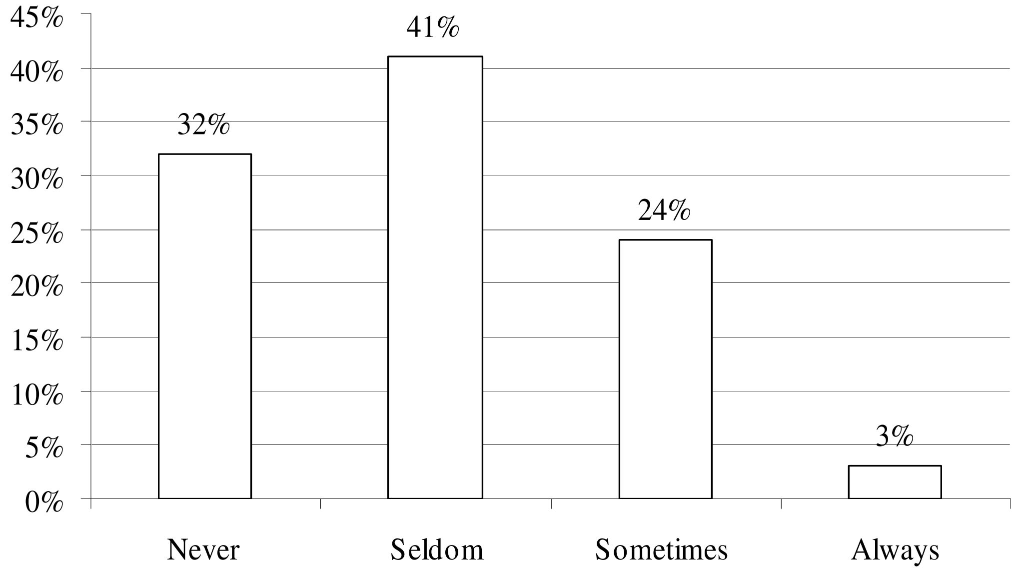

Figure 2: Rewards for acting ethically in construction

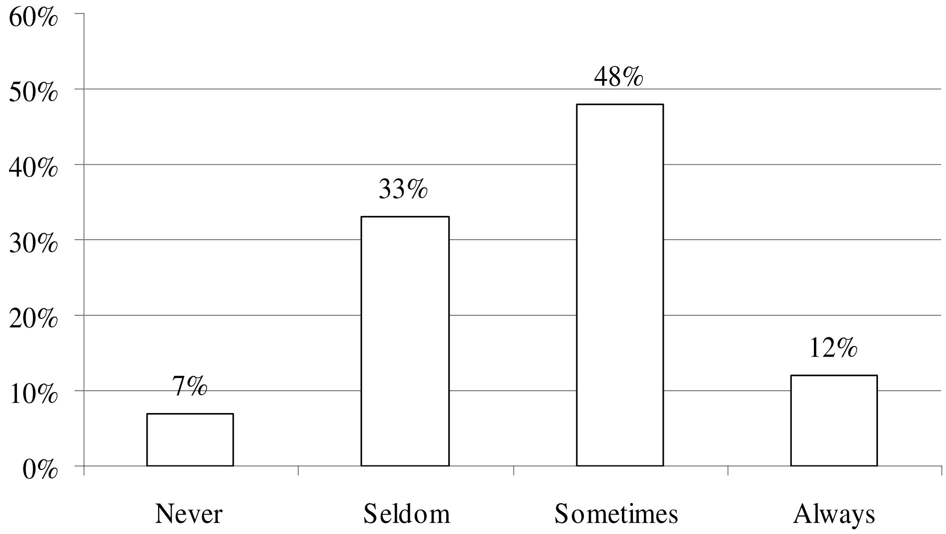

Figure 3: Sanctioning for acting unethically in construction

In terms of the equal treatment of management and employees 74.32% of respondents thought that managers and employees are treated similarly either ‘sometimes’ or ‘always’. It is worrying that a rather large 28.68% felt that managers apply different standards to themselves than they do to employees (Figure 4).

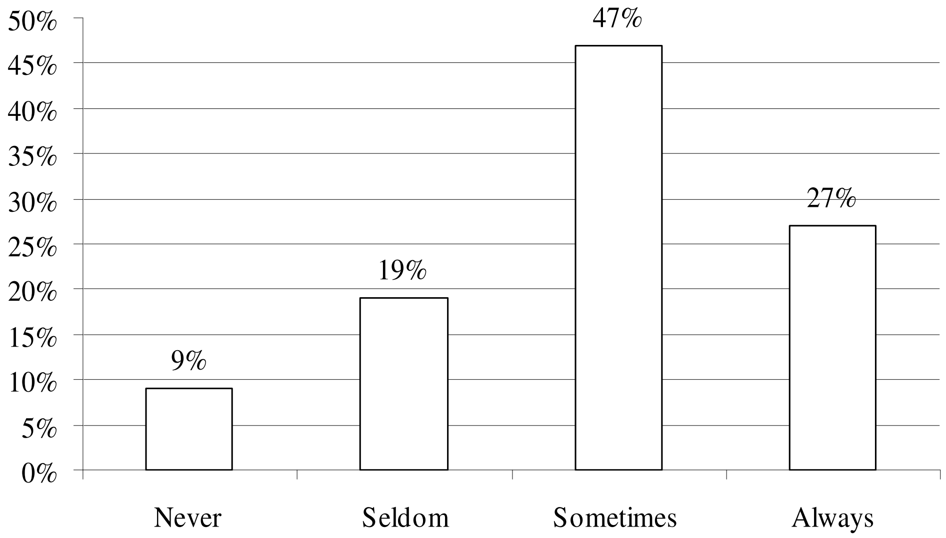

Figure 4: Equal treatment between management and employees exists in construction

The issue of visibility appears from our survey to be an area of particular concern for the construction industry. Figure 5 shows that 77.52% of respondents believe that it is ‘sometimes’ or always possible to hide unethical conduct from management and colleagues. It is also of note that the standard deviation of responses for this question was by far the lowest of any question asked, reflecting a high degree of consensus among our sample that low visibility is a characteristic of the industry’s practices (Table 1).

Table 1 Standard deviation of response for each question

Qn.	Organisational Factor	Standard deviation of data collected
1	Ethics training programs	0.7949
2	Existence of ethics codes	0.8848
3	Rewards and sanctions	0.829
4	Rewards and sanctions	0.7786
5	Equal treatment of management and employees	0.8904
6	Clarity of employer’s expectations of employees	0.79
7	Points of contact for ethical concerns	0.8149
8	Lack of ‘visibility’ in the workplace	0.6931
9	Absence of top management actions against unethical behaviour	0.7416

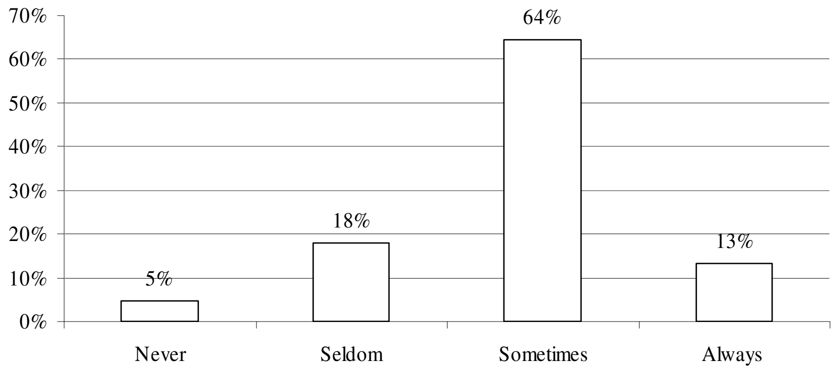

Figure 5 Visibility of unethical behavior

The incidence of codes of ethics was also an interesting finding in that 52% of our respondents said that codes of ethics are seldom or never used in the industry to promote ethical behaviour (Figure 6). When a code exists, the most common methods of distribution are shown in Figure 7 and categorized using Ho's (2003) findings as effective or ineffective in Figure 8. Figure 8 shows that when used, the communication process is likely to be effective in 63.94% of cases.

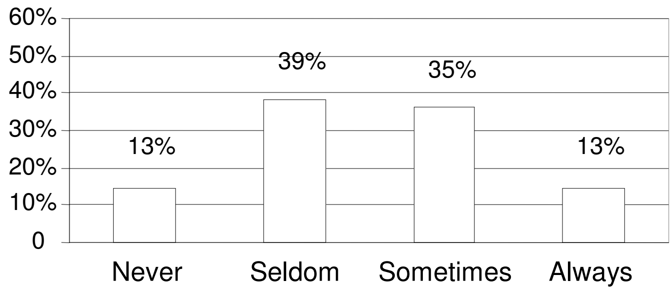

Figure 6 The use of codes of ethics to promote ethical behaviour

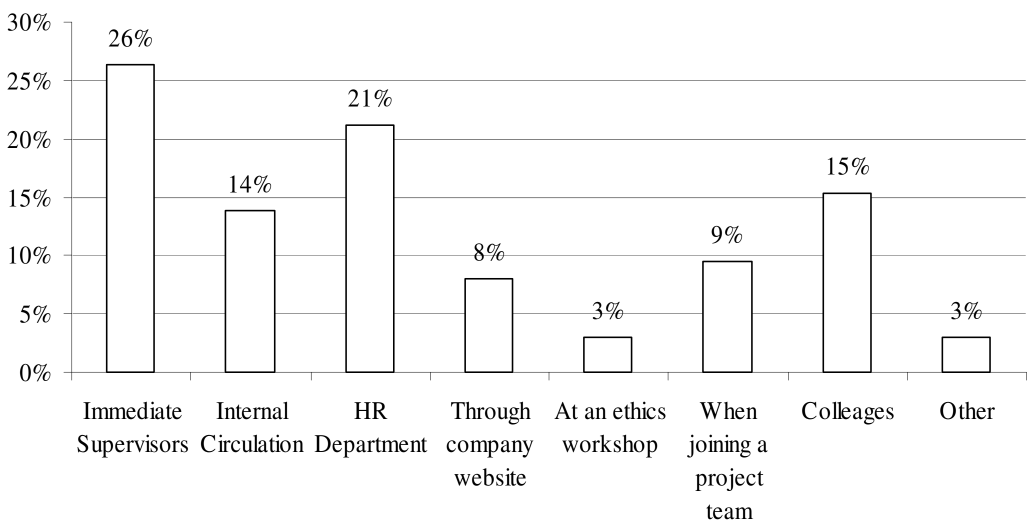

Figure 7 Methods of dissemination of codes of ethics

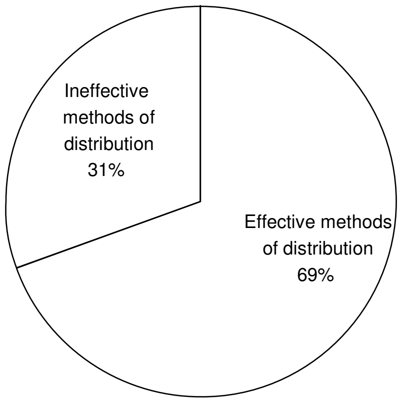

Figure 8 Categorisation of code distribution methods from Ho (2003)

The final question in our survey was an open-ended question which required respondents to list what they perceived to be the five main causes of unethical behaviour in the construction industry. The responses to this question can be organized into four main groups as illustrated in Figure 9.

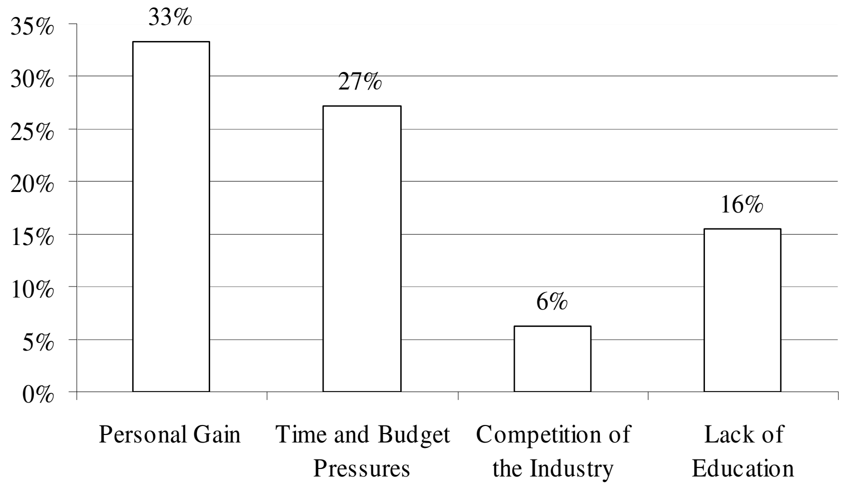

Figure 9 The most common causes of unethical behaviour

Although we were not able to elaborate on these responses via interviews because of the confidential nature of this research, they are worthy of further contemplation and investigation. For example, frequent reference to “ego”, “personal gain” or “greed” by our respondents implies that the masculine culture of the industry may have a role to play in promoting unethical behavior. References to “cut-throat industry”, “construction boom and downturn” and “everything is price driven” show that competitiveness also plays a major role in influencing the ethics of construction firms. These pressures are further exacerbated by the types of time and budget pressures mentioned by many of our respondents. “Lack of education” also featured prominently in peoples’ responses, presumably referring to both a lack of formal education (for example, secondary and tertiary education) and less formal education (ethics training programs, industry inductions).

CONCLUSION

The aim of this paper was to explore the organisational factors that inhibit and encourage ethical behavior in the construction industry. Three factors were perceived as particularly problematic in the construction industry, namely: the absence of ethics training programs; the absence of rewards for those who act ethically within the industry and; the low level of 'visibility' that exists within the industry. It was found that the most common perceived causes of unethical behaviour include individuals seeking personal gain, high levels of industry competition, time and budget pressures and poor education.

In terms of making some recommendations for future improvement our research suggests that the more extensive development and effective dissemination of corporate codes of ethics supported by ethics training programs might be a necessary. It is also clear that more could be done in regard to providing rewards for those who are seen to be conducting themselves ethically. It is in the area of "visibility" where the greatest improvement is required. However, addressing this problem in the construction industry will require significant structural changes to the way that projects are procured organizationally and contractually. Engineering and construction is a project-based industry where commercial relationships with business partners and customers are often one-off and dynamic and where work is executed by dozens, sometimes hundreds of small scale subcontractors in long, dynamic and unwieldy supply chains creating a maze of transactions that are difficult to monitor and this will need to be addressed.

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HEALTH AND SAFETY IN CIVIL ENGINEERING EDUCATION: A CASE STUDY

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ABSTRACT
The high rate of fatal and serious accidents in construction workplaces is annually reported. The recognized lack of health and safety, risk prevention and risk management content in undergraduate and postgraduate curricula of civil engineering, revealed some years ago the necessity of a specific regulation of construction sector. The introduction of these specific issues in the civil engineering curricula implied a study about civil engineering students' health and safety education and risk management attitudes. This paper demonstrated the method that has been used to introduce occupational risk prevention integrated in the construction process, in construction management units and in specific units. Surveys were applied to the students to evaluate their level of construction risk management training and its results are reported in this paper.

Keywords: Health and safety, Risk management, Civil engineering, Education and training.

INTRODUCTION
Occupational health and safety has long deserved great attention by the European Union and has been the object of a legal framework, extended to all activity sectors (Directive 89/391/EEC). In particular, the construction industry has deserved the special concern of the European Nations because of its specific nature and high contribution to fatal labour accidents. This led the European Council to release the Temporary or Mobile Construction Sites Directive (Directive 92/57/EEC). Both Directives are presently incorporated in the internal law of all European countries in the form of legal regulations, concerning health and safety conditions of workers during construction and subsequent operations.

Health and safety regulations take into account the specific nature of the construction industry and follow a general health and safety approach in construction sites, considering all phases of project development and enforcing liability of all project participants. The approach followed in the regulations is centred on the concept of health and safety coordination that must be assured by two coordinators, acting during the project preparation stage and project execution stage. However, these regulations establish a liability chain for health and safety, involving all other project participants in addition to coordinators and requiring their deep involvement in the task of eliminating/preventing health and safety risks for workers during the execution stage and in the course of subsequent construction and maintenance work. Therefore, according to regulations, all project participants should have enough knowledge of health and safety matters to perform their duties (Rodrigues, 1999).

The Temporary or Mobile Construction Sites Directive (Directive 92/57/EEC) created great challenges in health and safety risk management education and training, because it established new functions in occupational hazards prevention for all the participants in the construction sector and demanded the intervention of health and safety coordinators, from the initial project preparation stage (Rodrigues and Maranhão, 2007).

This Directive indicates occupational hazard prevention from before the execution phase. So, the existence of a competent health and safety coordinator from the beginning of the design phase is an important factor that contributes to reaching high safety levels on construction sites. The

Directive's contents will only be applied efficiently, with full achievement of its objectives, if specific education and training be provided to construction technicians. In this way they are able to achieve the skills and knowledge that enable them to implement the functions that are required by health and safety coordinators such as: coordinating the activities of all the participants during the design and the execution phase with the aim of integrating health and safety prevention principles. From the early design phase this will influence the execution of the construction schedule, the quality of the work, the construction, use, maintenance, repair, rehabilitation and demolition performance of the construction projects (Rodrigues and Maranhão, 2007).

Civil engineering has long been the most recognised technical degree for working in any construction area in Portugal. The previous civil engineering education in Portugal offered a broad five-year undergraduate programme, covering a variety of areas such as structures, foundations, hydraulics, construction materials, construction technology, roads and town planning. Accordingly, a considerable part of project design (including structural, foundation and most installation design), as well as project management, quantity surveying and quality management duties, is currently carried out by civil engineers in Portugal. All of the above duties must be conducted in accordance with health and safety regulations, therefore imposing specific training in this area on civil engineers. Otherwise, safety issues may be considered either through specific courses or included in current course syllabi (Rodrigues and Teixeira, 2003).

The problem is how to provide health and safety knowledge to construction professionals. Obviously, health and safety coordination should be the object of specific training designed for a variety of professionals with different backgrounds. Specific training must also be envisaged for people performing other functions in the construction activity, namely civil engineers. This could possibly be achieved in two ways or in a combination of both: either considering specific courses or including relevant topics on various subjects in current courses (Rodrigues and Maranhão, 2007).

A consequence of research on the construction health and safety coordinators' education and training, developed during the preparation of one of the author's Masters thesis (Rodrigues, 1999), was to improve the knowledge of construction health and safety of the Civil Engineering students of Aveiro University. An optional course on Construction Health and Safety was firstly implemented in 2003/04, and fundamental concepts of health and safety coordination have been introduced in the Construction Management syllabus since 2001/02. Positive impacts of this action have been registered as students use knowledge acquired on this topic in their final project work.

The transformation of the former system, which leads after five years of study to the academic degree of civil engineer, into the academic undergraduate course and the Master of Civil Engineering in accordance with the Bologna agenda, has been studied carefully, and new courses introduced. The aim of this paper is to show the methods that have been used to integrate health and safety risk prevention in the construction process, in construction management lessons and in specific courses, and the evolution of the students' knowledge and attitudes towards construction health and safety risks management.

THE CONSTRUCTION HEALTH AND SAFETY COORDINATORS' EDUCATION AND TRAINING

The lack of health and safety risk prevention and risk management knowledge of the construction technical intervenient are frequently the cause of severe and fatal injuries in this industry. This lack of knowledge and the poor attitude towards health and safety risk management lead the participants to fail to implement correct planning of risk prevention measures, throughout the entire construction act (design, execution and use phase of the constructed element). Neither do they evaluate the consequences of their decisions on safety. Over the years the recognised insufficient safety qualifications of construction technicians led to the exigency of health and safety coordinators created by the previously mentioned European Directive (Rodrigues, 1999).

The influence of the Regulations (Construction Design and Management Regulations – CDM Regulations) that had consequently come into force in the United Kingdom, were investigated and it was concluded that the regulations had failed to achieve the intended outcome. The responsibility was associated with design professionals for failing to make them work, this being the main influence on construction site safety temporary works design. Thus this is a problem of the safety attitude and/or awareness of the designers. In addition, during the execution phase companies have demonstrated a negative attitude towards health and safety risk management (Petersen et al., 2008). The same problems seem to occur in all European countries and these conclusions can also be transported to Portugal as the problems are similar.

The required fundamental modification of safety procedures depends on the qualifications of all the participants during the entire construction act. Only well prepared coordinators can achieve the most correct safety solutions and obtain from the entire design and execution team their understanding and implementation. These qualifications are only obtained through their academic background, their safety specific education or professional training and through professional experience.

Specific health and safety coordination training courses have been developed in Portugal. The first initiative took place in 1999 at the Technical University of Lisbon, and several editions have been conducted since. In 2002, the Portuguese Board of Engineers organised another initiative on the same topic and conducted several editions, followed by the Portuguese Board of Architects, Universities and particular training institutions. The University of Aveiro followed and ran its first specific training course in 2003 and has now conducted 7 editions. The courses consist of 120 hours of tuition and 80 hours of practical work and complies with the syllabus published by the Portuguese Health and Safety Authority (Working Conditions Authority – ACT).

HEALTH AND SAFETY CIVIL ENGINEERING EDUCATION

The Bologna declaration has triggered an important change in Europe in the organisation of academic engineering education (Biesen et al., 2009). In Portugal, as in many other European countries, engineering education had to be completely reconsidered and revised.

The previous engineering education system in Portugal was based on five years of study for the academic degree of civil engineer.

The transformation of the former system into a three year academic undergraduate course and two year Master of Civil Engineering in accordance with Bologna requirements altered the existing programme. The new programmes should be consistent with the European Credit Transfer and Accumulation System - ECTS, where an average of 30 ECTS per semester should be scheduled, yielding 60 ECTS per study year, or 180 ECTS for the undergraduate Civil Engineering degree and 120 for the Master degree. The new programmes must fulfil these requirements as well as technical ones, and should match the aspirations in the field, i.e., the labour market and the construction industry. Accordingly, at the University of Aveiro, the Civil Engineering curriculum was adapted, and the former Construction Management syllabus modified and three new courses were created during the two years of the Master: the compulsory unit of “Construction Management and Safety Coordination” and two other optional courses “Construction Risk Prevention” and “Construction Design and Execution Safety Coordination” (Table 1).

Table 1: New courses characterisation

Course	Characteristics	Summarised syllabus
Construction Management	Compulsory unit Master 1st year 1st semester Syllabus modification in the academic year of 2008-2009	Legal requirements applied to the construction sector. The construction design and execution intervenient's functions and responsibilities. Planning and preparing a worksite. Making the project bill. Studying and designing the working site of a construction including safety measures. To know the general safety rules on construction site management including working equipment.
Construction Management and Safety Coordination	Compulsory unit Master 1st year 2nd semester Beginning in the academic year of 2007-2008	Project planning. Planning software tools. Health and safety at construction worksites. Health and safety management system in construction. Environmental management system in construction. Quality management system in construction.
Construction Risk Prevention	Optional unit Master 2nd year 1st semester Beginning in the academic year of 2008-2009	Legal requirements on health and safety. Risk assessment and risk management. Constructive procedures analysis. Safety measures applied to constructive methods.
Construction Design and Execution Safety Coordination	Optional unit Master 2nd year 2nd semester Beginning in the academic year of 2008-2009	The health and safety coordination system implementation. Coordinators' functions and responsibilities. The construction design and execution intervenient's health and safety functions and responsibilities The drawing up of the: Prior Notice, Health and Safety Plan, Health and Safety File, accordingly to the Temporary or Mobile Construction Sites Directive (Directive 92/57/EEC).

In this way all the students during their Master first year (formerly equivalent to the fourth undergraduate Civil Engineering year) can gain general knowledge and a correct attitude towards health and safety issues. During this year, through the Construction Management and the Construction Management and Safety Coordination units' syllabi, the students gain knowledge about safety legal requirements, construction design and execution health and safety coordination, health and safety measures design and execution implementation. The students that attend the two specific options will be more thoroughly prepared to carry out risk assessment and risk management in construction work, to implement the construction health and safety coordination system and to draw up the health and safety instruments: the prior notice, the health and safety plan, and the health and safety file.

The Construction Management course was always part of the Civil Engineering curricula in the University of Aveiro and the lecturers have always considered general health and safety issues. The Construction Management and Safety Coordination units were introduced in the 2007-2008 academic year and the two options only during the 2008-2009 academic year. During the lessons of the two compulsory units and the Construction Risk Prevention unit, the lecturer explains the subject matter and the students are required to develop applied practical work related to this. The Construction Risk Prevention lessons also require specific research work including class oral presentation by the students.

In the Construction Design and Execution Safety Coordination unit the teaching method is similar but the lecturer complements the lessons with seminars conducted by invited specialists that are working in construction project design teams or on construction sites. These specialists are chosen because of their deep knowledge and experience in construction design and safety coordination as well as in construction technologies and processes, construction design and execution management. For one week the students also attend a practical construction site placement, being integrated in the health and safety execution coordination team.

In all four of these units the students are evaluated on their practical and research work and on a written final evaluation. In addition the Construction Design and Execution Safety Coordination evaluation is complemented with a public presentation of the unit's final piece of work. The evaluation of the completed work and its presentation is done by the lecturer and by an external specialist chosen from the several that have conducted the aforementioned seminars.

SURVEY DEVELOPMENT AND ADMINISTRATION

The surveys carried out for this study were developed by the authors, lecturers in the Civil Engineering Department of the University of Aveiro, and were administered during the second semester of the 2008-2009 academic year. The target population for this study was the third year undergraduate students and the first and second year Master students of the Civil Engineering Department, University of Aveiro, who were registered in the second semester for:

- two compulsory units (one in the third undergraduate year and the other in the Master first year: Construction Management and Safety Coordination);
- one optional unit, Construction Design and Execution Safety Coordination.

The compulsory unit in the third undergraduate year had 49 students enrolled and the one in the first year of the Master 68 students enrolled. The optional unit where the survey was also administered consisted of 15 registered students.

The focus of the survey that was directed to the students of the third graduate year (at the beginning of the semester) was to evaluate their attitude and knowledge of health and safety risk management before they attended course units where these matters are studied (the two compulsory units in their next year). The survey that was administered regarding the compulsory unit in the first year of the Master and the optional unit in the second year of the Master (at the beginning of the semester) aimed to evaluate their attitude and knowledge of health and safety risk management after they have attended one or two units whose syllabi contain health and safety matters. The questionnaire that was directed to these two units at the end of the semester aimed to determine the changes and evolution of their attitude and knowledge of health and safety risk management after educating them.

The following five-point Likert scale was developed for each question in both surveys: 1 = very poor; 2 = poor; 3 = normal (average); 4 = good; 5 = very good. The surveys were set as part of the coursework for all three units to ensure that they were completed by the students. The surveys were also administered on the internet.

A total of 29 third-year undergraduate civil engineering students completed their survey in the correct format and at the requested time. The percentage of these respondents corresponds to 16.6% of the registered student population of the third undergraduate year (175 students). A total of 59 students of the Construction Management and Safety Coordination unit and of the Construction Design and Execution Safety Coordination unit completed their survey in the correct format and at the requested time. Of these 25.4% were registered on the third-year undergraduate-programme, 32.2% on the first-year Master and 42.4% on the second-year Master. The percentage of these respondents corresponds to 80.8% of the target student population for these two units and to 73.8% of the registered students in the first and second years of the Master. The lower response rate of 16.6% from the third-year undergraduate students is explained as the survey was administered only during the classes of one unit that had 49 students enrolled. This number was considered representative of this year, because the expected answers of the rest of the students would be similar to those obtained.

With the recent transition to the Bologna format some students are studying units from the undergraduate years simultaneously with Master units. As the lecturer of the four units referred to in Table 1, one of the authors, had not lectured during the previous three academic years (from the beginning of the second semester of 2005 until the beginning of the second semester of 2008), the students that attended the Construction Management course did not study the current syllabus with a greater emphasis on construction site risk prevention. Of the other three units, one began in the 2007-2008 academic year, and the other two in the 2008-2009 academic year, as previously mentioned.

The results from the analysis of the administered surveys are described in the next section.

RESULTS AND DISCUSSION

During the surveys at the beginning of the 2008-2009 second academic semester, the students were asked if they had knowledge about occupational health and safety, health and safety legal requirements and construction risk prevention. Table 2 illustrates the knowledge of health and safety attitudes of the third-year undergraduate and Construction Management and Safety Coordination and Construction Design and Execution Safety Coordination students surveyed.

The third year undergraduate students that answered positively to the questions, mentioned that they had acquired general health and safety knowledge through the media (87.5%), and three of them (6.8%) had just attended the Construction Management and Construction Management and Safety Coordination units during the previous year (they are students due to take this third-undergraduate unit later on). The positive answer about the knowledge of health and safety regulations is in accordance with the positive answer to the first question. The third question's positive answers are unexpected because the percentage is higher than the 6.8% of students that have attended Construction Management classes. This may be explained by the students interpreting their limited experience of working within a safety conscious culture.

From the 64.4% of students of the other group (on the other two courses surveyed) that answered positively to the first question, 47.4% indicated that they had obtained that knowledge through the media (general culture), on attendance of: Construction Management 21.1%; Construction Management and Construction Risk Prevention 15.8%; Construction Management and Construction Management and Safety Coordination 2.6%; Construction Management, Construction Risk Prevention and Construction Management and Safety Coordination 7,9%. There is one respondent who had gained this knowledge from industry experience and another from the previously referred to optional course on Construction Health and Safety they had attended at the University (whose lecturer was one of the authors). All the positive answers to the second and third questions are from the students that have attended the courses: Construction Management, Construction Management and Safety Coordination and Construction Risk Prevention.

Table 2 – Self evaluation of students' occupational health and safety knowledge

Questions	Occupational H&S		H&S Legal requirements		Construction risks prevention	
Answers (%)	Yes	No	Yes	No	Yes	No
Third-year undergraduate unit	55.2	44.8	6,9	93.1	10.3	89.7
Construction Management and Safety Coordination unit, Construction Design and Execution Safety Coordination unit	64.4	35.6	30.5	69.5	23.7	76.3

The two groups of students were asked to rate their attitude and knowledge of health and safety risk management and related legal requirements using the five point scale. Table 3 illustrates the third-year undergraduate students' self-rating and Table 4 depicts the results of the students' self-rating of the two units surveyed: Construction Management and Safety Coordination and Construction Design and Execution Safety Coordination.

The results in Table 3 indicate that 65.5% of these students rated their attitudes towards construction health and safety prevention as poor or very poor, and about 76% maintained their knowledge of health and safety legal regulations and risk management on construction to be equally limited. The rest of the students rated their attitudes and knowledge as average. Additionally, the results of the other group of students (Table 4) depict a higher percentage of their self-rated attitudes towards health and safety risk management as good. These statistics indicate that there was a positive change in the attitude of these students towards health and safety risk management, after being educated in one or more than one of the Construction Management, Construction Management and Safety Coordination, Construction Risk Prevention units.

Table 3 – Third-year undergraduate self-rating of the student's attitude towards and knowledge of construction health and safety risk management

Questions	Very poor (%)	Poor (%)	Average (%)	Good (%)	Very good (%)
How do you rate your attitude towards construction health and safety risk prevention?	3.4	62.1	34.5	0	0
How do you rate your knowledge of health and safety legal regulations?	27.6	48.3	24.1	0	0
How do you rate your knowledge of construction health and safety risk management?	20.7	55.2	24.1	0	0

Table 4 – Self-rating of the students' attitude towards and knowledge of construction health and safety risk management of Construction Management and Safety Coordination, Construction Design and Execution Safety Coordination units

Questions	Very poor (%)	Poor (%)	Average (%)	Good (%)	Very good (%)
How do you rate your attitude towards construction health and safety risk prevention?	3.4	40.7	32.2	23.7	0
How do you rate your knowledge of health and safety legal regulations?	5.1	66.1	23.7	3.4	0
How do you rate your knowledge of construction health and safety risk management?	5.1	57.6	23.7	13.6	0

At the end of the 2008-2009 second semester the same enquiry was administrated to the second group of students. The questionnaire had only one new question: how do you rate the evolution of your attitude towards construction health and safety risk management?

The survey was presented separately to the students of the optional unit (Construction Design and Execution Safety Coordination) and to the students of the compulsory unit (Construction Management and Safety Coordination) to evaluate their different evolution, because the optional unit has a more specific and thorough syllabus on construction risk management and health and safety construction coordination.

Of the optional unit's students, 46.7% have attended the four courses, or the two compulsory units and the optional one, and only one student (2.6%) has attended one of the compulsory units and the optional one. 100% of the students responded positively to the questions about whether they have knowledge of occupational health and safety, health and safety legal requirements and construction risks prevention. The results in Table 5 indicate that 73.3% of these students rated their attitudes towards construction health and safety prevention and their knowledge of health and safety legal regulations as good or very good, and 86.7% rated their knowledge regarding construction risk management on construction as good or very good.

The positive evolution that they have achieved in their knowledge and attitude towards risk management on construction industry during the design phase, execution and use phase is clear. All the students self-rated the evolution of their attitude towards construction health and safety risk management as good (46.7%) or very good (53.3%). All these students have classified the lectures as good (46.7%) and very good (53.3). The conferences given by invited external professionals, specialists in the construction industry, were rated as good (33.3%) and very good (66.7%). The interest of the practical work they were asked to develop during the lessons was rated as good and very good (46.7%) and as average (6.7%), taking up 25% to 50% of their time dedicated to this unit.

Regarding the compulsory unit at the end of the semester, 100% of the students answered that they have knowledge of occupational health and safety and health and safety legal requirements. Regarding construction risk prevention knowledge, only two (7.1%) answered negatively in spite of having mentioned that they have average or good preparation in the subjects enquired about in the first 3 questions of Table 6. It seems that these students have not clearly understood the questionnaire. All the target students indicated that they have acquired this knowledge through the compulsory unit of Construction Management and Safety Coordination. However, only 25% of the students indicated that they also achieved this from the Construction Management compulsory unit, despite all of them having attended these lessons. This low rate is explainable because the second semester compulsory unit is more recent in their study memory.

Table 5 – Self-rating of the students' attitude towards and knowledge of construction health and safety risk management from the Construction Design and Execution Safety Coordination unit

Questions	Very poor (%)	Poor (%)	Average (%)	Good (%)	Very good (%)
How do you rate your attitude towards construction health and safety risk prevention?	0	0	26.7	60.0	13.3
How do you rate your knowledge of health and safety legal regulations?	0	0	26.7	73.3	0
How do you rate your knowledge of construction health and safety risk management?	0	0	13.3	80.0	6.7
How do you rate the evolution of your attitude towards construction health and safety risk management?	0	0	0.0	46.7	53.5

The results in Table 6 indicate that 88.1% of the students rated their attitudes towards construction health and safety prevention as average and good. There are 7.1% who rated their attitudes as poor and 4.8% as very good. These very good results can be justified by unreal perception of their own knowledge. 97.6% of students self-rated their knowledge towards health and safety legal regulations as average (69.0%) and good (28.6%), and 92.8% rated their knowledge of construction risk management on construction as average (57.2%) and good (35.7%).

It is clear that they have achieved a positive evolution in their knowledge and attitude towards risk management in the construction industry since the beginning of the second 2008-2009 semester, comparing the results of Table 6 with Table 4. The students self-rated the evolution of their attitude towards construction health and safety risk management, without any negative responses, as average (28.6%), good (52.4%) and very good (19.0%).

The vast majority of the respondents have classified the lectures as average (19.1%) good (71.4%) and very good (7.1%). Only one student (2.4%) has classified them as poor. The interest level of the practical work they were asked to develop during the lessons was rated as good and very good (78.5%) and as average (19.1%), consuming from 20% to 80% of their time dedicated to this unit. Only one student (2.4%) classified this work as being of little interest.

Table 6 – Self-rating of the students' attitude towards and knowledge of construction health and safety risk management from the Construction Management and Safety Coordination unit

Questions	Very poor (%)	Poor (%)	Average (%)	Good (%)	Very good (%)
How do you rate your attitude towards construction health and safety risk prevention?	0	7.1	50.0	38.1	4.8
How do you rate your knowledge's of health and safety regulations?	0	2.4	69.0	28.6	0
How do you rate your knowledge of construction health and safety risk management?	0	7.1	57.2	35.7	0
How do you rate the evolution of your attitude towards construction health and safety risk management?	0	0	28.6	52.4	19.0

Comparing Table 5 with Table 6's results, it can be concluded that the students evaluated in Table 5 revealed deeper knowledge than the students rated in Table 6. In fact the majority of these students have attended the two compulsory units and one or two optional ones that permitted them to achieve more knowledge of specific and deeper health and safety risk management.

LECTURES' EVALUATION

The evaluation of the students work (practical work and individual written evaluation) throughout the semesters indicates that the students that only attended the two compulsory units achieved a better understanding of the health and safety issues and obligations, and of a range of safety measures that must be implemented on construction sites. These students are conscious of these matters and can by themselves or through professional training gain deeper knowledge of health and safety risk prevention. Accordingly they are not prepared to conduct a construction health and safety coordination system without attending specific professional training.

On the other hand the 15 students of the optional unit, Construction Design and Execution Safety Coordination, effectively revealed deeper knowledge of risk management and are prepared to be integrated in health and safety coordination teams. Their individual evaluation has revealed that on a scale from 0 to 20: 20.0% have a very good rating (17 values), 46.7% a good evaluation (from 14 to 15 values) and 33.3% a satisfactory evaluation (from 11 to 13 values). These evaluations demonstrated that they have effectively gained a major and positive evolution in their knowledge of risk prevention, risk management and specifically in construction health and safety coordination. In spite of this, it is essential that they gain experience integrated in specialised construction design and execution teams.

CONCLUSIONS

The health and safety risk management record in the construction industry is still poor due to poor attitudes of construction professionals and their lack of knowledge of health and safety risk management. Although the rate of accidents has decreased over the last few years, the rate of accidents in the construction industry is still higher than all other industries in Portugal (ACT, 2009).

The Civil Engineering Department of the University of Aveiro has created a range of four units with general and specific subjects focusing on occupational health and safety, construction health and safety risk management, design and site construction health and safety coordination.

Through the results of the survey presented, it can be concluded that the methods and syllabus implemented embed a positive health and safety risk management culture within the student body. The attitudes of students towards health and safety risk management improved during their attendance of these units. The majority of the students that have only attended the two compulsory units claimed to have an average attitude towards health and safety risk management. On the other hand the majority of students that have also attended one or two of the optional units claimed to have a good or very good attitude towards these matters. Similarly the students perceived that their knowledge of health and safety risk management had improved: 100% of the optional unit surveyed claimed to have a good or very good understanding of health and safety risk management against 71.4% of the compulsory unit students. The students that have undertaken the four units are also prepared to exercise construction health and safety coordination in spite of their education needing to be complemented with in site and design experience.

This assessment method will be continuing in the following academic year to permit consideration of the continuing evolution of the results.

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AN EXPLORATION OF STRUCTURED AND FLEXIBLE APPROACHES TO RECOGNISING ENGINEERING COMPETENCE

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ABSTRACT

Construction industry deaths and injuries are amongst the highest despite considerable efforts from legislators and practitioners to improve safety. In 2005–06, thirty-nine employees per day sustained a serious work-related injury or disease. The link between construction site accidents and designers is not always obvious at the point and place of an accident. A key theme within construction-related professional code of ethics is that designers make the best use of resources in the care of the environment and in the best interests of OHS. Each designer brings their own unique skill and personality to every situation in which they function. The question is how can designers' competence be developed and used in a meaningful and beneficial way to ensure delivery of the objective that: "Designs should be such that they can be built, used, maintained and eventually demolished safely?" Since that responsibility lies initially and primarily with designers, the aspiring engineer's journey to independence of thought and action requires the provision of practical information about safe design principles. The Quebec Protocol (2003) defined "*the principles and measures designed to integrate occupational health and safety into vocational and technical education*" and the National OHS Strategy 2002–2012 concurs. Therefore it is for educators to assist students to comprehend the importance of designing safe products, buildings, processes and systems. This paper, using international examples, explores the integration of structured and flexible approaches leading to recognition of the competence of professional engineers, concentrating specifically on essential OHS attributes.

KEYWORDS: Engineers, OHS competence, Education, Professional ethics

INTRODUCTION

> "For the things we have to learn before we can do them, we learn by doing them." Aristotle, *Nichomachean Ethics*

"The role of engineering in [...] society is much greater than is generally believed. It comprises not only those who call themselves engineers or are entitled to this functional name but all those who practise engineering in the course of their professional activities and may include some who do not identify themselves with engineering" (FEANI, 2005).

What is it that makes someone an Engineer? Is it their academic and professional qualifications or is it the competence that they are able to demonstrate? Maybe this is a false dichotomy, that it is neither one nor the other but rather a combination of both qualification and competence. The truth of this can be tested with a few questions and an assessment of the validity of the responses. For instance does the holding of a degree in engineering confer on the graduate the status of engineer?

At first glance it would appear that the answer is yes, of course, and that is how the graduate would like to be considered. At this point of their career they have taken the first step and are on the engineer's development curve, and it may well be that over a long and successful career the starting point of being an engineer would be the date of their graduation. But if in the days after their graduation they moved into a totally different career path without ever having practiced as an engineer, it would be irrational to state that they became an engineer on the date of their graduation. What could be said is that they possess an engineering degree; that they have some knowledge of engineering. However there is more to it than that. The UK Joint Board of Moderators (JBM)[1] determined that graduate engineers must demonstrate attitude, knowledge and a degree of competence particularly with reference to health and safety (JBM, 2005). Thus the academic qualification in and of itself does not confer being, but is an important certificate of knowledge acquisition, to be held in order to pursue higher qualifications and an engineering career. Can the same be said of professional qualifications, i.e. chartered or licensed professional engineer?

IF NOT QUALIFICATION...

Professional qualifications differ fundamentally from academic qualifications in that they are awarded after a period of practice (normally mentored) during which the candidate undertakes professional development programmes in the context of engineering practice and will satisfy a panel of experts that he holds and is able to apply his knowledge at or above defined minimum competence standards, the attributes of which include occupational health and safety (Table 1). Often, but not always, the academic qualification is a prerequisite.

Table 1: Attributes for Corporate Membership of ICE

At Chartered Professional Review candidates for corporate membership of the Institution of Civil Engineers (ICE), Chartered Engineer (CEng) are required to demonstrate that they;

- Understand their personal responsibilities relating to Health, Safety and Welfare.
- Have a sound and up to date knowledge over the range of legislation relating to the construction industry and general construction-related hazards.
- Have detailed knowledge of the hazards applicable to their particular field of work
- Understand the social and economic benefits of good safety practice.
- Can apply risk management techniques.
- As a designer, they can apply the risk hierarchy to designs and interface with other statutory duty holders.
- On site, they can deal with people issues and interfaces to ensure a safe place of work using best practice solutions.
- Understand the need for a continuing acquisition of knowledge to drive higher standards of safety throughout the industry.

Furthermore, it is a requirement of the professional body that the aspirants to and holders of their qualification are practising within their standards as engineers. Thus to hold the professional qualification is to be an engineer. However the professional qualification did not confer the status of engineer but rather it conferred recognition after the fact and this is illustrated by the reality that there is no specific obligation on the engineer to seek the professional qualification[2]. Qualification therefore is not a necessary element to the definition of what makes an engineer, though this is not to underplay its importance in both facilitating the route towards and recognition of competence.

If not qualification, what then?

[1] JBM is the body that sets the educational standards for accredited civil related engineering degrees, which are officially recognised by the professional institutions as providing the requisite educational base for graduate engineers.

[2] This is an argument in logic that is not negated by any legal requirement to hold a professional practice qualification.

What is emerging in the analysis of qualification is that what makes an engineer is the condition of being an engineer, implying the act of doing engineering. However it seems less than sensible to suggest that by the mere fact of doing something, one can lay claim to the status of being an engineer. Members of a team building course who throw a plank across a stream are to a degree applying science to the problem of crossing the water, and successfully so, but it would be incorrect to call them engineers and even though they may be continually doing that or similar activities, the most that could be said is that they are demonstrating a propensity for engineering. Something more is required.

DEFINITIONS

Engineering has been defined as "the application of science to the optimum conversion of the resources of nature to the uses of humankind", (Encyclopaedia Britannica) and "the creative application of scientific principles to design [etc]...as respects an intended function, economics of operation and safety to life and property", (Engineers Council for Professional Development, USA[3]). In being an application it is an activity and by extension engineers are those who are actively engaged in said application.

Florida State defines engineering design as meaning "the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective...". Indeed the American Society of Civil Engineers (1994) states that "...[t]he sole purpose of state statutes requiring professional licensing of engineers is to protect the health, safety, and welfare of the public by identifying individuals that have met certain education, experience, and competence standards for licensing and have agreed to the ethical practice of their profession...". In this we again see the requirement for health and safety to be a core component of engineering competence. The UK Standard for Professional Engineering Competence (UK SPECS)[4] rather than defining it refers to professional engineering as a mindset and a way of life. Engineers they claim use judgement and experience to solve problems when the limits of scientific and mathematical knowledge are evident. Thus truly inspired professional engineers push the limits of knowledge further and / or apply more fundamental knowledge and skills in new and creative ways. Dauphin (2002[5]), argues that "competency is individual in nature", meaning, in this context that "each engineer "brings unique skills and personality characteristics to every situation in which they functions". For example in 1984, in response from a call from NASA for housing designs for construction on the moon and Mars Iranian architect Nader Khalili developed the Superadobe construction method, which in recent times proved an excellent temporary solution in the aftermath of the Asian Tsunami (2004). And finally the Irish Supreme Court held that safety is an integral component of competence (Dalton v Frendo, 1977).

Also within the definitions of what is to be applied there is contained the ends to be achieved. The former holds within it the requirements of knowledge and practical ability and the latter the means whereby the competence of the actor may be determined and thus the status of being or not being an engineer. Mertens (1996)[6] distinguishes between qualification and competency in that the former "is a group of knowledge and capacities that individuals acquire during socialisation and training processes", where-as "competency refers only to certain aspects of the store of knowledge and abilities: the ones necessary to achieve certain results demanded by a specific circumstance; the actual capacity to achieve an objective or result in a given context", such as the engineers' requirement to produce inherently safer designs.

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[3] Now Accreditation Board for Engineering and Technology

[4] Published by the Engineering Council UK on behalf of the United Kingdom's major professional institutions. It primary task is to set the standards for registration as a professional engineer and to maintain the register of engineers.

[5] Barry Dauphin, PhD, Professor of Psychology at University of Detroit Mercy, *Letter on Competency for Psychologists*; in response to the request from the Department of Community Health that psychologists answer six questions about competency in our field.

[6] Mertens, Leonard, Competencia Laboral: sistemas, surgimiento y modelos, Montevideo, Cinterfor/ILO, 1996, referenced in 40 Questions on Labour Competences (ILO 2004)

Though there are many definitions of competence, ultimately it is in the nature and the quality of the output that determines the degree of competence of an individual, and in that respect what makes an engineer is determined by both what he does and what he produces. Incrementally, the individual who is not an engineer becomes so by the acquisition of sufficient quanta of learning and experience until qualitatively what he does may be called engineering and he may be sensibly termed an engineer. Dawkins (1993)7 stated that "[t]he competent mind is continuous, that is it sees connections, develops solutions and it makes decisions", and the competent engineer, freed from dependency on the oversight of others continues through self-management to a point where he is competent to become competent, that is he has reached the point, akin to the pioneers of engineering, where he has the knowledge, experience and skills to make and re-make himself; not so much accepting his limits, rather recognising that his ability to transfer his skills allows him to continually expand his knowledge and competence.

Clearly from all the definitions above OHS attributes and competence are indivisible. It is here that we turn to the processes, both structured and informal that contribute to the acquisition of engineering competence.

STRUCTURED AND FLEXIBLE APPROACHES

Learning is "...the result of unhampered participation in a meaningful setting". Illich, *1971*

The difference between structured and flexible approaches to engineering competence is not so much that the former takes place within a more ordered environment than the latter, rather that it takes place within formal institutional parameters; the initial phase of which is bounded by set curricula with progress regulated by examinations, while the latter, although often utilising formal programmes of study, is constructed by the learner to meet his personal requirements rather than those of an institution. Despite the fact that his progress is less formally regulated and his career opportunities may be limited by statutory licensing requirements or inability to meet minimum academic and professional criteria his personal development is nevertheless equally as valid therefore, subject to him being capable of demonstrating the consistent application of the accepted standards of competence the barriers should, or rather must come down.

The route that an individual chooses may be determined by the success or otherwise at examinations at the end of his school years, as well as any economic and opportunity factors that prevail. Many do not meet the criteria for university at this stage and their future success in the field of engineering is very limited. The formal route is both desired by the student, and more accepted by the professions and by society to the detriment of those who would choose or are driven towards alternative routes. Though it has been shown that the development of competence is not dependent upon either route to the exclusion of the other, the fact that the formal is prevalent is as much to do with perceptions of this route as it is to do with its efficacy.

[7] Excerpted from *The Great Ape Project*, edited by Paola Cavalieri and Peter Singer London: Fourth Estate, 1993.

Since the responsibility to ensure that designs are capable of being built, used, maintained and eventually demolished safely lies initially and primarily with designers, the aspiring engineer's journey to independence of thought and action requires the acquisition of information about safe design principles. It is for educators to assist their students comprehend the importance of

> **Case Study**
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> Ron Greenman of Bates Technical College (Tacoma, USA) mentored an applicant with 25 years experience in industry including a number of certificates gained from courses he had taken in various colleges over that period to the bachelor's degree in Engineering Science at Thomas Edison State College (ESC). One route to the Bachelors degree in Fire Safety Engineering was the two year technical programme at Bates College. Greenman assisted his student in putting together a portfolio of evidence of prior learning and experience for submission to TESC. Though he had undertaken a programme in engineering statistics, TESC required a broader programme on general statistics which was facilitated by Bates College thus completing the portfolio and gaining the student entrance to TESC. After successfully completing his degree he went on to complete a masters degree in Fire Protection Engineering.
>
> The goal of the project had been to suggest that given modern methods of interactive communication, institutions can offer specialized coursework and through cooperation, with one being the student's parent school akin to a middle school homeroom, multiple institutions can offer esoteric coursework without having to duplicate that coursework at each one to offer similar degrees.
>
> This does not require that the student have a vast or any background knowledge or competency. What Greenman did was use a subject with many existing competencies to speed up the process.
>
> Greenman and a colleague have commenced a further distance learning project with new students, in one case acting as homeroom from afar and in that other repeating the same process of no paper to bachelors degree through competency education.

designing safe products, buildings, processes and systems as they embark upon their unique and individual journey towards engineering competence[8]. McAleenan & McAleenan (2007, 2008) refer to a unique journey to independence, arguing that the life experiences gained from birth onwards shape the person we become and every experience is part of the learning process. The belief being that education is a life-long process and that structured portions along the way, i.e. college degrees, are often incubators built for specific purposes. Who determines the degree content and stipulates the pre-requisites to progress, while doing so with best intentions needs to be aware of the potential to nullify the equally legitimate non-structured educational forms. Greenman (2009)[9] asked who should the decision makers of society's canon be and fundamentally whether such a canon should even exist. The answer to this, when applied narrowly to engineering, may open up greater possibilities for aspiring engineers.

Illich (1971) ascribes the adherence to structured learning to the myth that process, in this case schooling produces something of value and production necessarily produces demand. The demand for formal education tends to direct personal and social activities to take the shape of client relationships to other specialised institutions, hence the success and authority of universities and professional bodies to largely determine how success is measured in specialised careers. His view is that the self taught individual, or those engaged in nonprofessional activity are discredited, not by their failings but by the strength of the perception that more formal education means more value and that the value of this learning experience is measured and graded by exams, certificates and professional qualifications, all of which reinforces the separation between those with and without them. This is not an absolute and it only holds its position as long as the premise is

[8] The Australian Safety and Compensation Council (ASSC), produced safe design guidance as an educational resource for engineering students in March 2006, with the vision to have a Safe Design focus incorporated into a wide range of undergraduate subjects. The Joint Board for Moderators (UK) in September 2005 published standards for health and safety teaching in accredited engineering degree programmes and all of this falls in line with the Quebec City Protocol (October 2003) for the integration of occupational health and safety competencies into vocational and technical education, recognised by recognised by international organisations like the United Nations (UN), the United Nations Educational and Scientific and Cultural Organisation (UNESCO), the World health Organisation (WHO), the International Labour Office (ILO) and the International Social Security Association (ISSA) . In particular the Quebec Protocol that H&S competencies associated with each step of in the performance of a task must be integrated into the educational process. With all of this there is substantial evidence that health and safety competencies are required by law, standards or protocols to be integrated into professional development.

[9] In private correspondence with the authors.

universally accepted that formal learning produces something of value that in turn institutionalises the process. This is not the case.

The structuring of engineering programmes is not self-initiating but stems from the tendency to formalise the process of passing on any human experience worthy of transmission to the next generation. Engineers such as Telford and Smeaton[10], who began their working lives in careers other than engineering were pioneers who often learned “on the job” developing the profession bit by bit through their mistakes and their successes, (this favours the case for flexible or informal routes to engineering). Succeeding generations would skip the purely experiential route in favour of a taught programme supplemented with supported/mentored experience, the rationale being that if the pioneers pass on their valuable knowledge the next generation would more quickly attain the status of engineers and be into safe and healthy quality practices all the sooner, (the case for formal route). Very rapidly structured programmes of learning, supported by case studies would become the norm and accepted as a reliable way to becoming an engineer, fully cognisant of the design and quality issues and as judged by his peers, competent to practice.

The advantages of the structured approach lie in the fact that standards of engineering practice, based on what works and what hasn’t have been compiled, graduated and inform the stages of competence development. Such standards have been globalised and mutual recognition of degree programmes and professional qualifications are now established through the Washington, Sydney and Dublin Accords. The Australian National Professional Engineers Register (NPER) states “Registered Professional Engineers can be expected to comprehend complexity and function independently...while achieving desired outcomes within the context of a safe and sustainable environment”.

Without a doubt the message is that those who hold these formal qualifications have already proved themselves capable of undertaking engineering at a high level. From the perspective of an employer or client those who hold recognised degree and professional qualifications are well placed to succeed since professional certification, supported by continuing professional development, act as a reliable third party verification of competence. Those who take an informal route absent the certification have a difficult task proving their competence.

[10] John Smeaton (1724-1792) started educational life studying law, he left this behind to become a scientific instrument maker and from there he developed an interest in mechanical engineering before practising what is now largely known as civil engineering. Thomas Telford grew up as a farm hand herding sheep and cattle before starting out as an apprentice stone mason at age of 14. He was a prolific self-educator who became a surveyor of public works by the age of 30 were he gained a reputation in both engineering and architecture in a short space of time. Octave Chanute (1832-1910) at age 17 with no formal engineering education offered his services for free to Hudson River Railroad, New York, where he spent 4 years working his way to Division Engineer, before moving west to Chicago to become chief engineer. In later life he focussed on the study of flight. He was a prolific writer, past president of the American Society of Civil Engineers. There are many other examples of society’s great engineers starting their careers with a variety of educational and academic backgrounds.

Jacob Linville studied as a lawyer and switched to surveying then bridge building, referred to by his peers as one of the giants of 19th century bridge-building in USA. John Stevens, chief engineer on the Panama Canal was educated as a teacher and without technical training embarked upon an engineering career in the railroads of Canada and USA. One of Octave Chanute’s mentees George Morison was educated in law and called to the bar in 1866, before giving it all up and starting a civil engineering career in 1867, rising to the heights of President of the ASCE (Source http://content.asce.org/history/).

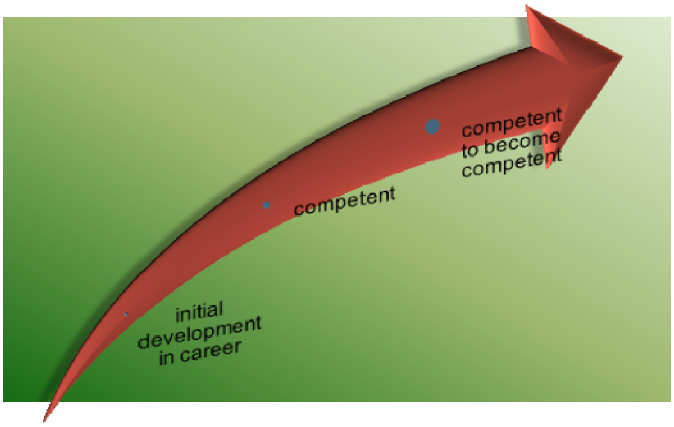

Figure1. Competency Development – Going Beyond Competence

The interaction between the student engineer and the environment creates change within the learner who in turn changes the environment, of which he is a part. This also in turn brings about the situation wherein the student incrementally changes until a point is reached when he is no longer a student but an individual who stands in contradiction to what he was independently able to decide and control the changes he makes on the environment, i.e. he becomes the engineer he wants to be.

But the individual as an engineer stands continuously as a contradiction in and off himself, both competent and not-competent at the same time[11]. He may remain at that point, sufficiently competent to maintain his status quo, or he may chose to progress, broadening his experiences and acting on ever increasing challenges until he reaches a point of excellence, a point where is he able to become competent in different and wider areas, he is competent to become competent; capable of continuously extending the boundaries of his knowledge.

Clearly there is merit in accepting both the structured and the flexible route as valid, recognising that people grow and develop at different rates. Not every student is ready for third level education at 18 years old. There are those who embark upon practical work, sometimes in the construction field and sometimes in other areas, indeed much like the early pioneers there are those who study and practice seemingly unrelated professions in their early career years, only become involved in engineering at a much later stage in their development, bringing with them novel perspectives to the challenges of engineering. As an industry the engineering professions need to be aware of and sympathetic to such situations, afterall engineers from diverse backgrounds can only serve to enhance our collective knowledge. The flexible route is acknowledged by Engineers Australia and ICE which affords the non-traditional candidate the opportunity to present their credentials to and have their flexible education and development recognised alongside their structure-developed colleagues.

The tenet of this paper is not to dismiss one form of development in favour of the other, nor is it dismissing formal professional qualifications. Rather it argues that professional qualification is a measure of competence, based on life and work experiences, knowledge, skills, attitude, ability to innovate, resourcefulness and authority. That all or at least most of these attributes are seen as achievable by both degree candidates and mature, flexibly developed individuals is a measure of the confidence the profession has in its peer review process.

HIGHER STANDARDS AND COMPETENCIES IN OHS

Engineers Australia recognise that competency is a measure of ability, regardless of how that ability has been acquired, however this recognition comes with the caveat that this is valid only if we understand in depth what constitutes dependable performance and dependable performance includes designing and building structures in a safe and healthy manner. Similar sentiments are expressed in the ICE technical routes to chartered status, together with the warning to those that think that flexible approaches are an easy option and a “cop out” for the Institution that the rigours

[11] For an explanation of this dialectic refer to Hegel, Kant, Marx and Engels.

of the approach will thoroughly test the candidate, including as it does an academic[12] and a professional review in addition to the production of an evidence-focused technical report. Candidates, following the flexible route are warned of this at the outset and are well advised to have a mentor to guide them through the process.

Since either of the routes; structured or flexible, are recognised and legitimate in many countries it comes down to choice of the individual and the pace of their personal development, often driven by circumstances, but clearly the desire is to have either route officially recognised though professional qualification. Is there room for the engineer who meets all the competency standards and through choice determines not to seek professional qualification? Why should he not be acknowledged as capable of contributing to the body of engineering knowledge? While it presents a high degree of inconvenience for the individual concerned this is, perhaps, more of a dilemma for the client or employer, who seeks to establish whether the non-professionally qualified engineer holds all of the requisite competences to deliver a safe product. Such individual choices must not be written off as maverick and unsustainable, since in doing so an excellent thinker, designer, strategist may easily be discarded and the engineering world would be all the poorer for it. The existence, therefore of protected titles such as chartered engineer or licensed professional engineer adds substantial weight to the credibility of the holder and the transferability of his professional qualification to other jurisdictions and presents security and comfort to clients and employers, but they have yet to be universally accepted.

How much more does the conferring of higher awards such as “Fellow” enhance the status of the individual and of the institutions within whose gift such awards lie? Fellowship awards do two things, firstly they recognise and honour exceptional achievement or contribution to the profession and secondly they may be awarded to anyone, irrespective of whether they are a member of the profession, who makes such a contribution. ICE may award those who are engaged in a position of responsibility for important engineering works, who have a high reputation in the field, who have made a significant contribution to engineering achievement, or “who by virtue of their position have been able to make a positive impact on the civil engineering or associated profession, *whether or not they are engaged in the practice of the profession* [our emphasis]*”*. Ordinary recognition is achieved by meeting the standards established, but the higher level requires that the recipient has gone above and beyond what is ordinarily required of an engineer. In this regard the door is open to all who are in or are associated with engineering to be recognised for excellence. It is a driver for the engineer not to rest on his laurels, nor to rest his competence level at a point that merely satisfies social and economic needs but to continue to see potential and creatively respond to it. It recognises contributions across a broad range of activities including management of major projects, the development of vision and strategies, marketing and promoting the profession, and demonstrating the importance of engineering to society. The range and breadth of criteria are more than sufficient to encompass the activities of engineers who by whatever route are in or associated with the profession.

One such area is in respect of health and safety and requires of the Fellow that he appreciates and manages the risks that arise as a consequence of his actions. It says much that this is a qualifying criterion for a higher award, rather than one that should be adjudged integral to the practice of engineering at all levels. At graduate level there is an insufficient awareness of the OHS issues associated with work in the field, though this comes with experience. It may well be that the future will recognise that health and safety is a core competency and that the current classification of it as a criterion for excellence is a recognition of its past absence from structured programmes. Certainly the Quebec Protocol (2003), has established principles for the integration of OHS competencies into the education programmes for all occupations, thus what is now regarded as exemplary will in time become the norm.

ICE is in the process of increasing the profile of health, safety and welfare (HSW) within the industry among professionally qualified engineers. This they have done through the introduction of the Construction Health, Safety and Welfare Register. Registered Members are professionally qualified, have built on their HSW competence level (above that demanded at the Chartered Professional Review), have been peer reviewed, and have met the additional attribute standards.

[12] The academic review is to allow the reviewer the opportunity to test how a candidates experience compensates for the shortfall in academic achievement, when compared with candidates whose educational base derives from the holding of an accredited degree.

They have demonstrated that they have sound knowledge of scientific, engineering and technical principles, experience of construction processes and knowledge that extends to future use, maintenance and demolition. This route is open only to any chartered professional engineer and is not restricted to ICE members.

CONCLUSION

For the engineer it should not simply be a matter of developing an awareness of and practicing safety when on site, but also of recognising the health and safety implications of his designs, of getting to grips with how the design will impact on the health and safety of the construction workers, of the public who will use the completed structure, the maintenance workers who will keep it in good order throughout its life and at some point in the future the workforce who will be required to demolish it. There is nothing new in the idea that those who design and construct a building should be held accountable for any failings in their design that leads to injury to another, but lawmakers are developing regulations that are not about supporting this as established practice, but are about compelling designers to adopt the practice.

From what we have seen the professional bodies across the globe are taking on board this requirement, though too often it is viewed as a mark of excellence rather than a core competency. For this to change the way forward lies with complimentary action between Government strategies and the policies that professional bodies adopt for membership e.g. in the National OHS Strategy the priority is to integrate OHS 'safe design' competencies into professional training. Developed before the Quebec Protocol, this strategy is in keeping with what ISSA has declared as a guiding principle, namely that safety and health are integral rather than an adjunct to competency.

In moving safety in design to the appropriate level of competency development, engineers, whether following a structured or flexible route, will be cognisant of their responsibilities and be making a significant contribution to the development of safe construction and reduction of accidents on site and throughout the lifetime of their structures. Prevention is the goal established at the World Congress of OSH in Korea (2008) and it is the responsibility of all the partners in the construction process, government, client, contractor and engineer to make this happen.

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PREVENTION THROUGH DESIGN AND GREEN BUILDINGS: A US PERSPECTIVE ON COLLABORATION

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ABSTRACT

Current green design and building practices are primarily aimed at minimizing environmental and resource impacts and improving the safety, health, and productivity of a building's final occupants and the public. Rating systems, such as the U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) put little, if any, focus on the safety and health of the temporary occupants, i.e., the construction workers. Yet such systems and their proponents represent a largely untapped opportunity for safety and health practitioners to enlist in efforts to promote designing for safer workplaces during their construction and maintenance.

In the United States, the likelihood of governmental regulations that would broadly specify Prevention through Design (PtD) efforts in upstream construction activities is remote. Because PtD has seen international support in enhancing construction worker safety, innovative and creative ways to diffuse the concept in the U.S. must be developed. This paper focuses on the congruencies between the green building effort as a sustainable holistic system and the safety and health of construction workers who build and maintain these buildings. NIOSH Construction Sector goals will be described as they relate to green building elements and ideologies and efforts to collaborate with the USGBC will be reported.

No entity that presides over avoidable workplace deaths, injuries, or illnesses can ever claim to be sustainable. For green construction to be considered sustainable, construction safety and health concepts must be integrated into upstream considerations.

Keywords: Sustainability, Green buildings, Prevention through design

INTRODUCTION

Current green design and construction practices are primarily aimed at minimizing environmental and resource impacts and improving the safety, health, and productivity of a building's final occupants and the public. Rating systems, such as the U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) put little, if any, focus on the safety and health of the initial occupants, the construction workers, or those that maintain these buildings. Yet such rating systems and their proponents represent a largely untapped opportunity for safety and health practitioners to enlist in efforts to promote designing for safer workplaces during the building's construction and maintenance. In the United States, the likelihood of governmental regulations that would broadly specify Prevention through Design (PtD) efforts in upstream construction activities is remote. Because PtD has seen international support in enhancing construction worker safety and health, innovative and creative ways to diffuse the concept in the United States must be developed. This paper focuses on the congruencies between the green building effort as a sustainable holistic system and the safety and health of workers who build and maintain these buildings. National Occupational Research Agenda (NORA) Construction Sector goals, whose formulation was facilitated by the National Institute for Occupational Safety and Health (NIOSH) in collaboration with external stakeholders, are described as they relate to green building elements and ideologies. Motivations and methods for design professionals to participate within NIOSH PtD and a new NIOSH program, Safe Green Jobs, are described. The basic premise of the paper is summed up by Gilding et al. (2002) who wrote "no entity that presides over construction projects or green buildings that experience avoidable workplace deaths, injuries, or illnesses can ever claim to be sustainable." For green buildings to be considered sustainable, construction safety and health concepts must be integrated into upstream considerations.

WHY SHOULD GREEN BUILDINGS BE CONSTRUCTED SAFER?

Green's eventual purpose is to benefit people

Green buildings are built by and occupied by people. As cited by Abbaszadeh et al. (2006), the USGBC defines green buildings as structures that have significantly reduced or eliminated negative impacts on the environment and the occupants. Construction workers are the earliest occupants in the initial lifecycle stage of a green building. Construction workers will also maintain, remodel, and decommission a green building throughout its lifecycle. Green design and construction are founded on the concept of promoting environmental sustainability and consequently perceived as doing the right thing for the ultimate benefit of the health and well-being of people. However, the construction industry is a highly hazardous industry. In the United States, over the past few years, the following statistics have remained fairly constant – the construction industry employs roughly 7.5% of the nation's workforce yet accounts for over 20% of the nation's occupational related deaths. See Table 1. The safety record in the construction industry is improving. The fatality rate decreased from 14.7 per 100,000 workers in 1995 (Toscano and Windau, 1996) to 10.5 per 100,000 workers in 2007 (BLS, 2008). However, each year more than 1000 workers are killed in the construction industry, and there is still a large disparity between the percentage working in construction and the percentage of construction fatalities in relation to all industries.

Table 1. U.S. Construction safety statistics, 1995, 2005-2007

Year	Construction Employment (thousands)	Total Employment (thousands)	% Construction employment	Construction Fatalities	Total Fatalities	% Construction Fatalities	Fatality Rate
2007	11,416	147,215	7.8%	1,204	5,657	21.3%	10.5
2006	11,312	145,501	7.8%	1,239	5,840	21.2%	10.9
2005	10,739	142,894	7.5%	1,192	5,734	20.8%	11.1
1995	7,153	126,248	5.6%	1,048	6,210	16.8%	14.7

Fatality rate = (N / W) x 100,000; N = the number of worker fatalities, age 16 and older; W = the annual average number of employed workers, age 16 and older.
Sources: Toscano and Windau (1996); BLS (2006 – 2008)

Green buildings are constructed with green materials and specific elements that are designed to improve a building's sustainability and hopefully earn the green or sustainable design designation; yet the processes used during construction have not incorporated elements to account for sustainability (i.e., safety and health) of the construction workforce. Construction literature and practice are filled with proven methods for constructors to work safely and remain healthy. The causes of injuries and illnesses in construction have long been recognized and their persistence continues to frustrate construction safety and health practitioners and researchers (Hill, 2003). Research has identified best practices which improve the safety and health performance of construction workers (for example: CII 2003; Jaselskis et al. 2006). Individual companies have reached incredible milestones of zero injuries and no accidents throughout their projects. In other words, in general, it is known how to work safely and how to manage construction safety and health to eliminate and reduce recognizable risks and hazards. These established best practices ultimately have a positive effect on people – the construction workers and their families. In his text on a contractor's guide to green construction, Glavinich (2008) addresses construction safety in one page but does not make the link that worker safety and health should be connected to green building design. Another text on green project planning and estimating (Greene, 2006) does not mention worker safety or health.

One example of a green building where construction safety failures occurred is at the Las Vegas, NV Mirage City Center which was striving for USGBC LEED certification at the Silver level. During this construction project, scheduled to be completed near the end of 2009, six construction workers died on the job in an 18 month period (CPWR, 2008). Regarding the safety and green link on this project, Ivanovich (2008a) posed the question "how many construction site deaths should there be to make a building 'not green' regardless of the environmental benefits?" Ivanovich (2008b) went on to suggest awarding one credit if a project is completed without a serious injury or death. He also proposed that green certifications should be revocable where accidental injuries or deaths occurred during construction and were proved to be complicit with negligence after the certification was awarded. While these comments are thought-provoking, proving such negligence or corruption is difficult. Rather, a more proactive suggestion would specify the incorporation of leading indicators of H&S performance in obtaining LEED certification rather than revoking it for occupational fatalities. Examples include fall protection anchor points (for both construction and maintenance activities), the inclusion of roof parapets where appropriate, recommendations for safe design of atria windows and skylights to facilitate building and maintenance, organization of the building site to facilitate the safe handling of building materials, etc, and other design suggestions (See Gambatese, et al., 1997).

Green concepts are evolving to sustainable concepts

The USGBC LEED Rating System measures how well a building or community performs across a spectrum of environmental and public health metrics: energy savings, water efficiency, CO_2 emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts. Yet these are predominantly environmental issues, and construction worker safety and health issues are not included among the metrics. With the LEED focus on the environment as an end goal, worker safety and health is only incidentally linked to the environment by the fact that many professionals in both fields have responsibilities in the other. As an example, professionals often have job titles that encompass both fields, such as Environment, Safety, and Health (ESH) Manager. The term 'green' is not synonymous with the term "sustainable." However, these two terms have been used interchangeably in the construction industry (Kibert, 2008; Kopec, 2009). The main contention of this paper is that construction worker safety and health and green construction development have linkages and opportunities for integration.

It is a misperception that including construction worker safety and health will dilute the green effort; on the contrary, sustainable design and green buildings must account for both environmental and human resources throughout their lifecycles. Sustainability is a broader concept which, in addition to the environmental aspect, addresses the continuity of economic considerations, resource conservation, and social aspects of human society. Sustainability raises the "green" discussion from materials and processes to include marketing, distribution, disposal and human labor (Evans, 2006). For a green building to be sustainable, consideration must be given to more than just protecting the environment. Worker safety and health are key issues within the social dimension of sustainability (for example: Holcim, 2009; Epstein and Roy, 2003; Gilding et al., 2002). Montoya (2009) references Trevor Hancock, a public health physician and first leader of the Green Party of Canada, whom he calls a pioneer of the "healthy communities" movement, and credits him with a definition of socially sustainable development that includes, among other items, safe working conditions. The USGBC is founded on a similar set of guiding principles, expressed in its Mission Statement "To transform the way buildings and communities are designed, built and operated, enabling an environmentally and socially responsible, healthy, and prosperous environment that improves the quality of life (USGBC, 2009)." Moreover, the USGBC Strategic Plan (2009) states that "the meaning of 'green' is evolving, to more fully include human and social relationships to the built environment." The USGBC is deeply rooted within six guiding principles that are incorporated into all aspects of their organization, consistent with promoting the triple bottom line (i.e., economic, social, and environmental responsibility).

The six principles are: (1) Promote the triple bottom line; (2) Establish leadership; (3) Reconcile humanity with nature; (4) Maintain integrity; (5) Ensure inclusiveness; and (6) exhibit transparency. However, no mention of construction worker safety and health, or construction workers at all for that matter is included in the USGBC Strategic Plan or other materials available on the USGBC website. The absence of construction worker safety and health under the context of sustainable construction is evident in other publications. Kibert's (2008) text on sustainable construction mentions the health and safety plan, however, the focus of that one-page section is to ensure that the completed building's final indoor air quality (IAQ) is not compromised by the construction process. Kopec's (2009) text on health, sustainability and the built environment discusses safety and ergonomic considerations for a sustainable building's occupants, but does not mention construction workers at all. The Holcim Foundation for sustainable construction is committed to the "triple bottom line" concept, which asserts that long-term and sustainable progress requires the balanced achievement of economic growth, ecological balance and social progress. Within their social equity framework, workers' safety and health is not mentioned. Kibert (2008) further states that sustainable construction is defined most comprehensively by addressing the ecological, social, and economic issues of a building in the context of its community, but construction worker safety and health is not mentioned as a social issue. Moreover, Kibert (2008 p.5), Lützkendorf (2003), and Sarja (2002) agree that sustainable construction must encompass the entire life cycle of the building. The entire life cycle includes the construction process itself as well as the maintenance of the building and building systems. Construction worker safety and health, as well as the safety and health of all workers, falls under the umbrella of the social dimension of sustainability, and that the construction safety process, by its current safety record, is unsustainable. In other words, green and sustainable buildings are built by an unsustainable process. Gilding et al. (2002) summed up this contention by stating "no corporate regime that presides over avoidable deaths, injuries and illnesses in the workplace can ever claim to be sustainable or even to understand what the concept requires of their business."

Is green construction safer or less safe than conventional construction?
Green buildings are not constructed with additional safety and health measures within the design and planning process. Construction firms selected to construct green buildings are not required to have special safety management systems or evidence of a particular safety performance. Therefore, a null hypothesis would state that the construction safety and health record used to construct green building is no different than conventional construction. Those statistics have been discussed previously and are included in Table 1. As yet, there are no records or published studies which describe the safety record of green construction. Gambatese et al. (2004) performed case study research to answer the following questions:

- "Do LEED buildings (i.e., green design and construction) impact construction worker safety and health?"
- "What is the impact, positive or negative, of LEED on safety and health on construction sites?"

They found that some features of green buildings designed and constructed to meet the LEED Rating System, such as the construction material recycling programs, may negatively impact the safety of construction workers, while others, such as the use of low VOC materials, may help to eliminate construction site health hazards. This study prompted further study by the same authors, and they recently had an article on this issue accepted for publication in the October issue of *Journal of Construction Engineering and Management* (Rajendran et al., 2009). The research surveyed construction companies on their safety records during green and conventional construction projects. Based on their research study, they found no statistical difference between green and non-green projects in terms of construction worker safety and health. With both green and non-green buildings having the same safety and health performance, a question arises as to whether LEED buildings should be labelled as sustainable buildings. Because no difference in safety and health performance is experienced, LEED projects are perhaps sustainable environmentally but not sustainable in terms of worker safety and health.

PREVENTION THROUGH DESIGN CONGRUENCIES

Overview of NIOSH PtD in Relation to Green

To organize efforts to explore and promote the role of design in the broad field of occupational safety and health, NIOSH and its partners convened the first PtD Workshop in Washington, DC in July 2007. The intent was to launch a National Initiative aimed at eliminating occupational hazards and controlling risks to workers "at the source" or as early as possible in the life cycle of items or workplaces. PtD includes the design of work premises, structures, tools, plants, equipment, machinery, substances, work methods, and systems of work. The workshop attracted approximately 225 participants from diverse industry sectors and disciplines. Initial partners included the American Industrial Hygiene Association, the American Society of Safety Engineers, the Center to Protect Workers' Rights, Kaiser Permanente, Liberty Mutual, the National Safety Council, the Occupational Safety and Health Administration, ORC Worldwide, and the Regenstrief Center for Healthcare Engineering. Others have joined and continue to do so since.

The central tenet of this initiative is expressed as follows:

> PtD addresses occupational safety and health needs by eliminating hazards and minimizing risks to workers throughout the life cycle of work premises, tools, equipment, machinery, substances, and work processes including their construction, manufacture, use, maintenance, and ultimate disposal or re-use.

The PtD National Initiative is framed by industry sector and within four functional areas: **Research, Education, Practice, and Policy**. Goals for each of these areas, and an additional focus area of small businesses, were established at a subsequent meeting of the NORA PtD Council in September 2008. More information on the initiative is available at: http://www.cdc.gov/niosh/programs/PtDesign/. Because the role of design is so closely linked to safety and health in so many applications identified through this initiative, the incorporation or adaptation of PtD into green building projects warrants consideration to ensure such projects are consistent with the concepts of sustainability proposed here.

The following PtD policy intermediate goal was established to move the PtD concept forward through sustainable construction practices: IG4.4: *Worker health and safety principles are included in sustainable design and construction practices*. Additionally, a comprehensive description of the PtD initiative is documented in an issue of the *Journal of Safety Research* (Volume 39, Number 2, 2008) dedicated to the proceedings of the 2007 PtD National Workshop. As a further step to recognize the potential linkages between environmental sustainability and worker safety and health, NIOSH launched an effort in June 2009 focusing on *Going Green: Safe and Healthy Jobs* (http://www.cdc.gov/niosh/topics/greenjobs/). A December 2009 workshop is planned to launch the effort.

Opportunities for collaboration – PtD and Green

Incorporating worker safety and health in to a system such as LEED would move safety into the design effort (Silins, 2009) and thus presents collaborative opportunities for the NIOSH PtD initiative and the green building movement. While the use of low VOC-materials will enhance construction worker health (Gambatese et al., 2004; Montoya, 2009), certain green features have documented risks associated with their construction and maintenance. Atria and skylights are often specified to increase the amount of natural light and heating, thereby reducing electricity usage. The construction and maintenance of atria present fall hazards which can be overcome with proper design and planning. A significant number of injuries and fatalities result from workers falling through skylights (NIOSH, 2004). In 2008, the American Society for Testing and Materials (ASTM) assembled a committee to evaluate skylight specifications and testing (eGlass Weekly, 2008). The standard will increase the required force from the 1984 OSHA standard, which specified that skylights be designed to withstand a load of at least 200 pounds. Dr. Nigel Ellis, lead for the ASTM skylight test committee, calls the 200 pound requirement woefully inadequate (eGlass Weekly, 2008). Alternatively, a specification could be included that the skylight be surrounded by a permanent protective guardrail. The literature associated with construction PtD has established over 400 additional specific methods where design professionals could positively impact construction and maintenance worker safety and health without interfering with constructor's choice of means and methods (Gambatese et al., 1997). The relationship between designer and constructor can be complicated by construction contracts, and the relationship between design decisions and construction safety and health is complex and multi-faceted (Behm, 2005). Therefore, sustainable PtD efforts are more about considering the safety and health of workers in relation to design and providing an opportunity for construction workers to work safely than about dictating means and methods. Success in PtD hinges on the relationship and communication between designer and constructor with both parties knowing their roles and responsibilities. The texts by Montoya (2009), Kopec (2009), and Glavinich (2008) go into detail on the specifications, environmental benefits, and construction aspects of specific green elements. It is recommended that revisions of these or future textbooks also include the safe design, planning, and construction of green elements. A suggested future research endeavour would be to find congruencies with these textbooks and construction PtD suggestions and establish specific design measures within the context of green and sustainable construction.

NORA CONSTRUCTION SECTOR GOALS

The NORA Construction Sector Council was formed in 2006 facilitated by NIOSH in collaboration with external stakeholders; the Council is comprised of invited stakeholders and subject matter experts from government, academia, industry groups, organized labour, and private consulting. During initial face-to-face meetings, the Construction Sector Council identified priority topic areas through a series of discussions and multi-voting processes. Among the resulting topic areas identified, safety by design, later renamed Construction Hazards Prevention through Design (CHPtD) for harmonization and consistency with the broader PtD initiative, was determined to be a priority area for assessing research needs as well as the translation and dissemination of best practices for preventing hazards in construction through design and engineering solutions. A core CHPtD workgroup was formed from volunteers on the Sector Council with interest and experience in this topic area. Additional corresponding members were recruited through the Sector Council in February 2008.

To apply the concept of designing for safety to the construction industry the NORA Construction CHPtD workgroup was given the task of providing leadership to develop goals and priorities. The main idea was to utilize engineering strategies in the design phase of projects to reduce accident producing situations. This is to be accomplished by the formation of partnerships, coordination of efforts, and facilitating networking between the construction industry and associated groups of design organizations. These activities were performed through a series of facilitated discussions, face-to-face meetings, and multiple teleconferences throughout a three-year period (2006-2008).

The following strategic goal (Goal 13) was established for the CHPtD topic:

> ***Strategic Goal 13 –*** Increase the use of "prevention through design (PtD)" approaches to prevent or reduce safety and health hazards in construction.
> ***Performance Measure –*** Increase the use of CHPtD by 33% over the next 10 years.

The intermediate goals (IGs) and associated performance measures were established to support the strategic goal and describe specific research or research-to-practice (r2p) activities identified as priority activities for this topic area. The draft goals, first disseminated in February 2008, were later revised in July 2008 as they appear below.

IG 13.1 – Characterize the current use of CHPtD and coordinate efforts to promote its use. (5 subgoals)

Performance Measures: Provide a baseline report within 2 years describing key measures of current national use of CHPtD within construction, along with a repository of currently available materials, current construction organization activities and contacts, and current training. Use findings to inform and begin at least three promotion activities. Collect data from at least eight (8) design/construction firms and other organizations actively involved in this process. Compile cost comparison assessments and business case models to characterize costs of CHPtD approaches. Develop a repository for large and medium size AE firms which deal with electrical, mechanical, civil, and commercial projects. For target audiences (i.e., engineers, architects, construction managers, and safety and health professionals), develop the following training programs to disseminate the principles and benefits of CHPtD:

- Full semester undergraduate course, and
- One week modules which can be incorporated into existing college courses 8-hour continuing education course.

IG 13.2 – Confirm the most prevalent obstacles to acceptance and implementation of CHPtD: *(3 sub goals)*

- Fear of liability;
- Lack of expertise in safety and in designing for safety; and,
- Increased costs associated with CHPtD.

Performance Measures: Conduct a survey or other quantitative research method of owners, AEs and professional liability insurance carriers to empirically confirm the factors hindering their adoption of PtD processes.

IG 13.3 – Develop tangible products and methods to address identified CHPtD obstacles and challenges. (*11 sub goals)*

Performance Measures: Develop tools, policies, sources of information, training courses and other formal mechanisms as described in the following goals to circumvent barriers to the acceptance and implementation of CHPtD.

IG 13.4 – Expand the use and evaluation of CHPtD practices. *(5 sub goals)*

IG 13.5 – Develop incentives for architects and engineers to include the following in facility design plans and specifications:

- Methods for safer project erection;
- Methods for safe operation;
- Methods for safe service and maintenance; and
- Methods for safety of the public.

Within each of these intermediate goals there are multiple research and r2p subgoals providing further detail activities for meeting the broader objectives. The CHPtD goals are found within the NORA Construction Sector Agenda, which can be accessed at http://www.cdc.gov/niosh/nora/comment/agendas/construction/. As NIOSH and the construction industry works on meeting these performance measures and goals, the incentives for designers to participate in construction PtD have the opportunity to evolve absent formal governmental regulation. Just as the design community has embraced green building design and the environmental pillar of sustainable construction, NIOSH provides the opportunity for architects and design engineers to embrace the PtD concept, construction worker safety and health, and that part of the social pillar of sustainability.

MOTIVATIONS FOR DESIGNERS TO PARTICIPATE IN PtD

As a new focus is revealed on the safety – sustainability link by NIOSH, safety researchers, and reporters such as Ivanovich, design professionals on the leading edge of new innovations as early adopters would likely choose to participate. As any new idea grows, it is the early adopters who will shape that idea. These early adopters would desire to influence the amount and type of safety through design modifications in such a safety – sustainability expansion, rather than having the other aforementioned groups dictate that amount upon them through such means as public outcry or regulation. As green and sustainable construction evolves, eventually the construction safety and health link will become obvious to all. Moreover, owners will start to see the link between safety and sustainability, and therefore will be interested in sustainable construction models that include safety and health. NIOSH's initiative on safety and green is kicking off with workshop entitled "*Making Green Jobs Safe: Integrating Occupational Safety and Health into Green and Sustainability*", and is scheduled for December 14-16, 2009. The NIOSH PtD initiative is a venue for design professionals to be involved. Additionally, NIOSH is planning a PtD conference in 2010.

SUMMARY

The crux of this paper is summed up by Gilding et al. (2002) when they stated "no corporate regime that presides over avoidable deaths, injuries and illnesses in the workplace can ever claim to be sustainable or even to understand what the concept requires of their business." Through this paper, this notion is applied to construction workers, the initial occupant of a green building, by contending that no entity (includes design professionals and project owners) that presides over construction projects or green buildings that experience avoidable workplace deaths, injuries, or illnesses can ever claim to be sustainable. Green and sustainable construction should have a better safety record than conventional construction. Rajendran et al. (2009) have shown that it currently does not.

The following future research activities are recommended:

- Determine the effect of specific green building elements on construction worker safety and health.
- Sustainable and green construction textbooks should consider construction worker safety and health as an element of importance, and should consider including previous research that has highlighted construction PtD efforts. NIOSH and their collaborators are ready to provide assistance.

Green and sustainable construction is predicted to evolve and grow over the next few decades (Yudelson, 2008). Perhaps what is labeled green construction today will simply be conventional construction in the future. The innovation and creativity that has and will positively affect the environment will be substantial. If construction worker safety and health is not part of this arrangement, any additional improvements in construction safety and health may lag behind environmental improvements. Green and sustainable buildings will continue to be built by a process that employs 8% of the nation's workforce yet experiences over 20% of its deaths. Green and sustainable construction should incorporate recognized construction safety best practices, including PtD, in order to truly have a positive impact on the dismal safety record and ensure a sustainable building life cycle.

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SAFE 'N' SOUND: BUILDING WITH INDIGENOUS WORKFORCES IN AUSTRALIA AND THAILAND

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ABSTRACT

Universities are finding exciting new ways to work beyond traditional boundaries. This paper discusses projects in which Australian students worked with workforces in dramatically different cultural contexts – in rural Thailand and in an indigenous Australian community. It outlines the ideologies and procedures used to maintain safety on both worksites. In both cases, new methods were required to manage the safety of the workers beyond the traditional 'health and safety seminar' typically provided at the beginning of these types of projects. Language difficulties, cultural differences, varied physical competences, varied expectations of the resultant outcomes, and the essentially 'untrained' workforce all contributed to an incohesive notion of workplace health and safety.

Formal procedures to maintain high quality health and safety procedures were maintained as a key requirement to satisfy university regulations. The project coordinators found it necessary to tailor our health and safety instructions to suit the diverse workforce in a number of key areas. Alongside theoretical demonstrations of health and safety equipment, we placed importance on the workforce gaining 'embodied' knowledge about safety procedures and practices. On the building site the project coordinators took a high level of control over the distribution and use of tools and maintained higher levels of vigilance than required with a less diverse workforce. However we found that the work teams quickly developed their own strategies to ensure positive safety outcomes using their developing embodied knowledge. It is argued that this embodied knowledge will ensure stronger health and safety outcomes in the long-term than the codified knowledge embedded in the formal procedures.

Keywords: Indigenous workforces, Construction safety, Embodied knowledge, Codified knowledge

INTRODUCTION

Students now view their education in context of a broader engagement with the community. Universities wish to demonstrate their capacity to address community development needs with off-campus projects both at home and abroad. Master of Architecture students enrolled in the Melbourne School of Design at the University of Melbourne are keen to enrol in programs that enable them to engage with issues of sustainability in its many forms – cultural, environmental and technical. There is also evidence that students wish to work with partner organizations to address 'real-world' problems rather than the 'make-believe' of the typical studio design program. Local community groups, NGO's and service provider organizations are also showing interest in working with universities in joint partnerships where expertise and common goals are shared. For these stakeholder organizations the oblique problem solving skills used by students and their academic mentors enables solutions that might not come easily in their pragmatic day to day approach.

Furthermore architecture students are demonstrating a wish to be a part of a team designing and then building structures at full-scale. This leads to their engagement with construction materials, construction tools and construction processes in the same manner as professional builders. Normally an apprentice carpenter, roofer, plumber or electrician is required to demonstrate their competency having completed several years training at school and on the building site. Although architecture students have ambitious plans to complete complex building tasks they do not have the same opportunity to learn their skills over such an extended period of time.

To realise their projects architecture students must be taught a similar set of skills as those taught to building apprentices at both trade school and 'on the job'. Furthermore to accommodate the broader pedagogical aims of these projects the students work alongside members of the broader community – and these additional groups must be taught the skills to contribute to the project. To date these additional participants have included indigenous groups from both Thailand and Australia. Hence these projects are run with diverse workforces that include a wide variety of participants with varying skill levels. Projects include people from quite distinct cultural backgrounds, with different ways of learning and different ways of processing knowledge. Workplaces include people of different ages, genders, attitudes to authority and project expectations. Language difficulties are commonplace as are the culturally intrinsic ways of problem solving

The primary focus in this paper is to outline the strategies used by the project coordinators to ensure a safe workplace for the diverse groups of workers on the construction sites. How can the diverse and fragmented construction teams be taught to avoid harm during the construction process? This paper will begin by outlining two mainstream safety pedagogies – one based on codified systems while the other employs embodied learning systems. The paper then discusses two key projects undertaken at the Faculty of Architecture at the University of Melbourne during 2008 and 2009 discussing how these systems were jointly used to ensure positive safety outcomes. It goes on to outline the University's policy and procedures and correlates these with the additional strategies used by the coordinators of the projects while actually on the construction sites. It concludes with an outline of the process used by the authors of this paper to maintain good health and safety outcomes among the diverse workforces they coordinate.

SAFETY PROCESSES AND PEDAGOGY

A recent study of the relationship between worker safety training and worker safety outcomes in higher risk professions, such as the construction industry, has demonstrated that the current legislation of codified regulations and procedures has not led to reductions in worker injury rates (Somerville & Lloyd 2006). This alarming piece of research suggests that safety processes must be understood in a more complex light and that the supervisor's role is far more than ensuring that the workforce merely goes 'through the motions' to claim competency.

While the most common safety training processes and pedagogy involves strict regulations and procedures monitored through competency-based checklists there is evidence that the codified knowledge gained from this strategy replaces 'embodied' learning and disregards established worker subjectivities (Farrell & Holkner 2004). Embodied learning is far harder to substantiate when regulators seek to monitor worker safety training programs. However evidence suggests that this type of learning is critical to holistic understandings of worker safety training.

Embodied knowledge, sometimes known as 'somatic' knowledge, is experiential knowledge that involves senses, perception, and mind/body action and reaction (Matthews 1998). It is based on the notion that the learner gains knowledge through their capacity to attend to the information they are receiving from their own interaction with their environment. It places the learner at the center of their own learning experience and utilizes knowledge previously gained over their lifetime. In a multicultural workforce, with both Western and non Western pedagogical processes at play, a more complete worker safety training program that accommodates different learning and understanding techniques must be developed.

What is the most effective way to reduce safety risks for workers participating in outreach programs? Given that workers are involved in these programs for short time frames what safety lessons could (and should) remain with them throughout their professional careers? This paper will now outline additional processes the authors have used to ensure good health and safety outcomes for the architecture students and their partner workers participating in projects at construction sites in Australia and Thailand.

THREE STAGED LEVELS OF EXPERIENCE

Students comment that they enrol in the subjects coordinated by the authors of this paper for a variety of reasons – the exposure to cultures other than their own, to address 'real-life' problems and to obtain experience building at full scale. Generally speaking the students have no experience working on construction sites and with power tools. Before they are taken to work with the community groups undertaking construction work they pass through two preliminary phases – one at the workshop attached to the Faculty building on the Parkville campus and the second at the University's rural campus at Creswick in Victoria.

At the Faculty workshop students first come into contact with the construction materials and the tools to shape and connect these materials. They work to clearly defined briefs and towards making components for a larger, shared product. In effect their task is to prefabricate components that are then transported to the Creswick campus for installation. Their initial nervousness at taking responsibility for design, scheduling, material acquisition, forming the 'kit of parts' and prefabricating components is shared amongst the groups of four students and confidence builds.

Figure 1. Students begin the projects by prefabricating building elements in the workshop on the University of Melbourne campus. Prefabricating components at the beginning of the project enables the project coordinators to more closely control the process.

Once any prefabricated components are complete the teams move to the University's rural campus at Creswick for on-site construction. Here the student's confidence grows, their familiarity with the tools and materials grows and their problem solving skills are put to the test. Over a three-day period the student teams work to assemble their components leading towards a collective outcome.

Figure 2. The prefabricated components are taken to the University of Melbourne's rural campus at Creswick where they are assembled by students. The skills learnt in this component of the subject enable the students to work safely and competently in the outreach component of the subject.

These preliminary exercises lead towards the main component of each project whereby the students work outside the university campus on outreach projects. To date one of these outreach projects has been located in a northeastern province of Thailand while the other has been located in an indigenous community in one of Darwin's 'town camps'. In both of these outreach projects the subject coordinators have worked alongside students and community representatives building habitable structures of significant size and complexity. The subject coordinators have overseen the health and safety of both the students and community representatives.

Figure 3. Australian students working alongside Thai students and Thai community members to build a pavilion beside the health clinic.


Figure 4. Indigenous workers helping students assemble a verandah.

Maintaining good health and safety outcomes whilst undertaking the outreach projects in rural communities is a difficult task. The partner organizations and community members have not undergone the same safety training or background construction skill training as the University of Melbourne students. Language difficulties, cultural differences, varied physical competences, varied expectations of the resultant outcomes, and the essentially ‘untrained’ workforce all contributed to an incohesive notion of workplace health and safety. ‘Western’ and ‘Eastern’ learning pedagogies and problem solving skills differ in subtle ways – ironically with the ‘Eastern’ way more closely aligned with embodied knowledge systems.

At this stage the University of Melbourne students have more experience at construction than the workers from the partner institutions. Most of the indigenous workers from both cultures have very limited building skills. Working in their teams the University of Melbourne students also play a role mentoring their co-workers – setting the tasks, the processes and developing strategies to do this in a safe manner. While all team members share the learning process in these teams the University of Melbourne students inevitably manage the main process and drive the project towards its outcomes.

REGULATORY SAFETY PROCEDURES

There are many strategies and processes for maintaining worker health and improving safety outcomes. WorkSafe Victoria administers the Occupational Health and Safety Act which aims to secure the health, safety and welfare of employees and other persons at work and eliminate, at the source, risks to their health, safety or welfare (Occupational Health and Safety Act 2004). While this document highlights the level of importance placed by government on the health and safety of workers it is focussed towards employee/employer relationships and responsibilities and does not accurately reflect the relationship between the university and its students – not to mention the associated community groups and individuals that work on our projects.

The University of Melbourne requires the coordinators of these types of subjects to demonstrate that they have addressed the requirements of a strict set of procedures and protocols. University regulations require workshop activities to be accompanied with written risk assessments with risk minimisation strategies to be practiced at all times. Power tools, both fixed and hand held, are subjected to individual risk assessments. Written instructions for correct use are provided to students prior to commencing any projects. Furthermore the students undergo strict training on safe operating procedures with written lists of ‘do’s and don’ts’ to eliminate potential misuse. Regulations require basic competency testing on top of training and then signed certification as proof of competency. Proof that procedures are followed comes in the form of pro forma documents that are required to be completed and submitted by subject coordinators to demonstrate that appropriate training as well as risk analysis and reduction has been undertaken.

The University's procedures are not unlike those in place at other higher education providers in Victoria – although university programs offer significantly less number of contact hours on health and safety training. At the Northern Metropolitan Institute of Technology (NMIT) students seeking trade qualifications undergo a protracted period of training and induction which includes single units concentrating specifically on individual power tools. Power tools have a required teaching component of up to forty hours which includes components of safe work practices and thorough instructions in all associated hazards.

To ensure that the university students are not disadvantaged by the reduced time allocation to health and safety training the coordinators of the projects outlined in this paper employ a range of strategies to address the shortfall. These additional strategies are outlined in the following section.

EMBODIED SAFETY PRACTICES

As discussed the authors, acting as the subject coordinators of these projects, are required to undertake the formal process as required by University of Melbourne's policy and procedures. However the authors also recognise that 'knowledge' gained through codified learning and the submission of documents that demonstrate that correct procedures have been followed cannot replace the value of embodied knowledge. Embodied knowledge cannot be learned in formalised learning environments and relies on strong contextual practices and connections (Blackler 2003). These outreach projects are ideal for initiating the student's understanding of ways to maintain health and safety beyond the codified lessons taught in classrooms. Although the outreach projects last for no longer than ten days – and therefore are not long enough for students to fully become acquainted with embodied understandings of health and safety – the foundations are put in place for this type of learning.

This is done in a variety of ways. Firstly the students see themselves as part of a team addressing complex problems in a studio using 'problem based learning' pedagogies. They understand that they are responsible for driving their experience and solutions with the subject coordinators working as 'facilitators' rather then working in the traditional 'teaching' role. In this sense the students also see themselves as responsible for their own safety and work to maintain their own safety as an integral part of the project. Peers look to each other for support to meet the project's objectives and at the same time collectively monitor each team member's wellbeing. Not addressing health and safety needs will 'let the team down'.

This capacity for the students to mentor each other is enhanced by their above average level of intelligence – both academic and emotional. Generally the students enrolled in these projects are in their mid-twenties and have spent four or five years at university and one year in professional employment. In most cases they have travelled widely. As such they are mature and highly motivated, and see themselves as very fortunate to be able to participate in cross-cultural exchanges. They highly value the opportunity to work with the indigenous workers in Thailand and Australia and welcome the local workers into their teams – making sure that their knowledge of building construction and safety is shared with the local workers.

It must be stressed that while on-site the project coordinators do not leave all health and safety practices to the students. A large number of pragmatic issues are addressed and enforced by the subject coordinators on a continual basis. The students are closely supervised at all times and clear instructions are made of what is acceptable practice. Tasks are never repetitive and as the process is new the students provide full concentration. Hence there is no time for students to develop poor work habits or become careless in their working procedures.

CONCLUSION

While the authors see a role for formalised health and safety procedures they see value in recognising the importance of a contextualised, ‘embodied’ learning of health and safety techniques. Within the projects described in this paper the coordinators have ensured that safety needs continue to be met, primarily through close supervision, but at the same time they argue that other factors have contributed to the safety of the students undertaking on-site construction work. The students themselves – working in teams that are often cross-cultural and employing problem based learning strategies – find themselves addressing health and safety needs as a matter of due course without relying on the coordinators to manage it on their behalf. In effect the students, and their local colleagues, learn to take responsibility for their own health and safety requirements. The project supervisors see clear improvements in the ways students work over the period of the projects and have not had to report any violations in worker safety or any incidents. While no statistical evidence has been gathered, close supervision has shown that the workers clearly use their improving embodied knowledge to anticipate the steps in the process and minimise risk.

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ASSESSING SAFETY MANAGEMENT PRACTICES AND THEIR IMPACT ON PERFORMANCE IN THE CANADIAN CONSTRUCTION INDUSTRY THROUGH ORGANIZATIONAL MATURITY

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ABSTRACT

The construction industry requires an ability to assess a given construction organization’s safety performance, and to identify areas in need of improvement. To fulfill this need, a framework has been developed to evaluate a safety management program with an emphasis on organizational processes. The result is an organizational safety maturity model based on the hypothesis that continuous improvement of the safety program denotes higher organizational maturity and greater safety performance. This paper presents the researchers’ development of the framework and its current application in collaboration with practitioners. The framework was developed through a literature review of safety performance, safety culture, safety climate, and maturity modeling research. The model consists of six main program components: (1) management commitment, (2) safety policy and standards, (3) worker involvement and commitment, (4) hazard identification, reporting, and control, (5) equipment, materials, and resources, and (6) working environment. These program components are expanded upon according to plan-do-check-act management steps. The framework subsequently defines the varying maturity for each step in each component. Ongoing validation of the framework includes elicitation from occupational health and safety experts, and application to a representative set (in size and expected maturity) of construction organizations. The validation and data collection processes are being completed in collaboration with the New Brunswick Construction Safety Association and WorkSafeNB (a regional government occupational health and safety organization). The framework demonstrates how the assessment can be used to assist improvements in safety management practices.

Keywords: Safety management practices, Organizational management maturity, Safety performance

INTRODUCTION

The construction industry cannot rely on the more common metrics for measuring safety performance as benchmarks through which to pursue improvements. The underlying hypothesis of the research described in this paper is that there is a direct relationship between the maturity of safety management practices and safety performance. It has been established that the safety performance of construction organizations is indicative of many other related aspects of the company, such as employee morale, project costs, and productivity (Mohamed 1999). Therefore, assessing construction safety management practices (at the organizational and industry level) against practices which result in better performance can provide some assistance in determining areas for improvement. This is a complement to measuring performance based solely on lagging metrics for safety performance such as the number of incidents per hours worked. From this perspective, an assessment of safety management practices provides a leading indication of safety performance and indicates, with more precision, areas which should be addressed to positively impact both safety and overall performance.

This paper describes research work that is in progress and is being developed in cooperation with the New Brunswick Construction Safety Association (NBCSA) and WorkSafeNB (a regional government occupational health and safety commission). The ultimate goal of the research is to develop a proactive solution to monitor the safety practices of a given construction company at the organizational level and identify areas that are in need of improvement. This paper will cover the first cycle of developing a framework for safety management and demonstrate how it is being implemented. The framework is essentially a collection of factors that reflect safety management practices. The factors are assessed through a combination of a series of questionnaires and data validation steps. Validation of the model through consultation with the collaborators and the pilot phase of data collection is in progress.

The framework is being developed for consistency within a national construction industry performance benchmarking effort. It builds on recent safety management research that focuses on the assessment of safety climate and safety culture, and employs the concepts of management maturity modeling. This is accomplished by delineating the key factors into six categories where each category of factors is analyzed according to a plan-do-check-act management cycle. The paper is intended for both industry researchers and practitioners.

POINTS OF DEPARTURE

To place this research in the context of assessing the performance of the construction industry, Figure 1 is presented depicting a high level process view of construction (Fayek et al. 2008). Measuring the performance of the process at some level of granularity (e.g., activity, project, organizational, sector, industry) typically measures the ratio of outputs to inputs (A to A) and the extent to which objectives are achieved (C), under a given set of conditions (B), while employing a set of practices (D). The research described in this paper explores the relationship between safety performance (C) and safety practices (D) and it does so at the organizational level of granularity. The aggregation (e.g., to a sector level) and/or specialization (e.g., to an activity level) of the assessment is not covered in the scope of the framework developed. With generally accepted performance metrics for safety, such as the number of reportable incidents, number of accidents, time lost due to accidents, property loss, etc., firmly established, and for the most part supported by legislation, emphasis is placed on development of the practices and framework for assessing them. This is accomplished through a review and synthesis of more recent construction safety management literature, as well as the adoption of a concept of management maturity.

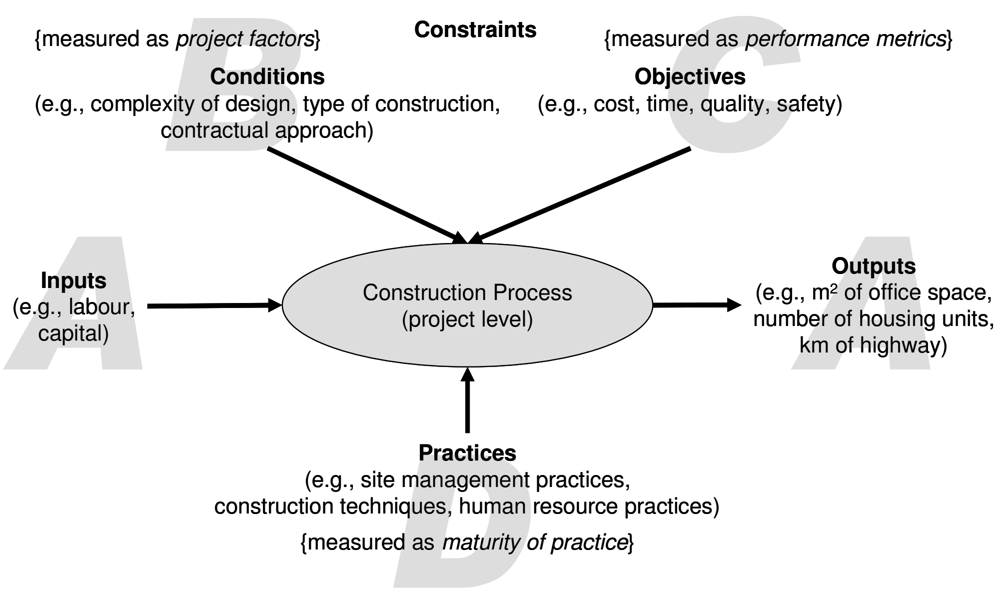


Figure 1: A conceptual model for assessment of the industry (from Fayek et al. 2008).

Safety Management

A more complete review of recent construction safety management research is presented in Goggin and Rankin (2009). The purpose of the review was to establish a set of factors with which to assess safety management practices. Previous research was generally categorized as focusing on safety climate or safety culture.

To summarize, the definition adopted for safety culture is the attitudes and behaviors exhibited by all members of an organization regarding its health and safety performance (Mohamed 2003). A common theme is the influence senior management has on overall safety culture (Choudry et al. 2008, Jaselskis et al. 1996, O'Toole 2002, and Sawacha et al. 1999). Other notable aspects include the influence of company policies and standards, and employee knowledge and awareness (Guldenmund 2007, O'Toole 2002). Safety climate, is considered to be a gauge of a worker's perception of safety's priority to an organization (Mohamed 2002, Zohar and Luria 2005). The relationship between safety culture and climate is that safety climate reflects the current status of an organization's safety culture (Flin et al. 2000). Safety climate also considers the effect of management's commitment and actions, leadership style (Zohar 2002), and many other project-level specific factors.

The six safety factor groupings identified are: (1) management commitment, (2) policy and standards, (3) worker involvement and commitment, (4) hazard management, (5) equipment, materials, and resources, and (6) working environment. The key references are listed in Table 1 along with the general factor groupings that each addresses.

Table 1: Key references and factor groupings.

Reference; (key topic)	**Factor Groupings**					
	1	**2**	**3**	**4**	**5**	**6**
1. Jaselskis et al. 1996; (safety performance)	✓		✓			
2. Williamson et al. 1997; (safety climate)	✓		✓	✓	✓	
3. Shannon et al. 1997; (injury rates)	✓	✓			✓	✓
4. Sawacha et al. 1999; (safety factors)						
5. Flin et al. 2000; (safety climate)			✓		✓	✓
6. Mohamed 2002; (safety climate)	✓	✓	✓	✓		✓
7. O'Toole 2002; (safety climate and culture)	✓	✓	✓			
8. Trethewy 2002; (workplace safety)	✓		✓	✓		
9. Mohamed 2003; (safety culture)	✓		✓			✓
10. Tam et al. 2004; (site specific safety)	✓		✓		✓	✓
11. Choudry et al. 2007; (safety culture)	✓		✓			
12. Guldenmund 2007; (safety culture and climate)	✓	✓	✓	✓	✓	
13. Choudry et al 2008; (site specific safety)	✓	✓	✓	✓	✓	

Management Practice Maturity

Process maturity modeling, gained its greatest attention in the software manufacturing industry (Finnemore et al. 2000) and is based on the earlier concepts of process improvement such as the Shewhart plan-do-check-act cycle, as well as Philip Crosby's quality management maturity grid which "describes five evolutionary stages in adopting quality practices" (Crosby 1979). Researchers at Carnegie Mellon University used this concept in the development of the Capability Maturity Model (CMM) (Paulk et al. 1995). CMM highlights the five thresholds of maturity which a process must transition through in order to be sustainably improved. Initially a process is (1) chaotic or ad-hoc and must be made (2) repeatable; after which it must be (3) defined or standardized. The process must then be (4) managed, i.e. measured and controlled. Ultimately, the process must be (5) optimized, i.e. it must be continuously improved via feedback and through the use of innovative ideas and technologies. The assessment of the maturity of a process at the organizational level entails determining the extent to which the process is defined, managed, measured and controlled (Dorfman and Thayer 1997); and this is commonly achieved by observing the practices within the organization. A more general definition is that maturity may be viewed as a combination of actions, attitudes, and knowledge rather than constraining the definition to a single set of actions or procedural norms (Andersen and Jessen 2003).

Closer to the construction industry and management of projects are more recent maturity models that include the Project Management Process Maturity (PM)2 Model (Kwak and Ibbs 2002), the Standardised Process Improvement for Construction Enterprises (SPICE) Model (Sarshar et al. 1998), and the related research area of learning organizations in construction (Chinowsky et al. 2007).

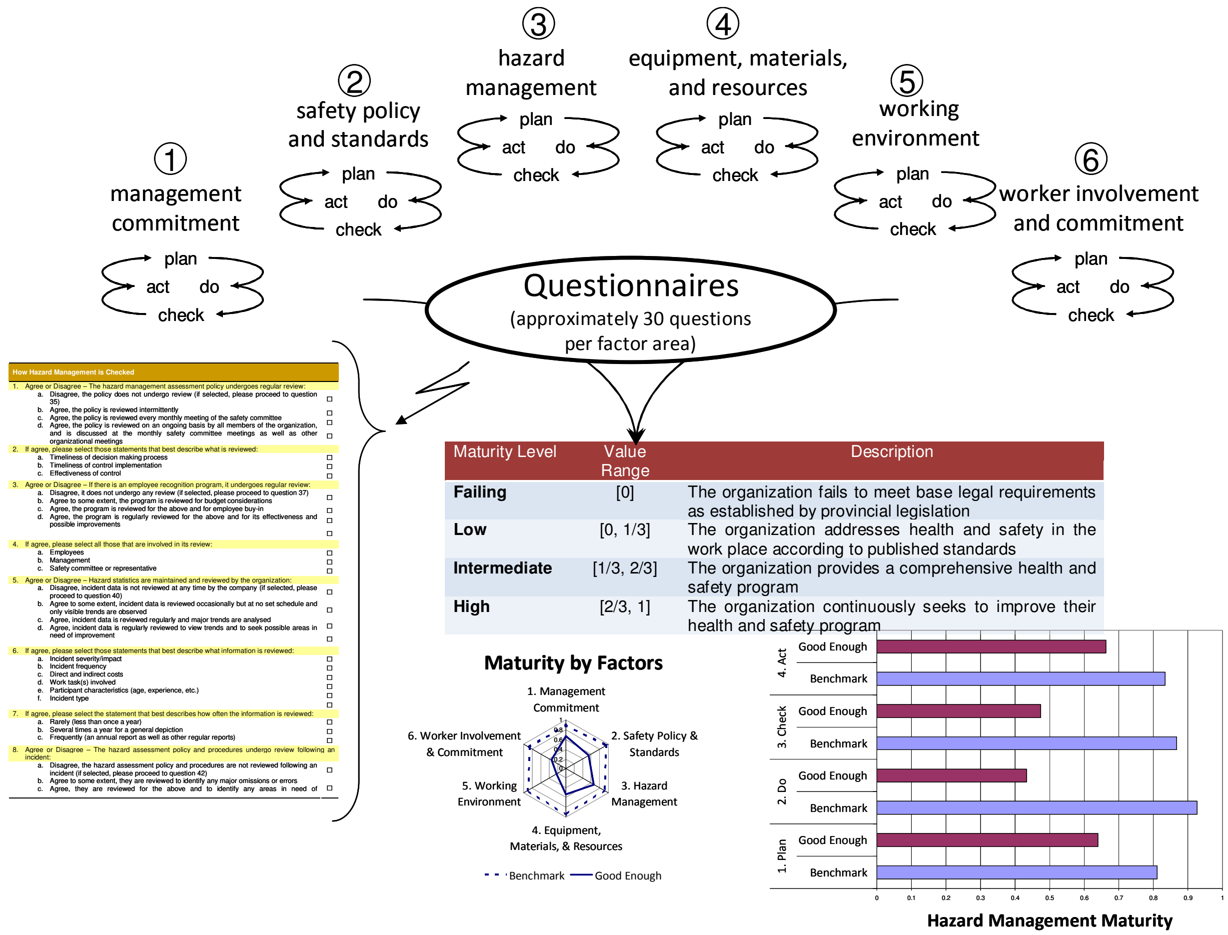
The assessment of maturity of safety management practices builds upon previous work on this topic. Willis and Rankin (2009) have defined a maturity model to assess management practices within the construction industry at an industry level. The model uses a three level construct for maturity where a practice is: (1) immature in that it is ad hoc in its application, (2) transitional mature in that it is defined and repeatable, and (3) mature in that it is measured and improved.

Safety Management Practices Framework

By combining the safety factor groupings with the concepts of process improvement and maturity, an assessment framework for safety management practices at the organizational level has been developed. Figure 2 is a conceptual depiction of the framework combined with the approach to implementing it for assessment. The six *factor* groupings are each assessed with respect to the *steps* of plan-do-check-act (PDCA). The assessment is completed through a questionnaire that determines the level of maturity for each *factor–step* couplet. The values of maturity (depicted as radar plots and bars charts) are then available to be used for identifying opportunities for improvement through comparison against other organizations, industry benchmarks, or to measure progress internally. It should be noted that at this time all factors are treated equal as a weighting of factors has not yet been complete.

Safety Factors

Six key safety factors groupings were identified from the literature review, selected due to their applicability at the organizational level, the breadth of information encompassed by them, and their logical influence on construction safety. Limiting the number of factors to six general categories also minimizes the model's complexity. Table 2 is an elaboration of the hazard management grouping, where a general definition of the grouping is provided, followed by a structuring according to the PDCA steps.



Maturity Level	Value Range	Description
Failing	[0]	The organization fails to meet base legal requirements as established by provincial legislation
Low	[0, 1/3]	The organization addresses health and safety in the work place according to published standards
Intermediate	[1/3, 2/3]	The organization provides a comprehensive health and safety program
High	[2/3, 1]	The organization continuously seeks to improve their health and safety program

Figure 2: Conceptualized practice assessment framework.

Table 2: Example of elaboration on each grouping through the PDCA cycle.

4. Hazard Management: *This program component is developed predominantly based on the Construction Safety Association's "Hazard Identification and Control" manual as part of their Core Requirements Program. It is considered a planning function as all aspects of the operation are examined and is executed at the organizational level (NBCSA 2008). It focuses on hazard recognition, evaluation, control, and monitoring.*
Plan: Planning of an information management system for the collection, control, and dissemination of hazard data among the organization and its members (e.g. the integration of the reporting process in the organization's policies and standards, the development of distinct guidelines for hazard identification process, and communication of the system's approach and significance to employees). As well, the establishment of a reporting reward system to promote awareness.
Do: Implementation of specific strategies for all members to follow and adhere to, and the communication of identified hazards to employees.
Check: Evaluation of the hazard management program's effectiveness and the reward system's promotional ability.
Act: Adjustments made to the reward system (e.g. removal or modification) and modification of the hazard identification, reporting, and control system for the improvement of overall hazard management.

Levels of Maturity

As previously noted, the safety management maturity scale is restricted to three levels. This minimizes the complexity of the model and aids in the data collection and analysis process. The three levels of the scale are defined as follows:

Level 1 – Low Maturity – The organization fails to meet basic regulatory requirements. Safety is assigned a low priority within the organization and there are few or no formal policies to dictate safety management procedures. Score of 0 - 1/3.

Level 2 – Intermediate Maturity – The organization adheres to base regulatory requirements as established by a governing authority. There are written formal policies to dictate safety management procedures and safety is regarded as a significant factor in project and company performance. Score of 1/3/ - 2/3.

Level 3 – High Maturity – The organization adheres to and exceeds regulatory requirements. Management actively seeks continuous improvement in their safety management procedures and all members of the organization are involved. The written formal procedures undergo regular review. Score of 2/3 - 3/3.

Figure 2 also indicates a *Failing* level of maturity, or a score of 0, in the cases where a factor is related to compliance with legislation. Maturity scores of organizations can then be compared against benchmark values, as represented by the radar diagram and bar chart.

Validation of Practices

The validation of the practices has been partially completed with the input of safety professionals with the New Brunswick Construction Safety Association (NBCSA). A weighting of factors is yet to be completed and is being based on pair-wise comparisons by employing the analytic hierarchy process, where each step within a grouping is weighted and then each grouping of factors is weighted. When completed for a group of experts, the geometric mean of the results will be used to determine the contribution to the maturity scores. This allows for analyses as is presented in Figure 3. The chart is indicating the relative importance associated with each step within the *Hazard Management* grouping of factors along with a maturity score achieved and opportunity for improvement (remaining) at an organizational level. In this illustrative example, the *Plan* factors for

Hazard Management are given a greater weight (0.46 of a total of 1.00) in comparison to the other steps. However, the highest opportunity for improvement for the organization assessed is within the *Act* factors (a remaining value of approximately 0.13). The values of *achieved* and *remaining* are derived with data collected through an organizational questionnaire.

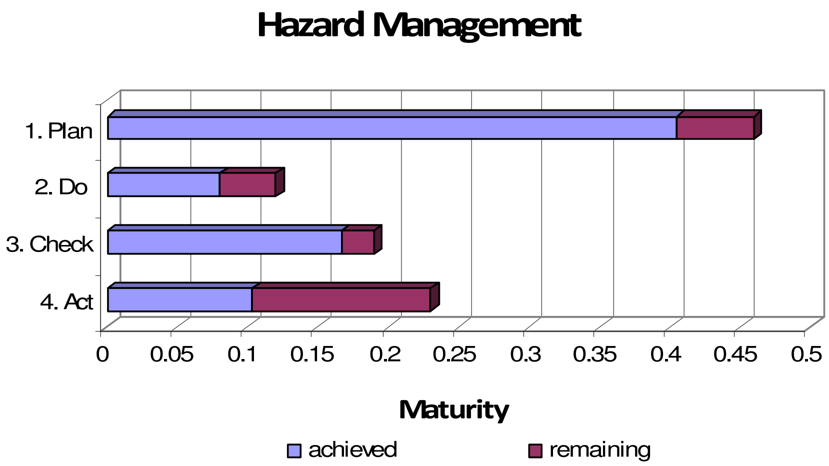


Figure 3: Example of maturity achieved and remaining for weighted PDCA steps.

Data Collection Questionnaire

The questionnaire depicted in Table 3 is an example (*Hazard Management* factor grouping; *Check* step) to demonstrate how information is collected to assess the maturity of safety management practices. The nine questions displayed in the example are from a set of 44 questions for the complete hazard management factor grouping covering all PDCA steps. Each question is structured according to a progression of maturity from ad hoc to continuously improving. The questionnaires are administered by a researcher to a cross section of employees from a given organization (from senior management to on-site workers).

Table 3: Example questionnaire for assessing the *check* step for *hazard management*.

How Hazard Management is Checked	
1. Agree or Disagree – The hazard management assessment policy undergoes regular review:	
a. Disagree, the policy does not undergo review (if selected, please proceed to question 35)	☐
b. Agree, the policy is reviewed intermittently	☐
c. Agree, the policy is reviewed every monthly meeting of the safety committee	☐
d. Agree, the policy is reviewed on an ongoing basis by all members of the organization, and is discussed at the monthly safety committee meetings as well as other organizational meetings	☐
2. If agree, please select those statements that best describe what is reviewed:	
a. Timeliness of decision making process	☐
b. Timeliness of control implementation	☐
c. Effectiveness of control	☐

3. Agree or Disagree – If there is an employee recognition program, it undergoes regular review:
    a. Disagree, it does not undergo any review (if selected, please proceed to question 37) ☐
    b. Agree to some extent, the program is reviewed for budget considerations ☐
    c. Agree, the program is reviewed for the above and for employee buy-in ☐
    d. Agree, the program is regularly reviewed for the above and for its effectiveness and possible improvements ☐

4. If agree, please select all those that are involved in its review:
    a. Employees ☐
    b. Management ☐
    c. Safety committee or representative ☐

5. Agree or Disagree – Hazard statistics are maintained and reviewed by the organization:
    a. Disagree, incident data is not reviewed at any time by the company (if selected, please proceed to question 40) ☐
    b. Agree to some extent, incident data is reviewed occasionally but at no set schedule and only visible trends are observed ☐
    c. Agree, incident data is reviewed regularly and major trends are analysed ☐
    d. Agree, incident data is regularly reviewed to view trends and to seek possible areas in need of improvement ☐

6. If agree, please select those statements that best describe what information is reviewed:
    a. Incident severity/impact ☐
    b. Incident frequency ☐
    c. Direct and indirect costs ☐
    d. Work task(s) involved ☐
    e. Participant characteristics (age, experience, etc.) ☐
    f. Incident type ☐

7. If agree, please select the statement that best describes how often the information is reviewed:
    a. Rarely (less than once a year) ☐
    b. Several times a year for a general depiction ☐
    c. Frequently (an annual report as well as other regular reports) ☐

8. Agree or Disagree – The hazard assessment policy and procedures undergo review following an incident:
    a. Disagree, the hazard assessment policy and procedures are not reviewed following an incident (if selected, please proceed to question 42) ☐
    b. Agree to some extent, they are reviewed to identify any major omissions or errors ☐
    c. Agree, they are reviewed for the above and to identify any areas in need of improvement ☐
    d. Agree, they are reviewed for the above and for areas beyond the incident ☐

9. If agree, please select the statement that best describes the actions that are taken:
    a. The procedures are checked to ensure compliance to legal codes of practice ☐
    b. The above and the procedures are checked to ensure adherence to the current work scope of the organization ☐
    c. The above and the procedures are checked to ensure that all available information sources ☐ are reviewed regularly for input (e.g. worker experience, past incidents/inspections, etc.)

CONCLUSIONS

The framework describes an approach for assessing safety management practices at an organizational level. By combining these with performance data, a relationship can be established. Using the approach of measuring the maturity of safety management practices for different factor groupings and the four steps in a continuous improvement process provides insight as to which areas provide the best opportunities for improvement. Extending the approach to a broader data collection exercise will also facilitate the use of the information collected for industry performance benchmarking and allow normalized comparisons across regions (e.g., provinces or countries). The research described is in a pilot data collection phase where the overall approach has been vetted with industry partners and factor groupings have been partially validated. The immediate steps to follow include completion of the weighting of factor groupings and steps, as well as an analysis of the relationship between practice and performance data.

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CULTURE: IMPROVING SITE SAFELY IS EVERY STAKEHOLDERS RESPONSIBILITY

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ABSTRACT

The responsibilities for safety of the various stakeholders involved in the construction process is often the subject of disputes as there is no common understanding of what these should be. There is a lack of understanding of safety responsibilities and what is expected of each stakeholder to ensure site safety. In Singapore, the government undertook a fundamental reform in the occupational safety and health (OSH) framework in 2006 in order to achieve a quantum improvement in the safety and health. The new workplace safety and health framework of Singapore emphasizes that to improve OSH on construction sites, the focus has to shift from technology and management systems to cultural aspects of the organization. The new framework calls for combined effort to deal with safety risks at their source. All stakeholders must assume responsibility for identifying risks and take steps to prevent or mitigate them with a safety culture deeply ingrained. This study originated in the need to establish ownership of the problems on work sites and the aim is to propose an empirical framework to effectively control risk and support the safe conclusion of work by construction stakeholders. A survey demonstrates that everyone on site has a role to play in improving safety levels and that, with realistic shared responsibilities, the overall level of safety on construction sites can be improved.

Keywords: Safety performance, Shared responsibilities, Safety culture, Safety role

INTRODUCTION

In 2004, there were 1216 accidents (with 24 fatalities) in the construction industry in Singapore and according to statistics from the Ministry of Manpower (MOM 2005a) the safety level has been unsatisfactory for years. One of the accidents - the Nicoll Highway Collapse - shocked the nation and caused the Occupational Safety and Health Division (OSHD) of Ministry of Manpower (MOM) - the authority which promotes OSH at the national level – to start an investigation. It appointed a Committee of Inquiry (COI) to investigate the causes of accidents, the need to establish ownership of the problems, as well the safety regulatory framework and its ancillary systems. The report by the COI, stressed that although the industry recognizes that safety has to be addressed (MOM 2005b), site personnel often do not know how to do so. It draws attention to problems related to the regulatory system. It suggests that human and organisational failures caused by lack of ownership of safety outcomes had contributed to the accident (MOM 2005b) and that the fatalities could have been prevented if the ‘warnings of the approaching collapse had been taken seriously’ (MOM 2005b).

The MOM accepted in its entirety the findings and recommendations of the COI (MOM 2005b). As a result, the Workplace Safety and Health Act (WSHA) was enacted in 1 March 2006 replacing the previous Factories Act which was repealed. From the COI’s report, there appeared to be no common understanding of safety roles. This reduced the efficiency of the legislation (Teo and Ong 2005). According to various studies, this will lead the various stakeholders involved in the construction process to assume safety roles which may result in a ‘blame culture’ (Gambatese 1996; Hinze 1997; Toole 2002b). The self-interest of each stakeholder and a continuing attachment to a culture of blaming everyone else are the traditional focus of the construction industry (Latham 1994; Bennett and Jayes 1995; Pidgeon and O’Leary 2000; Whittingham 2004). This implies not only an adversarial relationship but also affects the performance - especially the safety’s performance on site. It may disrupt work and, worse still, cost lives (Horlick-Jones 1996; Johnston 1996).

This ‘blame culture’ grabbed the attention of the nation after the collapse of Nicholl Highway as it demonstrated a lack of understanding of safety responsibilities and what is expected to ensure site safety (Teo and Ong 2005; Huang and Hinze 2006a & b). It showed that accident prevention and risk management are not main concerns of the stakeholders. They are more concerned with whom to blame when an accident occurs (Horlick-Jones 1996). The blame culture is not the only contributing factor for the unsatisfactory safety records. There are other problems such as (1) lack of understanding among stakeholders of site safety responsibilities; (2) lack of coverage and clarity in regulations and contracts; and (3) most important, the lack of a safety culture within the industry (COI Report 2005 – MOM 2005b). The COI report also highlighted the need to establish “ownership of safety on work sites’.

This utilises the empirical theory of Toole (2002b) - that there is a strong relationship between the stakeholders’ roles and the causes of construction accidents - as well as the empirical framework of Teo et al (2004) which identified four factors; Process, Personnel, Policy and Incentive (3Ps + 1I) that affect the safety performances. This paper reports on the second stage of an on-going research project, but before doing so, a brief discussion of the initial stage will set it in context.

The main purpose of the first stage was to determine whether the different stakeholders (namely developers, contractors, authority and safety auditors) have different perceptions on what affects the safety level the most. The findings of the first stage were that Analytical Hierarchy Process (AHP) was effective in assessing trends and patterns for easy evaluation. The results supported the hypothesis that different stakeholders have different roles to play and thus different perceptions on how to affect safety. They also suggested that influencing or controlling factors of each construction stakeholder can be integrated into the ‘3P + 1I’ framework discussed above. It can be broadly categorised on expertise in safety requirements, ability to evaluate the work and site conditions expertise in performing the task, ability to interact with the workers and control their behaviour and ability to control work on the site using motivation. The aim of this stage is to develop an empirical framework to effectively control risk by construction stakeholders by conducting a survey (the survey was conducted before the enactment of the new WSHA). The objectives are to (1) explore the stakeholders’ perception of their safety role and their abilities to affect the causes of accidents and (2) propose a framework which advocates partnering and shared responsibilities to improve safety for the construction industry.

There is an intrinsic-relationship among the three fundamentals of the safety problems in Singapore: the blame culture, the lack of a uniform allocation of responsibilities and the negative safety culture (Teo and Ong 2005). Hence, these problems cannot be addressed in isolation. The COI report points out that ‘safety culture is an attitude of mind and stresses that those responsible for the safe operation of construction works should not only be conversant with the relevant legislation but also should be actively committed to a safe approach to any operation’ (MOM 2005b). With a positive safety culture, shared, realistic expectations about the roles of each stakeholder can be established. This will reduce the uncertainty within the industry, and allow stakeholders to focus on the roles they can assume. In due course, shared expectations should improve the overall safety because shared expectations will lead to shared responsibilities that may prevent some accidents from occurring (Toole 2002b).

Many studies have shown that safety culture is related to safety outcomes (Sawacha *et al.* 1999; Toole 2002a; Champoux and Brun 2003). COI’s recommendations (MOM 2005b) underlined the fostering of “a generative culture where responsibilities are shared, mistakes are quickly corrected, conflicts are well managed, and roles and responsibilities clearly established.” Reform of the OSH framework was necessary because, it suggested, effective change in safety culture is only possible when there are prescribed duties for all stakeholders with enforcement focusing on systemic and cultural issues, rather than on physical lapses. The COI also moved away from the “deemed to comply” approach to a performance approach (Teo and Phang 2005). However, since the two approaches are vastly different, significant changes are required to achieve this. Contractors need to change their mindset from complying with standards and procedures to a commitment to constant evaluations of, and improvements in construction processes (Haupt 2003) and this is one of the biggest obstacles to the performance approach as the attitude of workers and management is a fundamental factor in safety (Cheyne et al 1998). Others (Sawacha *et al.* 1999; Lingard and Rowlinson 1997) stressed that the top management has an important role to play in affecting safety behaviour. The COI's report (MOM 2005b) stressed that 'effective management' depends on the commitment of senior management and how it mobilizes everyone to work together with their safety representatives.

The government was aware of the need to change workers' and contractors' mindset even before the COI's recommendation (MOM 2005). However, despite the emphasis by the government on safety culture and attitudes, the accident rates are still unsatisfactory (Teo and Ling 2006). The MOM's target is to halve the occupational fatality rate of Singapore from 4.9 fatalities per 100,000 workers in 2004 to 2.5 by 2015. The approach adopted is to seek a balance between production pressures and quality and safety goals' so as to ensure that safety considerations are integrated into the planning and coordinating processes at the worksite". This approach has met with some success in Hong Kong (Tam and Chan 1999). To further elaborate on the importance of establishing shared responsibilities the COI recommended that relevant Codes and Specifications should be developed to improve the performance of the design and construction processes. According to COI, a strict weighting system (including the safety records and culture of the bidder) must be built into the contract and tender evaluation system. The formalization of this system for public sector projects is through the Price-Quality (including Safety) Method which overcomes the shortcoming of contract and tender evaluation system based on price only.

The important thing here is to address the causes of accidents - "why" rather than "what" - (Whittingham 2004). Organizations must strive to create a blame-free environment where workers are not afraid to speak out and offer feedback. Organizations must be able and willing to respond promptly to any feedback from workers. A voluntary disclosure scheme could be adopted to disclose any infringements of safety regulations without disclosing the reporting party. It is important that the organizations realize that the main aim of this scheme is to prevent accidents from happening rather than apportioning responsibility to offending parties. Organizations must also promote a good safety culture on their sites. Only within strong systems will workers learn to work safely and thus improve safety. By constant supervision and guidance, workers will develop good practices leading to a safe working culture within the organization and improved site safety.

Finally, even though the general contractors are seen by other stakeholders as having primary responsibility on site, the expectations of the other stakeholders are not agreed upon. In the report for the Nicoll Highway Collapse, the COI noted that the complicated relationships between the stakeholders led to conflicts and confusion about responsibilities and critical gaps that "adversely affected judgment calls necessary to deal with the crisis and had caused uncertainty at the worksite." The issue of common understanding of site safety responsibilities and the abilities to control the causes needs to be addressed. However, no work had been done to facilitate this. To address this need, the second purpose of this stage of the research is to develop a research framework which attempted to reduce the uncertainty among stakeholders about safety roles by theoretically analyse the perceptions of stakeholders' abilities and compared these against theoretically derived abilities.

RESEARCH DESIGN AND METHODOLOGY

The study aims to evaluate the safety roles perceived by each party via a survey (survey was conducted before the enactment of the new WSHA) and evaluate these roles in relation to the abilities of the parties to affect the proximate causes of accidents. A survey was designed to determine the stakeholders' perception of the relative importance (based on AHP) of the safety factors contributing to safety on construction sites. The reasons for selecting AHP are its ability to handle complex problems, complementing hierarchical nature, wide application and its effectiveness in identifying trends and patterns for easy evaluation. The survey questionnaire was based on the pairwise comparison method with scale 1-9 as advocated by Saaty (1980). Respondents were asked to make comparative judgments of the factors. The raw data collected would then be input into Expert Choice Version 11, which is an IT version of AHP, to work out the priorities.

The perceived safety roles were contrasted with the actual control the stakeholders have over the causes of accidents. Discrepancies between the perceived roles and abilities to control the outcome may be a contributing factor to the persistently high accident rates in Singapore. The theoretical analysis and especially the abilities to affect the causes of accidents are based on Toole's framework (2002b), the COI's recommendation (MOM 2005b), Teo's and Ong's (2005) framework and Teo's and Ling's (2006) study. The focus is on the identification of the factors necessary to prevent the causes of accidents. The analysis assumes the traditional contractual arrangement where the Developer hires a Contractor to build and a Designer to design. This analysis is practical as the role of each party depends on its operational activities and not on morality or ethics. The detailed explanation of each category of factors necessary to affect causes is shown below:

<u>Factors necessary to affect causes - Policy (expertise in the safety requirements)</u>
The determining factor here is the ability of the stakeholders to recognize hazards and prevent accidents utilizing understanding of safety requirements.

<u>Factors necessary to affect causes - Process (evaluation of work and site conditions)</u>
Determining factors in this category are the abilities of stakeholders to evaluate site conditions to identify visible and hidden unsafe conditions in the performance of construction work.

<u>Factors necessary to affect causes - Personnel (expertise in tasks, interaction and control of behaviours)</u>
Determining factors in this category are the abilities of the stakeholders to use the most efficient tools, materials and methods and to interact with and control the behavioral of workers.

<u>Factors necessary to affect causes - Incentive (control work on site via motivation)</u>
Determining factors in this category are the abilities of the stakeholders to control jobsite work via motivation.

SURVEY FINDINGS

A total of 120 questionnaires were sent out requesting the participation of the different stakeholders in construction (see Table 1) including developers (Real Estate Developers' Association of Singapore registered developers), safety auditors (Ministry of Manpower registered safety auditors) and contractors (Building and Construction Authority registered contractors, including Sub-contractors). Designers declined to participate in the study, stressing that the regulatory framework, the Factories Act at the time of the survey, nominated the contractor as wholly responsible for safety outcomes. 75 surveys were sent to contractors, 25 to developers, 18 to auditors and 2 to authorities. Sixteen contractors, six safety auditors, seven developers and one authority responded.

Table 1: Breakdown of survey responses

	Sample Frame	**Population**	**Sent out**	**Responded**	**% responded**
Contractor	BCA registered contractors under CW01 (General Building) category	1759	75	16	21.3
Developer	REDAS registered developers (Property Development - General category)	92	25	7	28.0

Auditor	MOM registered safety auditors	21	18	6	33.3
Authority	BCA and MOM	2	2	1	50.0
Total		1874	120	30	25.0

The results of the survey are shown in Table 2 classified under Contractors, Auditors, Authority and Developers with the ranking indicated. The ranking was according to the respective relative importance of the factors generated by the Expert Choice. The numbers in parentheses are the AHP results. Raw data are entered into Expert Choice Version 11 (software developed in using the AHP model to produce priorities); thereafter, the priorities are derived and Inconsistency Ratio (CR) calculated. The highest number will top the rank (e.g. 0.391 ranked no. 1 and 0.144 ranked no. 4 of Table 2). Through the results, the perception of stakeholders on their safety roles could be determined and thus verifying the proposition. It is observed that there is a distinct difference in viewpoints on the importance issue impacting safety on site (Table 2) as there is no one unique set of results among the stakeholders. The findings of the survey support the proposition that the understanding of site safety roles is a problem. There is no common understanding about the perceived roles of the stakeholders and their abilities to control the causes of accidents. This will be discussed in the next section.

PERCEIVED SAFETY ROLES VS. STAKEHOLDERS' ABILITIES TO AFFECT CAUSES

This section discusses the stakeholders' abilities to affect causes of accidents under the 3P + 1I model(Table 3) and compare and contrast them with the perceived safety roles evident from the Survey (Table 2). Table 3 is the 'ideal' theoretical influence stakeholders should have based on the previous tested studies conducted by Toole (2002b), COI (MOM, 2005b), Teo & Ong (2005) and Teo & Ling (2006). These findings goes a long way towards explaining the poor safety performances on sites as determined by a lack of common understanding of site safety responsibilities and abilities to control the causes.

Table 2: AHP results and rankings of the perceptions of respondents' own influence

	Contractors' Ranking	Auditors' Ranking	Authority's Ranking	Developers' ranking
Policy (expertise in safety requirements) (AHP result)	3 (0.189)	3 (0.269)	4 (0.086)	4 (0.176)
Process (evaluation of work & site conditions) (AHP result)	4 (0.144)	2 (0.278)	3 (0.099)	3 (0.189)
Personnel (expertise in tasks; interaction & control (AHP result)	1 (0.391)	1 (0.288)	1 (0.432)	2 (0.274)

Incentive (control work on site via motivation) (AHP result)	2 (0.276)	4 (0.165)	2 (0.383)	1 (0.361)

Table 3: Factors affecting proximate causes (adapted from Toole (2002b), COI (MOM, 2005b), Teo & Ong (2005) and Teo & Ling (2006)) – the 'ideal' theoretical influence stakeholders should have

	Contractors	**Auditors**	**Authority**	**Developers**
Policy (expertise in safety requirements)	High	High	Low	Low
Process (evaluation of work & site conditions)	Mixed	High	Mixed	Low
Personnel (expertise in tasks; interaction & control their behaviours)	High	Low	Mixed	Low
Incentive (control work on site via motivation)	High	Low	Moderate	Mixed
Aggregate ability to influence proximate causes	High	Moderate	Mixed	Low

Contractors are attributed a ***high*** level of safety expertise and ability to influence safety through policy, because their employees are most exposed to hazards on the jobsite and they are required to train their employees on recognizing and avoiding hazards on sites (Toole 2002b). However, the survey findings show that Contractors do not pay too much attention to *Policy* (rank 3) as they adopt the 'compliance' approach - they only send the workers for the compulsory Construction Safety Orientation Courses (CSOC). They are reluctant to send foreign workers for extra safety training and view such training as a waste of resources as foreign workers can stay in Singapore for only four years. Training not only requires resources, but also takes away valuable work time. These findings are supported by the study of Teo and Phang (2005). The low emphasis on *Policy* reflects an emphasis on speedy completion rather than safety. Before the enactment of the new WSHA, Contractors are not required have a comprehensive safety and health plan to address the potential risks of the work. There is no structured risk assessment. As a consequence, the employees of Contractors do not fully understand safety requirements. The ability of the **Contractors** to evaluate potentially unsafe processes is ***mixed***. The contractors are expected to ensure that progress and conformance with specifications are satisfactory. Contractors have a high ability to identify visible unsafe conditions but on the other hand; Contractors have a low ability in identifying the hidden unsafe conditions because assessing hidden unsafe conditions such as temporary loadings on the permanent structure, is beyond their experience (Toole 2002b). The survey findings indicate that Contractors do not pay much attention to *Process* (rank 4). They adopt the 'compliance approach for reasons already mentioned.

Contractors are in a strong position to interact and control the behaviour of workers on site (Toole, 2002b). The **Contractors** ability to control is ***high*** because contractors are performing the actual construction work and specialize in a range of construction tasks using the most efficient tools, materials, and methods, and they rank *Personnel* number 1. Contractors abilities to control work and people on site via motivation (bonuses are one of the positive ways to influence the behavioural aspect of workers) is extremely high (Toole 2002b), because they are explicitly tasked with monitoring and coordinating the site work. Contractors also frequently provide equipment and facilities that are shared among stakeholders on site, but the survey shows that Contractors are not emphasising enough on *Incentive* (rank 2). They can do much more to motivate workers than just use disincentives, e.g. punish workers. *The survey shows that Contractors could use Policy, Process and Incentives more efficiently while there is no difference between their perceived role and their abilities to influence safety through Personnel.*

Auditors are attributed a ***high*** level of safety expertise through policy, because they are required to be trained in recognizing and avoiding hazards, and it is their responsibilities to help contractors to effectively identify and control risk by performance feedback through safety audits. Good safety audits can prompt improvements in reporting accidents, incidents and near misses (Teo and Ong 2005; Teo and Ling 2006). Based on the survey, Auditors are not paying much attention to *Policy* (rank 3). The reason given is that in practice, safety audit checklists vary between audit companies. Many undercut fees to win contracts and low fees have led some companies to cut corners and spend less time on site, thereby reducing the quality of their audits to the minimum. This finding is similar to these of Teo and Ling (2006). The majority of the respondents felt that not all Auditors spend enough attention to *Process* (rank 2). There is no standardized audit protocol and due to low fees, most of them do the bare minimum to survive. Although they do not spend much time on site they are well placed to implement specific safety recommendations and their audits provide feedback to Contractors on their safety performances (Teo and Ong 2005).

Auditors are not in a position to interact and control the behaviour of workers on site (Teo and Ong 2005; Teo and Ling 2006), because auditors are not performing actual construction work and have little or no knowledge of the most efficient tools, materials, and methods used on site. In contrast, the survey shows that they believe that they can control the behaviour (*Personnel*, rank 1) if only when Contractors believe in regular safety audits (which is not the case). The findings show that Auditors felt that they cannot exercise control over the jobsite and control people by *Incentive* (rank 4). In practice, their ability to exercise control over the jobsite is ***low*** because they are not on site enough to control the site and work and therefore not in a position to control people by motivation (Teo and Ong 2005; Teo and Ling 2006). *Auditors are less practicable in influencing policy, process and personnel then they assume. On the other hand, the data indicate there is no difference between the perceived role of Auditors and their abilities to influence safety through incentives.* The expected safety expertise for **Authorities** is ***low*** because its employees are exposed to hazards only occasionally during site inspections. Their representatives are trained to be well-versed with safety requirements but due to the very infrequent presence on site they will not have much influence in preventing accidents on sites (COI Report 2005 - MOM 2005b). The survey results show that the Authorities share this view and rank *Policy* low (rank 4). Authorities can influence the way the contractors work on site by regulating to ensure safety inclusions in the design but it is impossible for Authorities to inspect jobsite frequently, thus Authorities cannot evaluate work and site conditions regularly (Teo et al 2004; MOM 2005b). The survey shows that Authorities rank their control over *Process* at 3. Authorities can influence the way Contractors work on site by instituting fines and demerits points for unsafe practices but on the other hand, their presence on site is low, thus Authorities cannot control *Personnel* (COI Report 2005 - MOM 2005b). The survey shows that Authorities rank *Personnel* too highly (rank 1). The practical ability of **Authorities** to exercise control over jobsite through incentives is ***moderate*** (Teo and Ong 2005). The regulatory design decisions made by them can substantially influence what must be accomplished on-site. Authorities can also encourage Developers to motivate Contractors via monetary incentives. Authorities can also fine Contractors, issue them with demerit points or bar from tendering thus who do not use safe practices on site (COI Report 2005 - MOM 2005b). *The data indicate there is no difference between the perceived role of Authorities and their abilities to* *influence safety through policy, process and incentives but that they overestimate their level of influence over personnel.*

The expected influence on safety by **Developers** is ***low*** except for the potential use of incentives where it is mixed, as they visit sites only occasional when monitoring the progress of work. Also, they do not normally have safety training as it is not required. (Toole 2002b). The survey shows that the Developers share this view and give a low ranking to Policy (rank 4), Process (rank 3) and Personnel (rank 2). The practical ability of **Developers** to exercise control over the jobsite through incentives is ***mixed*** (Teo and Ong 2005). There are other ways for developers to influence contractors; but using incentives such as bonuses to exercise some control over Contractors has its merits but also limitations. Safety improvements require a positive safety culture. As they are not often on site, Developers cannot effectively monitor and control Contractors (Toole 2002b; COI Report 2005 - MOM 2005b). The survey found that Developers ranked their ability to control Process and Personnel too highly but that they ranked their ability to influence safety through policy and incentives correctly.

PROPOSED FRAMEWORK - SAFETY ROLES BASING ON ABILITIES TO CONTROL

This section proposes a framework for safety roles (Figure 1) by analyzing the perceived roles of the stakeholders against their abilities to control the proximate causes of accidents which in turn determine the appropriateness of the practice. The proposed theoretical framework was developed based on only mainly focusing on worksite behavioural issues. The proposed framework aims to eliminate any uncertainty on site safety responsibilities by establishing fair and practical expectations on site safety roles. According to Toole (2002b, p203) as long as the analysis of the factors of the survey are based on 'the assumption that stakeholders have limited abilities to prevent construction accidents should also have limited responsibility for site safety', such analysis can be used to establish fair and practical expectations on site safety roles.

Contractors Summary

Contractors generally have a ***high*** ability to influence the causes of accidents; hence, it is proposed that Contractors should emphasis all 3P + 1I. Contractors are the 'site' people doing the construction work and their actions would have most impact on safety as compared to other stakeholders. Contractors should have an effective risk management system in place so that deficiencies in construction processes can be recognized and expeditiously controlled. The Contractors, being the direct or indirect employers hold the key to the performance of the safety behaviour of workers. Hence, an effort to educate and motivate them through *Incentive* is fundamental.

Auditors Summary

Auditors generally have a ***moderate*** level of ability to influence the causes of accidents. As the inspectors of contractor's safety management on site, they are proficient in safety regulations and identification of unsafe practices and conditions. Auditors would be able to detect infringements and identify hazards and bring them to the Contractors' attention. Auditors should have the power to stop work when they feel that it is unsafe to carry on work on site. The findings indicate that Auditors should focus more on *Policy* and *Process*. Due to the undercutting of fees practiced by Auditors, the quality of safety auditing has been affected and there is a need to change the practice by standardizing the audit protocol so that Safety Management System governing structure is not lost. It is essential for safety Auditors to have comprehensive checklists when auditing sites and they need to be proficient in safety regulations so that they can detect safety infringements quickly and correct them.

Authorities Summary

Authorities generally have a ***mixed*** ability to influence the causes of accidents. On the whole, the Authorities perceive little difference between their roles and abilities to control. There is only one identified discrepancy as the Authorities slightly over-emphasized self-regulation and fostering a positive safety culture in place of the culture within the construction industry. To foster a positive safety culture 'the right mix' and 'type of legislation' is essential (Teo and Phang 2005). The findings indicated that the authorities constantly examine the adequacy of regulations in promoting safety and clearly stating the various roles and responsibility of the stakeholders. With clear guidelines, the stakeholders would be able to more efficiently carry out their safety roles. This is also the recommendation made by COI and the new safety regulatory system which incorporates such rules on roles and responsibilities implemented.

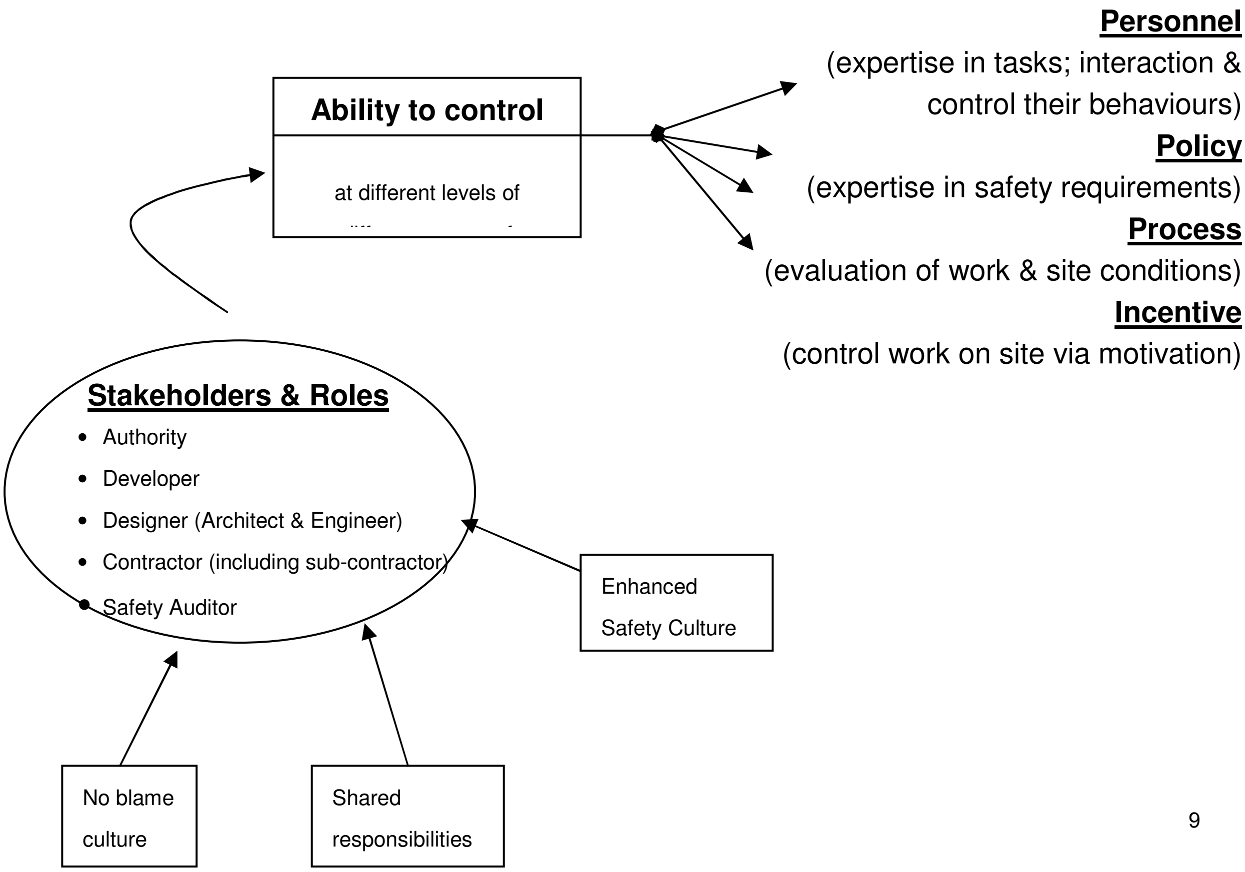
Developers Summary

Developers generally have little ability to influence the causes of accidents. It is the responsibilities of the Developers to incorporate in the process of evaluating tenders the safety aspects as one of the major criteria for selection (COI Report 2005 – MOM 2005b; Teo and Ling 2006). Though Developers' role in safety is quite limited they can engage competent Designers to ensure the robustness of the designs and reward the Designers a share of safety bonuses should the project be completed without fatal or serious accidents. Developers should emphasize to Contractors the message that safety cannot be compromised and motivate Contractors who practice safety on site with incentives and bonuses (Teo et al 2004). Thus, if Developers want to indirectly help to promote safety they could:

1) allow a greater budget to designer to cover added safety effort and responsibility,
2) assign a higher budget to contractors for safety implementation purposes, and
3) introduce bonuses to contractors to encourage safer work sites.

To effectively improve the safety level on construction sites, the proposed framework depicted in Figure 1 consists of three aspects; (a) clear safety roles specified in the contracts with shared responsibilities, (b) 'actual' safety roles based on the abilities to control causes of accidents and (c) removal of the blame culture. With these three aspects focusing on the concept of a positive safety culture, improvements in safety on construction sites could be achieved. Worksite safety responsibility falls on all in a project and no one party is capable of ensuring safety alone. Only with inputs and commitment from all stakeholders would safety be promoted.

Figure 1: Proposed framework for the abilities to control proximate causes



CONCLUSION

The limitation of this paper is that the proposed theoretical framework was developed based on only mainly focusing on worksite behavioural issues and hence more sophisticated, multi-layered models of influence on construction OHS has not been the focus of this paper. Nonetheless, from the above discussions, it could be seen that safety level on site is hampered by a lack of common understanding of site safety responsibilities among stakeholders. The analysis offered here will reduce the uncertainty among stakeholders about site safety roles by theoretically analysing their respective abilities to influence the proximate causes of accidents (Figure 1). The safety expectations that are practical; establishing realistic, shared expectations about the safety role that each party can play, can be easily achieved. This will reduce the uncertainty within the construction industry. Most importantly, realistic shared expectations will help to prevent some accidents from occurring and hence improve the overall level of safety on construction sites. Moreover, the findings of this study can help all stakeholders fully appreciate the importance of self-regulating approach which is advocated by the new WSHA with the common understanding of site safety responsibilities among them. This research will act as a good platform for further research works to be conducted in this area to include more sophisticated, multi-layered models of influence on construction OHS for local construction industry.

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DYNAMIC INTERPLAY BETWEEN SAFETY CULTURE AND WORKPLACE DIVERSITY

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ABSTRACT

It has been reported that, in the U.S., Hispanic construction workers are at higher risk of work-related injuries and illnesses. The disproportionate risk is also associated with other subgroups, including non-union workers, women workers, new workers, young/older workers, day labourers, etc. In recent years, the concept of safety culture has started gaining popularity in the construction industry. It has been gradually perceived that a positive safety culture can improve the safety performance of an organization and reduce accident costs in all aspects. However, the complexity of a safety culture related to multiple subgroups has not been adequately studied, understood, and manipulated. This limits the development and implementation of a positive safety culture in a diverse workforce environment.

This paper presents exploratory research that aims to explicate the dynamic interplay between organizational safety culture and diverse subgroups. The final goal is to enhance safety performance of these subgroups by developing, improving, and implementing a goal-directed group-oriented safety culture model. The paper not only explains the interactions between an overall organizational safety culture and safety sub-cultures of diverse groups of workers, but also emphasizes that: 1) the variation of construction workforce and its safety awareness/behaviour climate, 2) the creation of a goal-directed group oriented safety management system; 3) the effectiveness of group oriented communication, supervision and implementation; and 4) enhancing the overall organization culture should be considered in the development and improvement of a safety culture model. This will advance an organizational safety culture and its efficacy in improving safety performance of diverse subgroups.

Keywords: Safety culture, Workplace diversity, Construction, Immigration workers.

INTRODUCTION

It is well known that construction is a risky occupation for workers, particularly within the US construction industry. According to the most current census data provided by U.S. Bureau of Labour Statistics (BLS, 2008), of the 5,488 fatal work injuries recorded in 2007, 1,178 or 21.5% occurred in construction. The fatality rate (10.3 per 100,000 employed) ranked fourth highest among various industries. Besides elevated safety regulations and prevailing safety enhancement solutions such as behaviour-based safety, the establishment of a positive safety culture has been gradually perceived as an effective measure to prevent accidents and improve safety performance of construction firms (Vecchio-Sudus and Griffiths, 2004; Choudhry et al., 2007b).

In recent years, the U.S. construction industry has undergone rapid demographic changes due to labour shortage. In 2008 the U.S. construction trades workforce was made up of just below 30% Hispanic workers (BLS, 2008). This large number of immigrant workers, female workers, and young/older workers can be seen throughout the workforce. New workers (change of jobsite or turnover) and non-union/union workers have intensified the workforce diversity. Though the impact of such a diverse workforce has not been adequately understood, in terms of safety, it has been noted that these subgroups are facing higher or substantial risk of work-related injuries or illnesses (Welch et al., 2000; Fabrega and Starkey, 2001; Dong and Platner, 2004; Windau and Meyer, 2005; EU-OSHA, 2006; Mah, 2007). The trend is more obvious in non-union and/or smaller construction firms as well as in special trades such as roofing (Suruda et al., 2003).

This study explores the dynamic relationship between a company's safety culture and its diverse workforce and proposed to focus the development of a superior safety culture model on 1) enhancing the overall organizational culture, 2) goal-directed group-oriented safety management systems, 3) enhanced supervisory roles for effectively communicating and implementing safety policies and measures, and 4) establishment of positive safety culture and safety climate of subgroups. This will advance an organizational safety culture and its efficacy in preventing accidents and improving safety performance of diverse subgroups.

LITERATURE REVIEW

Accident Causation

Understanding of root causes of accidents instead of symptoms is always important before proposing any remedies. Among various accident causation theories and models, the work of Heinrich is most fundamental (Heinrich, 1959). According to Heinrich's Domino Theory, five factors leading to an accident in the sequence of events are: ancestry and social environment, fault of person, unsafe act or condition, accident, and injury. The first two dominos are related to worker personality that can be passed along through inheritance and/or developed from a person's social environment. In fact, according to the Accident Prone Theory, permanent characteristics in some workers make them more likely to have an accident than others. Personnel factors including lack of understanding or ability, improper motivation (bad attitude), and illness, mental, or personal (non-work-related) problems are also contributors (Vincoli, 1994). These findings are important for us to understand why Hispanic construction workers may have higher safety and health risks than whites within the U.S. construction industry.

The Human Factors Theory suggests three broader factors leading to accidents: overload, inappropriate response, and inappropriate activity. Overload results from imbalance between a worker's capacity and the load that person is carrying in a given state. However, the environmental factors, internal factors (personal problems, emotional stress, worry), and situational factors (level of risk, unclear instruction, novelty) magnify the work load. Inappropriate response is also determined by the worker's abilities, limitations, social behaviours, and practices. According to

Kerr's Adjustment Stress Theory, workers, who are not adjusted to their situation or integrated with it, will tend to have more accidents than others. This adjustment is affected by the tensions and stresses (i.e., physical and psychological) to which workers are subject (Kerr, 1957). These understandings are very beneficial when we deal with safety issues associated with vulnerable workers, notably young/old workers, new workers, and female workers.

Safety Culture

For a long time, safety research and industry practice mainly focused on safety management controls and procedures, safety programs and performance, and safety training of jobsite operations/behaviours to reduce unsafe acts and unsafe work environments (Jaselskis et al., 1996; Tsai et al., 2003). In recent years, the role of organizational safety culture in promoting a safe work environment as well as the methods to define and assess safety culture have been established by researchers (Mohamed, 2003; Nieva and Sorra, 2003; Choudhry et al., 2007a, b). Culture interventions have also been gradually adopted by individual companies and government agencies in their practice. The "Culture and Safety Awareness" campaign launched by Dutch Ministry of Social Affairs and Employment showed very positive intermediate results one year after launching the program. A 30% incident reduction was reported in participated companies in the concrete construction industry (Oh and Sol, 2008).

Cox and Cox (1991) define safety culture as "the attitudes, beliefs, perceptions and values that employees share in relation to safety." Safety culture relates to both organization and individuals since policies and procedures are established at the organizational level but are executed at the subunit/group level (Zohar, 2000). Williams et al. (1989) argue that beliefs, attitudes and values about the organization, its function or purpose can vary among divisions, departments, workgroups, or individuals, leading to the existence of sub-cultures, which can also be named in a hierarchical way as executive culture, engineer culture and operator's culture (Schein, 1996). As highlighted by Pidgeon (1998), subcultures serve a useful purpose and can provide a diversity of perspectives and interpretation of emerging problems in safety. They can be measured to enable comparisons within an organization or among organizations to promote "best safety practice" (Cooper, 2000).

Safety climate is viewed as a subcomponent of safety culture and defined as a summary of molar perceptions that employees share about their work environments (Zohar, 1980). There are organization-level and group-level safety climates. The latter could be found different in an organization due to between-groups variation mainly caused by supervisory safety practices (Zohar, 2000).

Creating and implementing a superior safety culture model is a very challenging task due to the complexity of safety culture. The proposed culture models in the literature focus on three dynamic and interactive factors: person/people (measured by safety climate surveys), job/behaviour (measured by behaviour sampling), and environment/situation (measured by safety management system audits) (Geller, 1994; Cooper, 2000; Choudhry et al., 2007b). However, such full safety culture models are rarely applied in practice.

Also a top-down approach is often seen, which strengthens the influence of safety culture in the direction from higher level management personnel (e.g., executives, superintendents, etc.) to low level workers in subgroups. The least studied is how the group workers' characteristics, traits, or culture (mainly referring to the inheritance and social environment which affects their attitudes, perceptions, and behaviours) can differentiate the effect of organizational safety culture. This issue is critical especially when the worker's group is very unique and influential, like Hispanic workers. Also, the work relationship among co-workers and the interactions between supervisors and their subordinate workers can affect group-level safety climate (workers' perception) and contribute to their actual safety performance.

RESEARCH METHODOLOGY

At the current stage, this study is mainly focused on a review of literature related to safety causation, safety culture and climate, and safety culture models and their main elements. The purpose is to identify major contributing factors from the cultural aspects that might influence the safety performance of construction workers. Those factors need to be incorporated in the superior safety culture model and corresponding measures need to be established and properly implemented. Also, data published by safety- and health-related public agencies, organizations, and programs worldwide are collected and analyzed to help explore and understand characteristics and safety performance of the studied sub-workgroups and underlying causes leading to poor safety records. Based on the findings, recommendations for improving existing safety culture models are made.

CHARACTERISTICS AND SAFETY STATUS OF SUBGROUPS

The disproportionate risks of injury and illness to the afore-mentioned subgroups have begun to receive increasing attention from safety- and health-related agencies. National Institute for Occupational Safety and Health (NIOSH) indicated that more profound understanding of underlying causes needs to be established to address those disproportionate risks to subgroup workers; in the U.S. this is especially relevant to Hispanics. The National Occupational Research Agenda (NORA) Construction Sector also highlighted that certain sub-populations such as immigrant workers, new workers, young/older workers, etc. are at higher risk of injury or illness due to various risk factors including language proficiency, literacy, inexperience, and group culture. It is necessary to evaluate how safety and health culture influences these key construction subgroups and to identify ways that will reduce risks to these workers. The Construction Economics Research Network met on December 5th and 6th, 2007 to address the role of immigrant workers in construction and discuss their safety and health issues that might hinge on various variables such as immigration status, education, unionization, training, day labour, etc. Unfortunately, so far, a thorough understanding on what caused disproportionate risks of injury and illness to these construction workers is still not well developed in the literature of construction safety management.

In the following, the characteristics and safety performance of three selected subgroups are presented. Through exploring potential causes of their poor safety performance, this study provides clues on what needs to be addressed and dealt with in a safety culture model (Table 1).

Immigrant Workers
According to Pew Hispanic Center, the U.S. construction sector employed 11.8 million workers in 2006, among which Hispanics accounted for 2.9 million or 25%; 75% of them are foreign-born workers. Although the latest data showed that the unemployment rate of Hispanics in the U.S. rose to 6.5% in the first quarter of 2008, there are no signs that they are leaving the U.S. labour market. Hispanic workers are more likely to work in production for the trades of drywall, concrete, roofer, labourer/ helper (new immigrants), carpet and tile, brickmason, welder, etc.

According to the June 4th issue of CDC's *Morbidity and Mortality Weekly Report*, in 2006, Hispanic workers had a fatality rate of 5.0 per 100,000 compared with 4.0 for white workers and 3.7 among black workers. 34% of such deaths from 2003-2006 occurred in the construction industry. Although safety- and health-related agencies have made great efforts in recent years to improve the safety and health conditions among Hispanic workers (OSHA, 2002), progress is still limited.

OSHA's past efforts mainly target language deficiency of Hispanic workers. However, the literature reveals that unique features of Hispanic construction workers include their group culture, living status, work condition, job or non-job related stress, limited construction experience, etc., which also need to be adequately addressed. National Safety Council's *OSHA Up To Date* (2008) pointed out that efforts should be focused on ensuring safe work environments and providing safety education and training that is not only linguistically but also culturally appropriate.

Female Workers
Recruiting women workers into the construction industry is a viable solution to labour shortage. According to BLS' Current Population Survey, women workers made up nearly 10% of the U.S. construction industry or more than 900,000 nationally in 2003. While 2-3% actually work as skilled tradeswomen in the fields of paperhangers, woodworkers, insulation workers, welders, construction helpers, painters, etc., the rest (7-8%) work as architects, engineers, project managers, secretaries, surveyors and the like.

The average fatality rate for women working in the construction field was more than twice the all-industry average for women based on a study of 139 deaths of U.S. female construction workers for the period of 1980-1992 (Ore, 1998). BLS (2008) discloses that 8% of total jobsite fatalities involve women workers. The risk is high considering that tradeswomen only account for 2-3% of construction workforce. WorkSafeBC statistics (2007) show that the percentage of female claimants has increased from 28% in 1998 to 31% in 2007 in British Columbia, Canada. Research found that women have a different pattern of fatal injuries and other nonfatal injuries than men. For example, female labourers were at a higher risk (10.8 deaths/100,000 workers) for motor vehicle injury (Welch et al., 2000) and more prone to sprain/strains and nerve conditions of the wrist/forearm when working as carpenters (Lipscomb et al., 1997).

Welch et al. (2000) and OSHA (1999) state that women in construction face six safety and health issues including reproductive hazards, ergonomic concerns, lack of adequate sanitary facilities, workplace culture, ill-fitting personal protective equipment and clothing, and lack of proper health, safety, and skills training. Workplace culture is one of the most critical issues since it could make other issues worse. As pointed out by OSHA (1999), many tradeswomen were reluctant to report workplace safety and health problems due to unfriendly workplace relationships; mistreated by co-workers and supervisors were frequently reported. Distractions while working and hostile workplace also resulted in on-the-job injuries and chronic stress reactions. Suggestions to improve women's job satisfaction and safety performance are provided by Dabke et al (2008). Welch et al. (2000) emphasize that "working smarter, not harder" is the key to staying safe, uninjured, and healthy for both women and men.

Old Workers

Due to the baby boom during 1946-1964, the size of the 50+ populations in the U.S. will more than double over the next 35 years. In 2000, only 13% of the workforce is 55 and older. The number will grow to 21% by 2014 (Rix, 2006). The U.S. inevitably faces an aged workforce in various industries including construction. To view this trend in a positive way, the employer can actually benefit from old workers because of their strong work ethics, loyalty, better knowledge and expertise. They could serve as excellent mentors to train young workers.

However, the safety performance of old workers is not optimistic. Reported by BLS (2008), while fatalities incurred by workers age 65 and older decreased 7%, these workers were still about 3 times more likely than all workers to be killed on the job. Although WorkSafeBC (2007) disclose that mesothelioma (lung cancer) is the dominant cause of death of old workers after years of exposure to asbestos, comparatively, they were still more prone to back-related and shoulder injuries because of the physical demands of construction. This leads to a higher number of medical claims and longer average duration of lost workdays (LHSFNA, 2005). The adoption of ergonomic interventions is the best strategy deemed by OSHA but weakly accepted by companies though those interventions are beneficial to all workers.

Table 1. Potential causes of injury and illness and expected remedies for subgroup workers

Subgroup categories	Characteristics that affect safety performance	Needs to be addressed in safety culture model
Immigrant workers *(mainly refer to Hispanic workers)*	Language proficiency; Literacy; Communication/understanding level; Age; Culture and human dynamic; Past construction practice and experience; Training and documentation; Legal status; Living status and pressure; Discrimination; Job security; Pay and benefit; Unionization rate; Temporary job/day labours	Safety materials in English and Spanish; User-friendly visual materials; Safety training programs and on-the-job training; Cultural awareness training for supervisory personnel; Increase supervision; Increase of construction knowledge; Work in pairs and/or groups; Toolbox meetings and lunch conversations related to safety; Incentives; Mentors; Good communication channel with their supervisors; Promotion of Hispanics to supervisory positions

Female workers	On-the-job training/mentoring; Ill-fitting PPE, PPC, equipment & tools, and inadequate facilities; Severe jobsite work conditions and inclement weather; Attitude barriers caused by the male-dominated environment; Discrimination and sexist/hostility atmosphere; Isolation; Level of support; Overly masculine workplace culture; Difficult assignments (e.g., lifting); Job security; Family pressure; Union membership; Gender-related personality traits	Women work as supervisors and co-workers; Considering physiological limitations when assigning tasks; Supporting them during pregnancy and childcare; Training program for supervisors focusing on communication and techniques to manage diversity; Ergonomic improvement; Apprenticeship programs sponsored by employer and labour groups; The change of construction culture; Fostered equality in the workplace; Sexual harassment prevention
Old workers *(defined as 55 and above)*	Physical condition; Pre-existing injuries; Assignment (e.g., bending, lifting, etc.); Easy to feel weak and tired; Job security	Adaptations in the workplace (e.g., better lighting and less clutter); Ergonomic adjustments/staging; Better jobsite planning; Train supervisors to value ergonomic interventions; Part-time and flex schedule; Shared jobs; Mentoring system to value their knowledge, skills, and experiences

ENHANCED SAFETY CULTURE MODEL

In practice, constructors seldom develop and apply a comprehensive safety culture model (three dynamic and interactive factors) in their organizations when using safety culture as a measure to improve safety performance, not to mention how they would adapt the model based on their workforce characteristics, subgroup culture, and people's actual perception/behaviour. Problems perceived often include: standard safety policies and procedures without adaptation, ineffective communication and enforcement at the lower level, poor safety climate perception from workers, lack of safety culture assessment and feedback, etc. This study recommends enhancement in the following four aspects to improve the effectiveness and completeness of a safety culture model.

Enhancing Organizational Culture

Safety culture is an integrated subcomponent of organizational culture, but often times ignored. When rebuilding the safety culture, it is necessary to investigate and rearrange the relationship between safety culture and other components of organizational culture. When necessary other organizational culture components should be adapted to strengthen the safety culture. The organizational culture profile usually comprises the following main components:

- Structure, leadership, and power distance
- Communication

- Individualism vs. teamwork/collectivism
- Personal (life) value, work value, organizational value, occupational value, social value, and world value
- Work ethics
- Job performance
- Development of the individual
- Innovation, adaptive to changes, and attitude to unknown

In order to mitigate the above-presented issues related to various construction subgroups, a few components of organizational culture should be added or strengthened. For example, "*equality*" and "*diversity*" should be added and strengthened in an organization; this applies to the situation when Hispanic and women workers are present. Knowing the difference between American culture and subgroup culture is very helpful to determine the appropriate strategies and measures. At the same time, "*teamwork*," "*trust*" and "*cooperation*" should also be emphasized since working as a group has already been approved an effective measure to reduce jobsite accidents/incidents. In evaluating job performance, productivity should not be the dominant factor or only factor. Training and continuous professional development should be valued and related costs should be granted. These adjustments are required to be integrated into an organization's overall culture.

Creating Goal-Directed Group-Oriented Safety Management Systems

Goal-directed safety management systems are not rare in practice. For example, constructors were seen to set up safety performance goals as: raising the safety knowledge and awareness, positively changing individual safety behaviour, cutting down the number of fatalities and injuries in categories such as fall, struck-by, caught-in-between, and/or electrical. However, seldom were the goals set up for special subgroups, whose disproportionate risks were caught up mainly by safety- and health-related agencies rather than individual companies.

Since the development and improvement of safety culture is goal-directed, it is possible to consider the variations of the construction workforce, their associated risks and subculture and to determine multi-dimensional safety cultural goals, focuses, and corresponding policies/procedures based on the workforce the company deals with. For example, instead of cutting down the total fatality and/or injury rates by 50%, specific goals such as reducing fatality and/or injury rates for Hispanic workers by 75% or zero motor vehicle injury for female workers might be more appropriate. A simple demographical check or survey within the organization associated with past accident statistics can provide better information for this purpose.

When procedures and measures are to be determined, their effectiveness to different workers may be considered by constructors. In practice, it has been proven that promoting the importance of family to Hispanic workers is more effective than purely talking about the importance of safety. Visual materials are more effective than textual safety documents no matter what language is used. Providing fitting clothing and personal protective equipment to women workers is the basis for preventing accidents and injuries. The more adequately the group difference is considered in the development of safety management systems, the more effective and comprehensive those policies, procedures and measures are.

Enforcing Supervisory Role

The developed organizational safety policies, procedures, and measures at the high management level have to be implemented at the subunit level, for which supervisors are deemed as the most important bridge. How effective those measures can be executed in subgroups is largely dependent on supervisors' communication skills and implementation ability. Supervisors' attitudes toward safety also have a huge impact on workers' perception about the company's safety culture.

In practice, safety training such as 30-hour OSHA certification is often mandatory for construction supervisors. However, training for communication skills and techniques for managing diversity is usually not required. Universities such as Iowa State University provide training specifically for American supervisors with Hispanic craft workers to increase their awareness of Hispanic cultures, skills for jobsite communication, and construction-related Spanish language skills. The reason is just simple: Supervisors are fewer in number and much better educated.

To effectively implement the safety culture model, enforcing the supervisory role is crucial. This includes: increasing the level of supervision; providing more training to supervisors, and promoting Hispanic and women supervisors. Supervisors should be at key positions to reduce and eliminate jobsite discrimination and hostile work environments for minority and other vulnerable workers.

Enhancing Personal/Subgroup Safety Climate

One of the research questions raised by this study is whether workers at different subgroups can perceive the safety culture at the same level when considering the biologic, social, economic, and cultural characteristics variations among those groups. Such a concern is natural by simply thinking about the language and cultural barriers Hispanic workers face. Perceptions will be affected by the ways in which massages about safety culture are communicated to them, whether relevant resources for safety performance improvement are readily available, and how effective and strict the implementations are.

Safety climate surveys are considered an important instrument to assess the effectiveness of transmitting organizational-level safety culture to group-level safety climate perception. The surveys can also provide comparison and feedback to the management for improving the safety culture model. However, this is merely done in the field. This paper recommends that constructors design safety climate surveys that meet the needs of the organizations as well as their diverse workforce and use the results for continuously improving their safety culture model instead of using accident statistics as an assessment instrument.

CONCLUSION

This paper addressed the interactions between safety culture and workforce diversity. In building and implementing a positive safety culture model, specifically, unique characteristics, culture, and safety behaviour associated with diverse subgroup workers such as Hispanic workers, women workers, young/old workers, etc. in the U.S. construction industry were considered. This paper briefly reviews the root causes of accidents in a diverse workforce in order to disclose some underlying reasons that are often ignored by safety management personnel. Safety culture and its multiple levels were discussed to explicate its complexity. After exploring the characteristics and safety performance of various subgroup workers, this paper further identified, from the cultural aspects, potentially underlying causes for elevated safety and health risks associated with these workers. This helped the identification of elements that might need to be addressed in a superior safety culture model and corresponding measures that might be effective to solve the problems. Finally, recommended enhancement to the safety culture model is summarized in four aspects:

- Enhancing organizational culture: It is necessary to investigate and rearrange the relationship between safety culture and other components of organizational culture. Equality, diversity, teamwork, trust, and cooperation should be either added or strengthened in an organization.
- Creating goal-directed group-oriented safety management systems: Specific safety performance goals should be set up for subgroups with disproportionate safety and health risks. The group difference should be considered in the development of safety management systems and evaluation of the effectiveness of procedures and measures applied.
- Enforcing supervisory role: Training must be provided for supervisors to increase their awareness of cultural difference of subgroup workers, skills for jobsite communication, and techniques for managing diversity. Increasing the level of supervision and promoting supervisors from subgroup workers are also beneficial.
- Enhancing personal/subgroup safety climate: Safety climate surveys designed for specific subgroups will be used to assess the effectiveness of transmitting organizational-level safety culture to group-level safety climate perception. Feedback should be used to continuously improve the safety culture model of an organization.

Future research will be focused on detailing goal-directed group-oriented safety management systems and developing a safety climate survey (or a set of surveys) that can monitor the issues associated with various subgroups as discussed in this paper. This will enhance the effectiveness and completeness of the applied safety culture models.

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A PRACTICAL GUIDE TO SAFETY LEADERSHIP IN THE CONSTRUCTION INDUSTRY

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ABSTRACT
Developing safety culture, leadership in safety and improving safety performance are continuing challenges for the Australian construction industry. Although there have been improvements in OHS performance over the past decade or so, the injury and fatality rate in the Australian construction industry remains a matter of concern. In the main, legislative compliance remains the first resort.

This paper reports on a project in which safety leadership has been identified as a useful approach to develop safe behaviours in the construction industry. Improving safety culture is featured as an important tool in embedding safety awareness and compliance in everyday practices on construction sites. The problem for the industry is how to create and maintain a positive safety culture from senior management down to site level.

Recent investigations into construction site safety culture culminating in the publication *Practical Guide to Safety Leadership* have provided a means through which the industry could address this issue. This research, with significant input from industry, initially developed the *Construction Safety Competency Framework* which identified 39 Safety Management Tasks (SMTs) and 11 Safety Critical Positions which are crucial to understanding which 'safety critical position' holders in an organization are responsible for which safety task (s).

Development of training and education, industry liaison processes and stakeholder ownership are discussed as well as future implications for skills acquisition relating to safety critical tasks, recruitment and professional development.

CONTEXT
Primarily this paper reports on a project devised to continue development of *A Construction Safety Competency Framework* (Dingsdag, Biggs, Sheahan, Cipolla, 2006) by formulating comprehensive leadership implementation guides premised on safety critical positions identified in the Framework. Culminating in the publication *Practical Guide to Safety Leadership* (Biggs, Dingsdag and Roos, 2008) developmental safety culture and leadership issues identified from industry consultation are discussed as well as future implications for skill acquisition of safety critical tasks, safety leadership and related professional development objectives.

Improving safety performance premised on incorporating safety culture has been an ongoing challenge for the Australian construction industry. Although there have been improvements in OHS performance over the past 10 years or so the injury and fatality rates in the Australian construction industry remain too high. Safety culture, based on active leadership roles, has been identified as a useful way to improve safety performance in the safety literature (*vide*, Biggs, Dingsdag and Roos, 2008a; Choudhry, Fang & Mohamed, 2007; Glendon, & Stanton, 2000; Zohar, 2003). Subsequent to the Chernobyl disaster in 1986, from when safety culture was identified as a discernible approach in minimising and injury and death, increasingly safety culture has been correlated with positive improvements in a variety of traditional ‘lag’ indicators (*vide* Guldenmund, 2000 and Guldenmund, 2007 for example). However, safety culture and its core components, effective communication, positive behaviours, shared knowledge and appropriate training and education appear difficult to implement in the construction industry (and other industries). Consequently, in the main, acquiescence with legislative compliance remains the first resort for many construction organisations, in particular smaller ‘second’ and ‘third’ tier companies which may not have the means to progress beyond compliance, unlike the largest ‘first’ tier principal contractors who have considerable resources at their disposal.

In all probability, in the construction industry, senior managers of the larger ‘first’ tier companies see value in promoting that safety culture affects safety positively when successfully bidding for project contracts where past safety performance is the ‘clincher’: These safety results frequently indicate that projects that have; a) low numbers of LTIs, i.e., good safety performance (with no down times owing to major critical incidents such as fatalities or serious injuries); b) co-ordinated task scheduling with no down times (elaborated further below); c) quality outcomes for project product; and d) finishing times either on or ahead of scheduled completion and e) completion under budget. Other than these success stories for well resourced principal contractors which imply that safety culture may be a contributing factor, the challenge for the industry is how to create and maintain a positive safety culture in organisations with highly variable resources.
Further, perhaps because the concept is not well understood in an industry (possibly comprising a transient workforce of more than 800,000) by management and workers alike, or maybe because there is a large array of approaches promoted by academics in learned papers and/ or by practitioners, the application of safety culture is inconsistent. It is often not fully understood, neither is it used consistently conceptually or terminologically. In addition, it is often confused and conflated with the concept organisational climate. In fact, both concepts, safety climate and safety culture are quite distinct and are subject to a divergent literature and have different organisational applications. To distinguish between the two concepts/ constructs Biggs, Dingsdag, Sheahan and Stenson (2005) when examining the convergent constructs found:
The safety culture construct is used to describe the values, norms, attitudes and beliefs that are held collectively towards safety within an organization (Cox, Tomas, Cheyne, & Oliver 1998; Glendon & Stanton 2000; Williamson, Feyer, Cairns & Biancotti 1997). It is thought that these values, attitudes, norms and beliefs guide behaviour by indicating to employees and management what will be rewarded or punished by the organization (Biggs, Dingsdag, Sheahan and Stenson 2005).

Whereas for safety climate they relied on the following definition:
With specific reference to the Australian construction industry, Mohammed (2002) used structural equation modelling to investigate the independent factors that accounted for safety climate. He found four independent constructs determined safety climate: management, safety, risk and competence. The management construct incorporated the following aspects: communication, commitment, supervisory environment, and supportive environment (Biggs, Dingsdag, Sheahan and Stenson, 2005).

We might come to the conclusion that the two constructs are not dissimilar and that their separation conceptually and theoretically is the result of academic 'nit picking' and that may be a valid critique. In all probability, each can be applied to an organisational setting. What is important is that they must be used uniformly across an industry, but more importantly that their application improves safety performance. What remains uncertain in practice is whether either has the capacity to do so, although in the Australian construction industry there are indications that safety performance may be influenced positively by certain styles of leadership which may, or not, be couched in safety culture.

OBJECTIVES: SAFETY CULTURE AND SAFETY LEADERSHIP AS PART OF INTEGRATED SAFETY MANAGEMENT ON CONSTRUCTION SITES.

Notwithstanding doubts over the efficacy of safety culture expressed above, in the construction industry, in order to improve safety performance there is a shared understanding that active and full participation of employees and management in working safely is essential: However, this understanding is not necessarily embedded in safety culture, but rather it is shaped by an instrumentalist perspective wrongly enshrined in Robens style legislation which a) is not premised on safety culture principles) and; b) has the mistaken assumptions that management's and employees' interest are the same or at least intersect when applied to safety; and c) has its premise accepted at highly variable levels by management and workers as well as by OHS professionals frequently leading to minimalism in legislative compliance.

Consequently, in many construction sites poor safety performance is due to ineffective, mediocre or even negative safety culture and lacklustre leadership. In most instances where there are unsafe practices they are characterised by:

- a lack of commitment and leadership by management;
- poor or poorly communicated organisational safety values;
- an absence of a safety culture or one that is not articulated;
- a non-existent occupational health and safety management system or one with no resources to implement procedures determined by policy;
- poor safety communications, generally top down with little or no input into safety policy by employees;
- scant or no co-operation in putting safety into practice and;
- because employees haven't been 'co-opted' there is no sense of 'ownership (Dingsdag, 2009, p.55).'

Investigations into construction site safety culture and safety leadership by the authors of the *Practical Guide to Safety Leadership* have provided a means through which the industry could address these issues. Initial research conducted between 2004 and 2006 (*vide*, Dingsdag, Biggs and Sheahan, 2006; Dingsdag, Biggs, Sheahan, Cipolla, 2006) with significant input from industry, developed *A Construction Safety Competency Framework* which identified 39 Safety Management Tasks (SMTs) and 11 Safety Critical Positions which are crucial to understanding which 'safety critical position' holders in an organisation are responsible for what safety task (s).

The safety critical positions within the industry that have a significant impact on safety culture were mapped, and the behaviours and competencies required to successfully drive a positive site safety culture were identified. Essentially, the Competency Framework identified, in detail, which process should be followed when completing particular tasks; the knowledge, skill and behaviours required to complete the task effectively; and what cultural outcomes should be achieved if the task is completed effectively. The Framework also provided some initial recommendations to industry on training, educating, mentoring and employee motivation. The Framework proved to be a useful tool in developing safety culture and was taken up or adapted by many of the organisations that participated in the research. However, feedback from industry indicated that additional resources were necessary for industry to be able to adopt the Framework more meaningfully by making the role of leadership clearer based on a step by step process.

These themes were consistently borne out during the course of an articulated subsequent research project 'Safety Effectiveness Indicators' conducted from 2007 to 2009 (*vide* Dingsdag, Biggs, 2008) as well as the Competency Framework project (Dingsdag, Biggs and Sheahan, 2006). There is also additional anecdotal evidence from the industry that safety culture can enhance the management of safety and improve safety performance. Industry respondents, many of whom were highly credentialed OHS professionals in first tier companies, when interviewed, claimed they 'knew' that their site safety culture had a positive, but immeasurable, impact on safety performance. When prompted to identify what the visible attributes of a vibrant safety culture might be, the most consistent response was ‘good housekeeping.’ The rationale for these claims was that if housekeeping was attended to regularly, the more essential safe behaviours and related actions, such as conducting regular proactive risk assessments, would also be more likely to be conducted properly (Dingsdag, Biggs, 2008; p. 150).

Other constant safety culture attributes indicated were:

- ‘Good’ toolbox talks
- Planned alignment of the disparate phases of the construction process
- Holding pre-construction/design phase meetings with contractors and Subcontractors…’

A ‘lessons learnt’ overview of safety culture and the related task and safety performance, undertaken either at the ‘close out’ stage of the project or about 60 per cent through the project…and visible and engaged leadership and collaboration, for example:

- regular site walk-arounds by senior management and/or board members
- all management regularly seen on-site (wearing the correct PPE)
- work done collaboratively (based on consultation)
- listening to each other
- the need to treat people as people and to have respect for the individual
- commitment from workers and from management built on mutual trust
- explanations given of why actions suggested at toolbox talks/ pre-start meetings were undertaken or not (Dingsdag, Biggs, 2008; pp. 150, 151).

According to this research active and visible leadership in safety by senior management is essential and is often identified in safety research and literature as the primary requirement for a vibrant safety culture. Whether safety culture has the capacity to impact positively on safety performance or not remains a moot point and is not a topic of full discussion for this paper. In all probability, leadership in safety (and generically) has the capacity to generate a level of collaboration between management and workers to make the workplace safer. As with safety culture, whether or not a particular leadership style actually influences safety performance directly, is an unsettled point and to the knowledge of the authors of this paper there is no hard evidence that establishes beyond doubt that there is a direct relationship between it and improved safety performance.

KEY MESSAGES: IMPLEMENTING THE PRACTICAL GUIDE TO SAFETY LEADERSHIP

In order to make the principles of safety culture clearer the *Practical Guide to Safety Leadership* linked eight steps and nine cultural actions from *A Construction Safety Competency Framework* to essential leadership attributes to make clear that, ‘…leadership is integral to safety competency.’ Eight steps were created to explain how individual organisations could simplify the complexities of safety culture with prompts identifying the precise purpose of each step (Biggs, Dingsdag, Roos, 2008) These steps are easy to follow and were developed to ensure that they could be adapted with low cost ‘in-house’ resources so that third tier and smaller construction businesses could also incorporate them according to their organisational needs without spending large amounts of money on hiring consultants. Some industry feedback had indicated that the Framework was too ‘meaty’ to implement in its entirety although it was not the intention of the authors that it should (interestingly, critique ranged from the Framework being too complex and being too wordy to not being extensive enough, i.e., too short). The overwhelming feedback was that industry needed more direct guidance on leadership in fewer words. In each step the elementary premise from the Framework that customising and the creation of organisational ‘fit’ are essential was reinforced.

The resulting eight steps and brief implementation strategies are:

1) Understand safety culture
Understand how a safety culture can be built and maintained through staff competencies and actions. This approach should be linked to your organisational strategies and objectives.

2) Identify safety critical positions
Customise the safety critical position list for your organisation and identify who currently holds these positions.

3) Customise the Task and Position Competency Matrix
Customise the matrix to align with your organisation and map the competency requirements of your safety critical position holders.

4) Plan
Plan how material can be used in training, education and development, performance management, and recruitment and selection activities.

5) Adapt the competency specifications
Review the processes, knowledge, skills and behaviours listed for each individual safety task and adapt to your organisational context.

6) Use a step-wise approach
Break the implementation of this material into small steps – reduce 'culture shock' and allow for early success to build support and momentum.

7) Implement
Implement strategy and material.

8) Show continuous improvement
Evaluate, review and reflect on strategy. Continuously improve strategy and implementation (Biggs, Dingsdag, Roos, 2008; p. 2).

The Framework also identified nine broad culture actions considered essential to the development of a positive safety culture. These were also refined for the *Practical Guide to Safety Leadership* and were supported with case studies and key learnings from organisations that had participated in its industry consultation process and who were asked to provide successful examples of their implementation of the Framework incorporating safety culture and leadership. The nine key elements of these culture actions are also essential leadership behaviours if safety culture is to succeed:

1. Communicate company values
2. Demonstrate leadership
3. Clarify required and expected behaviour
4. Personalise safety outcomes
5. Develop positive safety attitudes
6. Engage and own safety responsibilities and accountabilities
7. Increase hazard/risk awareness and preventive behaviours
8. Improve understanding and effective implementation of safety management systems
9. Monitor, review and reflect on personal effectiveness (Biggs, Dingsdag, Roos, 2008; p. 3).

Each culture action was then explained in more detail so that that their inherent contribution and value to implementation was made clear. In order to clarify the difficult areas of understanding expressed in the critique of the Framework, as an exemplar Step 1 was linked to all nine culture actions which are expressed in actual safety actions well understood as normal OHS procedures (but not necessarily as culture actions) and practised (in highly variable fashion) in the construction industry. In order to minimise word length the remaining seven steps relied on industry examples based on case study excerpts, brief overviews of leadership roles expected of senior managers and brief implementation guides for each step.

A partial overview of Step 1: Understand safety culture, explains the process used for its implementation and is reproduced here:

> Why is this step important?
> A safety culture is an organisational culture that places a high level of importance on safety beliefs, values and attitudes - and these are shared by the majority of people within the company or workplace. It can be characterised as 'the way we do things around here'. A positive safety culture can result in improved occupational health and safety (OH&S) and organisational performance.
>
> For a safety culture to be successful it needs to be led from the top - that is, safety culture needs to be embraced and practised by the CEO and senior managers. Their behaviour is directly related to safety performance as it demonstrates by example to employees what actions will be rewarded, tolerated or punished, which in turn influences what actions and behaviour employees initiate and maintain.
>
> The first part of management commitment is to examine individual attitudes towards safety. Senior managers need to ask themselves:
> • how important is safety?
> • is safety important most of the time or all of the time?
> • is it OK to compromise on safety if it's going to be more expensive?
>
> Companies that want to have a positive safety culture, which everyone owns, should develop and promote managers with the right knowledge, skills and attitudes to successfully undertake the responsibilities of the safety critical positions…(Biggs, Dingsdag, Roos, 2008; p. 3)'

'Culture action 1 Communicate company values *Relate behaviours, decisions and attitudes that are expected, supported and valued by the company…*(Biggs, Dingsdag, Roos, 2008; p. 3)'

> The real message for any safety values approach is *safety first*. Safety should become a part of your everyday values and action, and not be seen as an 'extra task'.
>
> Messages can be communicated and embedded via:
> • company OH&S policy statements
> • safety posters
> • toolbox talks
> • 'walk-arounds' by management
> • regular reinforcement by all 'non-safety' managers
> (Biggs, Dingsdag, Roos, 2008; p. 3).

The concluding stage of Step 1 includes a checklist which, when the eight steps' relevant criteria have been completed, can be 'ticked.' This process is intended to be implemented according to each organisation's time and resource capacity. Attuned with risk assessment and related safety 'tools' (for example (AS/NZS 4360: 2004 and AS/NZS 4804: 2001) and continuous improvement principles, the process is iterative. With these customary industry practices in mind a loose copy of the checklist is also included in the *Practical Guide to Safety Leadership* 'tool kit' so that it could easily be photo-copied to encourage continuous use. In order to make the tool kit complete, for cross referencing purposes, a hard copy of *A Construction Safety Competency Framework* is included and a separate blank (Safety Management) Task and (Safety Critical) Position Competency Matrix, as well as a CD-Rom of the package's entire contents so that they can be 'dumped' electronically and integrated into the organisational health safety management system for example.

CONCLUSION

In order to make safety leadership and safety culture a living process, planning of safety leadership principles should be introduced. This process could be encouraged through the development of appropriate training and education based on adult educational principles as well as through performance management and recruitment and selection activities. These are elaborated in Step 5: Plan. Developing a job description for getting the candidate who has the correct task skill attributes can also assist in selecting the person with the necessary safety and leadership competencies as well as the relevant behavioural competencies. Similarly, the skill and safety competency levels of existing employees are key issues for training, education and development. Also, performance management should be designed to promote and encourage the desired behaviours that align with the organisation's safety values. Incorporating safety competency and demonstrated safety performance improvement in performance appraisals reinforces organisational values, while also giving incentive to individuals to focus on safety as part of their everyday actions.

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SAFETY CLIMATE: RECENT DEVELOPMENTS AND FUTURE IMPLICATIONS

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ABSTRACT
Safety climate is of current interest to construction practitioners and researchers. The concept of safety climate has been actively explored in the field of industrial and organizational (I/O) psychology but is just gaining popularity in the construction industry. This paper aims to review the literature of safety climate in a systematic manner and highlight future directions for safety research and development of safety practices in the construction industry. The value of safety climate lies in its ability to predict safety behaviour. Safety climate, as a mediator, unfolds the relationship between organizational variables and safety behaviour. It, as a moderator, affects the effectiveness of any safety initiatives to improve safety performance. Future research directions would be likely to look at relationship between organizational factors and safety climate using a multi-level analysis. To the construction industry, safety climate measurement is a good indicator to assess safety performance. Empirical studies show that frontline supervisor would be the best conduit to create a positive safety climate at workgroup level. This paper is beneficial to researchers interested in behavioural aspects of construction safety and industry practitioners striving for achieving better safe behaviour on site.

Keywords: Safety climate, Repair maintenance alteration and addition works, Construction industry of Hong Kong

INTRODUCTION
Safety has been one of the chronic problems of the Hong Kong construction industry. The Hong Kong Construction Industry Review Report (HKCIRC, 2001) advocates safety to be one of the six major areas for improvement. A pressing need to improve construction safety is also evidenced by the latest statistics. Accident rate per 1000 workers of all industries in Hong Kong were 29.3 in 2007 whereas accident rate per 1000 of the construction industry in 2007 was 60.6, a figure that was surpassingly high (Labour Department, 2008). Accidents of repair, maintenance, alteration and addition works (RMAA) are particularly alarming. Fatal rate of RMAA works accounted for 55.6% of the whole construction industry in 2006 (Labour Department, 2008). Safety legislation and policies can effectively drive down accident rate to a certain point; however, continuous safety improvement can only be done through promoting a positive safety culture in the construction industry.

The Occupational Safety and Health Council (OSHC) has been actively promoting safety culture to the Hong Kong construction industry. Safety Climate Index (SCI) recently developed by the OSHC has been promoted to the industry for measuring construction safety climate as an indicator of safety performance. Industry practitioners have practical reasons to know more about safety climate so as to make better use of safety climate scores. For example, meaning of high/ low level of safety climate, implications to organization policies and management, the way to further improve safety and etc. Safety climate is a prevalent issue that interests practitioners in the construction industry.

Safety climate has been used to predict organizational safety performance for more than two decades. Industrial and organizational psychology (I/O) researchers have attempted to use safety climate to deal with unsafe behavior in industries and organizations. The notion of safety climate has been applied in different industries such as manufacturing (Brown and Holmes, 1986; Clarke, 2006), chemical processing (Hofmann and Stretzer, 1998), nuclear processing and also construction (Dedobbeleer and Béland 1991; Mohamed, 2002; Siu et al., 2004; O'Toole, 2002; Fang et al., 2006; Zhou et al., 2008; Teo and Feng, 2009). Safety climate is relatively new to the construction industry as compared to other industries such as manufacturing. As research proliferates, safety climate has emerged to be a promising construct to affect people's safety behaviour and in turn safety outcome. Seen in this light, it is high time to review the recent research development of safety climate and see how new research initiatives could be extrapolated to the construction industry.

This paper aims to develop a fuller understanding of safety climate through a systematic review of published literature, find out implications to future research and safety practices of RMAA works. As safety climate evolves to be a mature construct, it often appears in the form of a moderator or mediator, or contextual variable in models of more general interest (Reichers and Schneider, 1990). Reviews and discussions are thus more focused on the latest development of safety climate as a moderator or mediator. This paper is believed to be useful to researchers interested in construction safety and industry practitioners using safety climate as a safety performance indicator for their projects.

CONCEPT OF SAFETY CLIMATE

Safety climate and culture are considered to be subsets of organizational climate and culture (Coyle et al., 1995). Safety culture forms the context within which individual safety attitudes develop and persist and safety behavior are promoted. Safety climate is regarded as 'the manifestation of safety culture in the behavior and attitude of employees' (Cox and Flin, 1998).
Zohar (1980) defines safety climate as 'a summary of molar perceptions that employees share about their work environments… a frame of reference for guiding appropriate and adaptive task behaviors' (p.96). Griffin and Neal (2000) advocate that perceptions of employees towards policies, procedures, and practices relating to safety comprise safety climate. As stated by Zohar (2003 a), safety climate reflects the true perceived priority of safety in an organization. Safety climate is a current-state reflection of the underlying safety culture (Mearns et al., 2003).

Safety climate is a social-cognitive construct. People make sense of organizational safety priority from procedures-as-pattern rather than discrete procedures (Zohar and Luria, 2004). With this in mind, unsafe behavior can be explained. Safety system and polices do not automatically generate safety; it is the true priority of safety that are consensually perceived by people that affect their safety behaviour. Safety climate influences one's behavior through behavior-outcome expectancies (Zohar, 2003 a). Low safety climate implies that people assign lower weight to safety but greater value to short-term gains; for example, finish the work faster. In low safety climate, people also underestimate the likelihood of possible injury. It is believed that expectancies influence prevalence of safety behaviour which in turn influences company safety records. Climate strength may be the moderator variable for this climate-behavior relationship because the less homogeneity of climate perceptions, the weaker the climate-behavior relationship (Zohar and Luria, 2004).

According to Clarke and Cooper (2004), the definition of safety climate suggests that it might be regarded as a mediating variable between organizational characteristics and workers' safe/ unsafe behaviours. Empirical studies have supported a mediation role for safety climate (Neal et al., 2000; Barling et al., 2002; Zohar, 2002 a, b). Safety climate has been found to mediate the relationship between organizational climate (Neal et al., 2000), leadership style (Zohar, 2002 a, b) on measures of safety performance.

METHODS AND RESULTS

A systematic literature search was done through books, conference proceedings and electronic database *ISI web of knowledge* which contains a wide coverage of academic journals with scientific citation index (SCI). Another electronic database *Scopus* was also searched for cross reference and to capture those articles, if any, not published in journals with SCI. Article titles with keywords “safety climate”, “safety culture” and “safety performance” were searched for up to 2009. 78 articles were identified in *ISI Web of Knowledge* and 38 articles were identified in *Scopus*, confirming results of each other. Another keyword search of “safety climate” was done in construction field related journals. By scanning through their abstracts, articles were mainly categorized into three different themes for review. They are measurement of safety climate, role of safety climate as a mediator[1] and its role as a moderator[2].

MEASUREMENT OF SAFETY CLIMATE

Safety climate is agreed to be a multi-dimensional construct. However, there is yet any consensus to number of dimensions and items to form the measurement scale of safety climate. Zohar (1980) initially identifies eight dimensions of safety climate, namely: perceived importance of safety training programs, perceived management attitudes toward safety, perceived effects of safe conduct on promotion, perceived level of risk at the workplace, perceived effects of workplace on safety, perceived status of the safety officer, perceived effects of safe conduct on social status, and perceived status of safety committee. Similar studies have been conducted subsequently (Brown and Holmes, 1986; Dedobeleer and Béland, 1991; Coyle et al., 1995) hoping to clearly identify the dimensions of safety climate. However, results are not replicable. Number of dimensions identified range from two to seven.

Factor structure of safety climate seems to unstable (Coyle et al., 1995) and tends to be industry specific (Cox and Flin, 1998). Items developed in one industry cannot generalize to other industries. Lin et al. (2008) attribute the safety climate factor structure difference to a combination of reasons, such as different populations in different industries or cultures, and the researchers’ discretion to determine the structure by different procedures of factor analysis. Usage of non-interval data in the factor analysis, type of rotation applied, and unipolar dimensions also affect the factor structure of safety climate (Guldenmund, 2000). Shannon and Norman (2008) critically point out that variation in safety climate scales are, at least partly, due to the incorrect application of factor analysis. Data input for factor analysis are usually individual workers’ perception on safety management system, practices etc. The object of measurement in safety climate scale items are, however, the work group or the company, making the scale items multi-level. Individual workers’ perceptions are often added together without considering their within group homogeneity. In that case, multi-level statistical analysis, such as multi-level confirmatory factor analysis, should be more appropriately employed to derive factor structure of safety climate.

The measurement of safety climate has evolved from a single level construct to multi-level. Thus, Zohar (2000) put forward a group-level model of safety climate. Zohar’s study is an echo to Hofmann and Stetzer’s study (1996) which adopts a cross-level approach of safety climate investigation. It is meaningful to analyse group level safety climate because there are variations between different groups. Since safety practices, policies are carried out at work group level by different supervisors, some work group may have higher level and strength of safety climate while some do not even within the same organization.

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[1] Mediator is defined as any variable that ‘accounts for the relation between the predictor [independent variable] and the criterion [dependent variable]’ (Barron and Kenny 1986).

[2] Baron and Kenny (1986) define moderator as ‘qualitative (e.g. sex, race, class) or quantitative (e.g. level of reward) variable that affects the direction and/ or strength of the relation between an independent or predictor variable and a dependent or criterion variable’.

ROLE OF SAFETY CLIMATE AS A MEDIATOR

Organizational factors play an important role to safety performance improvement. Recent research has attempted to link safety climate to organizational climate. Safety climate plays an intervening role between organizational factors and safety-related outcomes. 'Safety climate becomes a potentially useful intermediate indicator of safety performance within the organization' (DeJoy et al., 2004).

One example of safety climate as a mediator goes together with high performance work systems (HPWS). HPWS are high commitment and high involvement-oriented organizational strategies. Work practices generating high levels of commitment are believed to enhance safety behaviour. As show in Figure 1, Zacharatos et al. (2005) investigate the relationship between high performance work systems and occupational safety. Safety climate is found to be a mediator between high performance work systems and safety incidents.

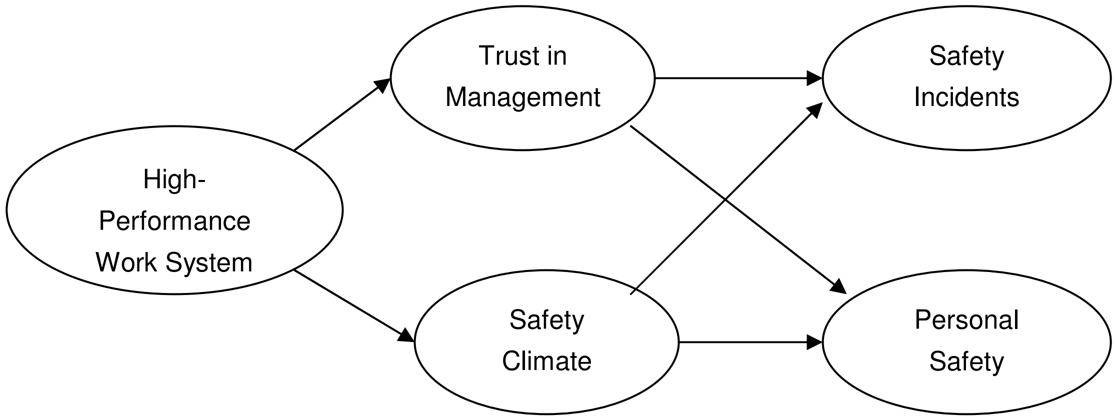

Figure 1: Simplified model of effects of a high-performance work system on occupational safety at the employee level (Adopted from Zacharatos et al. 2005).

Another example is found between leadership and safety behavior. Zohar (2002 a) examines the mediation effect of safety climate on different styles of leadership. Results indicate that there are full mediation effects of safety climate on transformational leadership whereas there is only partial mediation effect on corrective leadership. Findings of Barling et al. (2002) show that leadership quality predicts safety climates both directly and indirectly subject to the group members' level of safety consciousness. Safety climate then predicts safety-related events (i.e. safety behavior) (Figure 2).

Transformational leadership is characterized by four dimensions: individualized consideration; intellectual stimulation; inspirational motivation and idealised influence. Empirical evidence shows that these dimensions have indirect effect on occupation safety (Barling et al., 2002; Yule et al., 2007; Zohar, 2002 a). Transformational leadership shows greater concern for subordinates' welfare and develops closer individualized relationships, which promotes supervisory practices and in turn affects safety behavior. Transformational leadership works particularly well to improve work group safety behavior when job nature is not routine and safety procedures are not formalized. Transformational leadership allows people in the work group to make discretion decision following general pattern of safety procedures. On the other hand, transactional leadership characterized by non-individualized and hierarchical exchanges is found to be associated with higher accident rates (Barling et al., 2002).

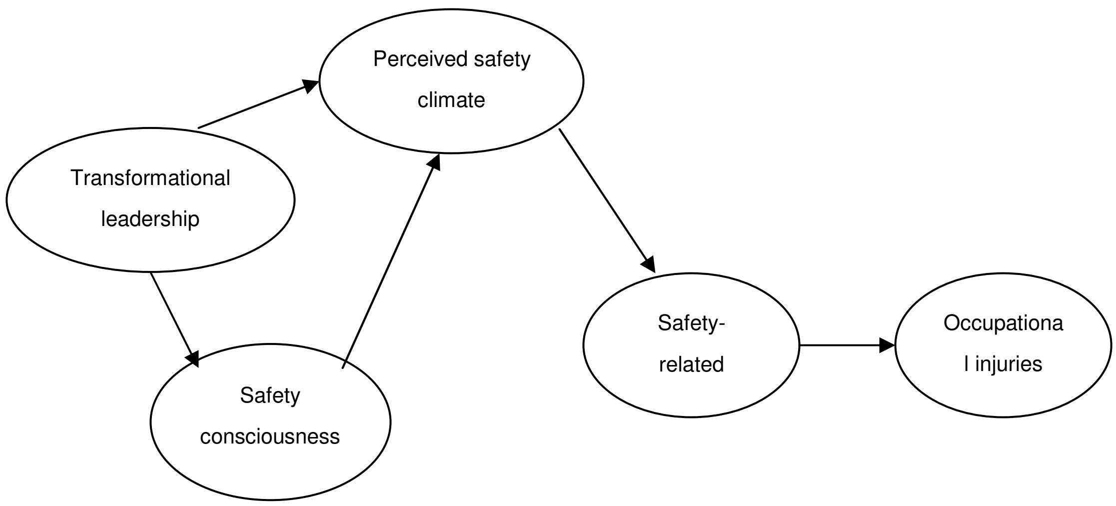

Figure 2: Model linking transformational leadership and occupational injuries. (Adapted from Barling et al., 2002)

Besides these, there are other examples which model safety climate as a mediator, for example, organizational climate (Neal et al., 2000; Wallace et al., 2006), job satisfaction, job involvement and organizational commitment.

ROLE OF SAFETY CLIMATE AS A MODERATOR

An example of safety climate acts as a moderator is found in the relationship between leader member exchange (LMX) and safety citizen behavior (Hofmann et al., 2003). LMX is the relationship between supervisor and subordinate. Reciprocity, a basic tenet of social exchange theory (Gouldner, 1960), suggests that subordinates reciprocate high-quality supervision by extending their role beyond normal role requirements. They will perform citizenships behaviors (i.e. extra-role behavior) to benefit their supervisor and the organization. When safety climate is high, safety is perceived as the avenue to reciprocate high-quality LMX.

Referring to Figure 3, safety climate acts as a moderator to leader-member exchange and safety citizenship role definition. With the presence of high-quality LMX and positive safety climate, employees will likely to expand their role definition and perform safety behavior but such role expansion will not exist when safety climate is less positive (Hofmann et al., 2003).

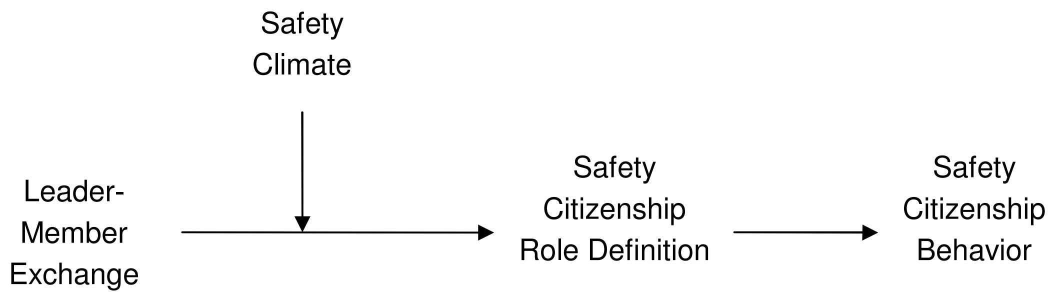

Figure 3: Safety climate as a moderator of leader-member exchange and safety citizenship (Adopted from: Hofmann et al. 2003)

One may notice that the leadership study of Hofmann et al. (2003) investigates the moderation property of safety climate by modeling safety climate as a higher order context variable. By contrast, Barling et al. (2002) and Zohar (2002 a) examine the mediation property of safety climate by modeling safety climate at the same level with leadership. Leadership style seems to exert both direct and indirect effect on safety behavior. Safety climate can be a mediator or a moderator on the relationship between leadership and safety behavior.

Job insecurity is commonly found to be associated with more injuries; however, researches with contrasting results (Parker et al. 2001) emerge as well. The study of Probst (2004) sheds light on the relationship between job insecurity and safety performance by incorporating safety climate as the moderator (Figure 4). Their study reveals that job insecurity, in fact, has low effect on safety behavior. Rather, it is the moderating effect of safety climate that affects safety behavior. When safety climate is positive, employees would perceive that acting safe is the way to retain their jobs but not productivity. In contrast, when safety climate is negative, employees tend to neglect safety because they would perceive that productivity rather than safety is important to job retention.

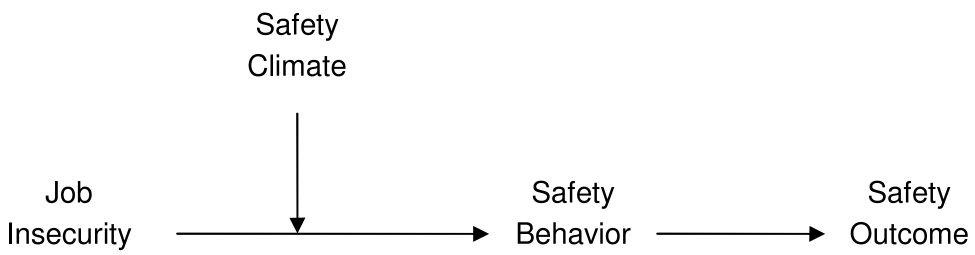

Figure 4: Safety climate as a moderator of job insecurity and safety behavior.

FUTURE IMPLICATIONS: RESEARCH

Future research directions may turn to antecedents of safety climate; what are they and how they affect safety climate. The value of studying safety climate lies on its ability to predict and explain safety behavior. Safety climate researches in the construction industry have tried to identify key dimensions of safety climate (Mohamed, 2002) and establish the relationship with safety performance (Fang et al., 2006). Despite these research efforts, there is still a lack of specific guidelines for improving safety climate and in turn improve safety performance. More research could be conducted to determine the role of safety climate as a mediator and an intermediate indicator of safety performance (DeJoy et al., 2004).

To establish a causal relationship between safety climate and safety performance, longitudinal study or quasi-experimental study would be needed. Most of the safety climate researches have been cross-sectional survey designs. Without temporal difference, casual relationship could not be plausibly established.

Appropriate data analysis methods should be employed in future safety climate research. As statistical data or self-reported accidents/ injuries may not follow the requirement of normal distribution, they would be more appropriately analysed by logistic regression (Fang et al, 2006) or probit regression which are designed for categorical and limited dependent variables. Rather than multiple linear regressions, hierarchically nested data drawn from safety climate measurement may be more appropriately analysed by Hierarchical Linear modelling (HLM) which is designed for multi-level analysis (Hofmann and Stretzer, 1996).

A mixed methodology, which includes both quantitative and qualitative methods, is recommended. Safety climate research has been overwhelmingly on quantitative side; there may be a need for qualitative research as well for theory building. Safety climate research is popular because it allows, to certain extant, quantitative measurement of safety culture. However, safety culture, which is still not theoretically well-defined, is the ultimate target for change. For further research progression, future studies may need to incorporate the research merits of safety climate and safety culture.

FUTURE IMPLICATIONS: PRACTICE

Positive safety climate needs to be established on site. Construction works, no matter new works or repair and maintenance, are located away from head office of contracting companies. Despite safety policies and management system are in place, true priority of safety cannot be easily conveyed to workers situated on site. To successfully establish a positive safety climate, it is very important that project managers, resident engineers, safety supervisors/ officers and subcontractors on site consistently demonstrate that safety always overrides.

Safety supervisor plays an important role to uphold safety. Safety training to workers only temporarily changes their behavior expectancies but does not last long. Frontline supervisors, however, can create positive project-level safety climate by consistently rewarding those perform safety while punishing those do not. This may infer that unsafe behavior could be more effectively controlled with the help of frontline supervisors. Efforts to raise safety awareness of group leaders or supervisors would be much needed.

Employment of casual workers may not necessarily lead to more injuries (Parker et al. 2001). Most of the construction workers are not direct labour, that is, they do not have job security. They may not have received enough safety training as those direct labour and they are more prone to accident. As Probst et al. (2008) reveal, safety shortcomings of employing indirect labour could be lessened by frontline supervisors promoting positive safety climate on site.

Appropriate leadership style helps to improve safety performance. Although repair, maintenance, alteration and addition (RMAA) works are perceived to be routine, they account for equally high or even higher accident rates than new works in Hong Kong. Research shows that it is more difficult to promote workers' safety behavior in routine tasks because people tend to underestimate the potential risks. Immediate and frequent personal reward is the most effective action taken to change one's expectancy value in routine tasks (Zohar and Erev, 2007). Leadership and supervision has important effect on safety behavior of workers. Zohar (2003 b) proclaims that in highly routine jobs, transactional leadership style could enforce workers' safety compliance; whereas in less routine jobs, transformational leadership could motivate workers' safety participation. As for RMAA work, transactional leadership may be more effective to enforce safety compliance by adhering to practice guidelines issued by the OSHC or the Labour Department.

CONCLUSIONS

To conclude, although safety climate has been studied widely in recent years, more research is needed especially in the construction industry. Discussions in this study are not exhaustive but may enlighten researchers and practitioners how to improve safety. Vast majority of safety accidents in the construction industry stems from unsafe behavior. However, Heinrich, et al. (1980) claims that unsafe behavior is one of the symptoms of failure (Seo, 2005). Underlying causes are usually traceable to poor management policies and decisions, personal and environmental factors. Only when antecedents and intervening variables leading to unsafe behaviour are identified can effective safety measures be made. Safety climate, as a mediator, predominantly offer a way to unfold the relationship between organizational factors and safety performance. Safety climate, as a moderator, can intensify or attenuate the effectiveness of safety policies and safety management system to improve safety performance. Having established its value, more safety climate research is worthy to be done in the construction industry.

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ORGANIZATIONAL SAFETY CLIMATE IN CONSTRUCTION: THE DEVELOPMENT OF INSTRUMENT AND FACTOR STRUCTURE

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ABSTRACT

Safety climate was recently recognized as a mixture of organization–level and group–level construct. Organization–level safety climate, which has not been studied sufficiently, can set the tone and confine the variation of safety climate within the organization, and can be measured by top management's commitment to safety. This paper conducted a survey using an 18–item instrument developed to measure top management's attitude and actions on safety. 623 lower and middle management, rather than front line workers, from 17 construction companies participated in this survey.

Two factors, e.g. “Active and Declarative Practice” and “Safety Priority”, were extracted by Exploratory Factor Analysis. Statistical analysis revealed that “Active and Declarative Practice” was evaluated with significantly higher scores than “Safety Priority”. Results indicated the necessity to improve top management's values and commitment on safety. Implications on the practice and efficacy of safety climate survey using the instrument developed in this research were also discussed.

Keywords

Organization–level, safety climate, active and declarative practice, safety priority

INTRODUCTION

While organizational climate has been traditionally considered at a single level of analysis, safety climate should be re-defined as a multi–level construct (Zohar and Luria, 2005; Zohar, 2008). Both theoretical rationale and empirical data indicate the presence of significant variation among organizational sub-units. Currently the safety climate is recognized as a mixture of organization–level and group–level construct. However, most researches used to measure safety priorities as the core of safety climate, interchangeably on organization-level and group-level. Thus, the safety climate scores they collected is a mixture of both levels and can not provide unique features on either level.

Group-level safety climate was deemed as a mediator or moderator between organizational variables, such as organizational climate (Zohar and Luria, 2005; Wallace et al., 2006) and leadership (Hofmann and Stetzer, 1998; Hofmann et al., 2003), and outcome variables, such as occupational accidents and safety behavior. Mearns and Flin (1999) postulated that, organization-level safety climate is a concept for describing an organization's "state of safety", and best describes employees' perceptions, attitude, and beliefs about risk and safety. However, few researchers have specially studied the organization-level, not group–level or mix–level, safety climate.

Prevalently, Safety climate survey is conducted using the sample of operators, with the purpose to evaluate their perceptions of safety priorities, deriving from their observations into the actions of senior, middle, and lower management. Whereas, the operators have few contact with senior management, thus they can not provide exact estimations on the actions of senior management. In the construction industry, Hinze (2006) defined that the first-line supervisors, more commonly called foremen, act as the lower management. While the superintendents, referring to the top company personnel at the project level who are residents at the site of the construction project, in most instances include project managers, play the role of middle management. The top or senior management in construction are the president and the chief executive officer. Thompson et al. (1998) suggested that senior managers support safety through indirect means such as establishing safety policies and procedures, setting production goals, etc.. While supervisors act as the link between management and shop-floor, they monitor workers' compliance to safety rules and provide feedback to workers concerning their behavior.

Zohar and Luria (2005) studied the organization-level and group-level safety climate respectively, using different questionnaires. However, they used the same sample, production workers of small–to medium–sized manufacturing plants, to provide evaluation on both organization–level and group-level safety climate. The imprecise response on organizational level safety climate, given by front line workers In their paper, was questionable.

TOP MANAGEMENT'S COMMITMENT ON SAFETY

In the review papers with the theme of safety culture and safety climate (Flin et al., 2000; Guldenmund, 2000), management commitment was deemed as one of the common factors of safety climate, in different countries or different industries, although in most papers the management label is used so ambiguously that it was difficult to ascertain the level of management which was being assessed (Gadd, 2002). Top management's commitment and attitude to safety was extracted as the principal factor of safety climate (Dedobbeleer and Beland, 1991; Cheyne et al., 1998; Arboleda et al., 2003; Fung et al., 2005; Zohar and Luria, 2005) and was recognized to be the core meaning in the multi-level construct of safety climate (Zohar, 2008). Whereas, safety climate instruments, concerning management commitment to safety, were not specially designed to assess the actions and attitude of top management, but were used as a measure of ambiguous mixture of different levels of management.

Unlike the fixed location of plants and settled workers in manufacturing industry, the construction industry features in scattered sites and fluid workers. Thus the top management in construction companies can hardly inspect every site and be familiar with front line workers. In the construction industry in China, the lower management daily communicates with workers, by supervising their operations and participating in daily toolbox meetings. While the middle management contacts with workers by participating in new worker orientation and safety training. However the top management seldom visits the construction sites, resulting in imprecise evaluations, given by front line workers, on the actions of top management. Thus top management's commitment to safety should not be measured with sample of front line workers.

The safety climate survey in this research focused on measuring the employees' perceptions on the actions and attitude concerning safety of top management. To describe top management's safety commitment more precisely, it is necessary to point out that, the employees, or the samples, should be lower management and middle management, rather than front line workers. Therefore, the aims of this paper were:

I. Developing an organizational safety climate instrument, with the focus on measuring top management's commitment to safety in construction.

II. Extracting the factor structure of organizational safety climate in construction, naming these factors, and exploring the diversity between factors' scores.

METHOD: INSTRUMENT DEVELOPMENT

A pilot survey was conducted to examine whether the initial safety climate instrument was appropriate, and how could it be revised to better fit the organizational safety climate survey in construction in China. The initial organizational safety climate instrument, used in the pilot survey, was developed from the 16–item questionnaire applied in the research of Zohar and Luria (2005). These 16 items were reduced from their 27–item questionnaire of organization–level safety climate, by covering the range of activities outlined in the British Standards Institute's safety management code, known as OHSAS 18001.

Zohar (2008) postulated that safety climate measures should include the following three types: (a) unmediated assessment of managerial commitment, or priorities, which is prompted by direct statements; (b) mediated assessment by universal indicators; and (c) assessment based on industry specific indicators. He pointed out that the first two types allow unlimited and between–unit comparisons, while the third type increases measurement sensitivity for within–unit and within–industry comparisons.

Reviewing the reported questionnaires of safety climate, items in safety climate instrument were most likely required to be responded on a five Likert Scale (strongly disagree, disagree, neither disagree nor agree, agree, and strongly agree). The reported items in safety climate instrument were preferred to be phrased positively (Glendon and Litherland, 2001; Zohar and Luria, 2005; Neal and Griffin, 2006; Fernandez–Muniz et al., 2007; Ivar and Nesset, 2009), however, negatively phrased items were also widely used (Fang et al., 2006; Tharaldsen et al., 2008; Zhou et al., 2008; Vinodkumar and Bhasi, 2009). Therefore, the safety climate instrument in this paper comprises both positively phrased items and negatively phrased items.

In this research, the organizational safety climate was initially measured by 18 items, modified from the 16 items used by Zohar and Luria (2005). The modifications included adding: (a) some negatively phrased items, concerning the priority of safety compared with capital, profit, schedule and promotion; and (b) some industry–specific items; such as construction site inspection and construction project management. The 18–item organizational safety climate instrument in the pilot survey and the source of 16–item instrument are listed in Table 1 for comparison.

Table 1 Comparison of the Safety Climate Instrument

(Zohar and Luria, 2005)	This research
Top management in this plant–company . . .	Top management in this subsidiary construction company
	1. Will definitely emphasize company's safety creed when introducing company's core values.
	2. Would probably reduce safety inputs when company is in lack of profitability.
1. Reacts quickly to solve the problem when told about safety hazards.	3. Not always inspect the site right away when informed about serious safety hazards, but he will refer to his schedule to make the choice. 3. Would refer to his schedule prior to making the decision whether to inspect the site right away when informed about serious safety hazards.

2. Insists on thorough and regular safety audits and inspections.	4. Insists on thorough and regular safety audits and inspections. (for example regular site inspections by top management)
3. Tries to continually improve safety levels in each department.	5. Tries his best to continually improve safety performance on each site.
4. Provides all the equipment needed to do the job safely.	6. Provides all the equipment needed to do the job safely.
5. Is strict about working safely when work falls behind schedule.	7. Would not be as strict as usual about work safety when work falls behind schedule.
6. Quickly corrects any safety hazard (even if it's costly).	8. Would probably reduce inputs on eliminating safety hazards when company is in lack of liquidity.
7. Provides detailed safety reports to workers (e.g., injuries, near accidents).	9. Does not provide detailed safety reports to workers (e.g., injuries, near accidents).
8. Considers a person's safety behavior when moving–promoting people.	10. Does not consider a person's safety behavior when moving–promoting people.
9. Requires each manager to help improve safety in his– her department.	11. Repeatedly requires each project manager to help improve safety on his site.
10. Invests a lot of time and money in safety training for workers.	12. Invests a lot of time and money in safety training for workers. 12. Is lack in the input of time and money in safety training for workers.
11. Uses any available information to improve existing safety rules.	13. Regularly convene safety personnel meetings on how to improve existing safety rules and standards. 13. Should attach more importance on the improvement of existing safety rules and standards.
12. Listens carefully to workers' ideas about improving safety.	14. Proactively listen to ideas of employees in all positions about improving safety. (for example listen to ideas of front line workers on sites)
13. Considers safety when setting production speed and schedules.	15. Considers safety when setting company's long–term prospective goals and short–term production goals.
14. Provides workers with a lot of information on safety issues.	16. Provides workers with as much safety educations and safety trainings as possible.
15. Regularly holds safety–awareness events (e.g., presentations, ceremonies).	17. Regularly holds presentations and training programs for all managers (not limited to safety managers) to raise their safety awareness
16. Gives safety personnel the power they need to do their job.	18. Does not authorize safety personnel sufficient power they need to do their job on site. (For example the safety personnel do not have power to suspend the work when they discover serious safety hazards.)

Note: Items in gray, the ones used in the pilot survey, were replaced by new items in the same numbers in Table 1 in the next round of organizational safety climate survey.

Participants

The pilot survey was conducted in the safety training & seminar of a leading construction group in China in December 2008. The participants were lower and middle management, including safety supervisors, safety managers, project managers, and chief engineers. They were asked to complete the questionnaires within 20 minutes during a tea break of the seminar. 108 questionnaires were distributed and collected on the spot with valid responses, indicating a 100% response rate and a 100% valid rate. The mean age of the respondents was 37.59, with the standard deviation of 8.74. The mean working experience (measured by years) they have on safety management (referred as working experience) wais 7.04 years, with a standard deviation of 6.13.

Reliability Analysis

The reliability study indicates the degree of internal consistency between the multiple variables that make up the scale, and represents the extent to which the indicators or items of the scale are measuring the same concepts. The Cronbach's alpha was used to test the reliability, with the purpose of guaranteeing the maximum reliability of the scales proposed. The Cronbach's alpha of the 18–item instrument used in the pilot survey was 0.837.

Item analysis makes it possible to increase the overall quality of a scale while shortening it, either by eliminating unsatisfactory items or by removing redundant ones (Ivar and Nesset, 2009). Spector (1992) recommended that, the items have a low Item/Total correlation, as well as the items that increase the Cronbach's alpha, should be eliminated in the first step. The "Item/Total Correlations" and "Cronbach's Alpha if Item Deleted" for each of the 18 items were calculated. It was suggested that the item with Item/Total Correlation below 0.15 should be dropped from the instrument (Isla and Diaz, 1997; Vinodkumar and Bhasi, 2009). Considering that this was a pilot survey, and the revised instrument would be used in the next round of survey, the items, including item 3, 12, and 13, with Item/Total Correlation below 0.15 were decided to be revised rather than deleted.

Items Revision

It was found that the wording of these three items (e.g. item 3, 12, and 13) made them easily misunderstood by respondents.

Item 3 was worded in a long and ambiguous sentence that respondents would get confused, resulting in the largest standard deviation (1.401) out of the 18 items. Item 3 was revised to have clearer wording, and was worded negatively to attract attention:

> *Item 3. Not always inspect the site right away when informed about serious safety hazards, but he will refer to his schedule to make the choice.*

The respondents would easily get consensus on the wording, e.g. "is lack…" in item 12 and "should…" in item 13. As a result, 67% respondents (72 out of 108 respondents), highest proportion among the 18 items, gave the answer "agree" on item 12. The standard deviation of item 13 was 0.726, the lowest among the 18 items, indicating the strongest consensus on this item. Thus, the item 12 and item 13 were revised and the wording "is lack" and "should" were abandoned (The revised instrument is also shown in Table 1):

Item 12. Invests a lot of time and money in safety training for workers.

Item 13. Regularly convene safety personnel meetings on how to improve existing safety rules and standards.

METHOD: ORGANIZATIONAL SAFETY CLIMATE SURVEY

Participants

The revised instrument, in which item 3, 12, and 13 were revised, was applied in the next round of survey on organizational safety climate. The survey was conducted in the safety training of BCEG (a leading construction group in China) in February 2009, participated by lower and middle management, including safety supervisors (taking a proportion of more than 90%), safety managers, and project managers. The participants were asked to complete the questionnaires within 20 minutes during a tea break of the training course. 623 questionnaires were distributed and collected on the spot, with 613 valid responses, indicating a 100% response rate and a 98% valid rate. The mean age of the respondents is 44.7, with the standard deviation of 9.52. The mean working experience is 8.62 years, with a standard deviation of 6.44.

Transformation of Raw Scores
It should be noted that the stronger disagreement to the negatively worded items resulted in a higher score in favor of safety for those items. In order to keep consistency within the whole instrument, the raw scores of the negatively worded items, including item 2, 3, 7, 8, 9, 10, and 18, should be transformed to be consistent with the positively worded items. The formula of transform here is:
Transformed Score = 6-Raw Score

The transformed scores were applied in all the following analysis. For all the items in the instrument, the stronger agreement indicated more favor on safety.
The Cronbach's alpha of the revised 18–item instrument was 0.880, indicating a good internal consistency (Nunnally, 1978). None of the items had an Item/Total Correlation below 0.15.

RESULT

Factor Structure Extracted by EFA
The 613 valid responses, collected in the survey of organizational safety climate, were analyzed by Exploratory Factor Analysis (EFA), with principal component extraction method followed by varimax rotation. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy value was 0.927, showing that EFA could be applied to the data set (Kim and Mueller, 1978). Two factors, corresponding to all the 18 items, with an eigenvalue larger than 1 were retained. The first factor explained 36% of the total variance, and the second factor explained 10.5% of the total variance.

In the rotated factor loading matrix, the larger one of the two factor loadings of each item was retained, and the smaller one was also reported in parentheses in Table 2 (see Table 2). As was shown, none of the factor loadings had a value less than 0.4 (Coyle et al., 1995; Williamson et al., 1997; Varonen and Mattila, 2000; Havold, 2005); and both retained factors comprised more than three items (Varonen and Mattila, 2000; Seo et al., 2004; Fang et al., 2006). Therefore, the two extracted factors with all the 18 items in the instrument should be retained in the final solution of factor structure.

Table 2 Factor Loadings, Convergent Validity, and Descriptive Statistics

Item No.	Factor Loadings		SLP	t Values	Mean	S. D.
	Factor 1	Factor 2				
1	0.62	(0.15)	0.61	16.17	3.97	0.79
2	(0.24)	0.63	0.62	15.98	3.38	1.09
3	(0.16)	0.65	0.60	15.35	3.76	1.16
4	0.54	(0.23)	0.60	15.98	4.19	0.90
5	0.65	(0.24)	0.70	19.27	4.15	0.89
6	0.60	(0.28)	0.65	17.40	3.73	1.06
7	(0.28)	0.71	0.77	21.11	3.62	1.09
8	(0.28)	0.70	0.77	21.16	3.61	1.13
9	(0.11)	0.68	0.63	16.24	3.57	1.07
10	(0.22)	0.61	0.58	14.52	3.33	1.08
11	0.48	(0.09)	0.44	10.92	3.79	0.89
12	0.71	(0.21)	0.77	22.10	3.91	0.98
13	0.73	(0.12)	0.75	21.29	3.99	0.89
14	0.73	(0.25)	0.79	22.91	3.79	0.95
15	0.70	(0.17)	0.73	20.44	3.94	0.76

Item No.	Factor Loadings		SLP	t Values	Mean	S. D.
	Factor 1	Factor 2				
16	0.77	(0.15)	0.82	24.05	4.09	0.89
17	0.68	(0.16)	0.74	21.06	4.09	0.85
18	(0.07)	0.43	0.24	5.63	2.57	1.28

Reliability and Validity Analysis

The values of Cronbach's alpha of the two factors were 0.883 and 0.773 respectively, indicating a good internal consistency for each scale.

The validity of the scales was tested by calculating the convergent validity, with CFA technique applied. The convergent validity evaluates the extent to which two measurements of the concept may be correlated (Hair et al., 2005). Convergent validity can be analyzed by means of standardized factorial regression coefficients, relating each variable observed with the latent one, viz., by means of standardized lambda parameters (SLP) in CFA (Fernandez–Muniz et al., 2007). The results of the CFA model fit were: χ^2 (134) = 544.07, p=0.00, RMSEA = 0.071, NFI = 0.96, NNFI = 0.96, CFI = 0.97, indicating an excellently fitted model. A strong condition of convergent validity is that those coefficients are over 0.5 and are significant at a confidence level of 95%, requiring the t values greater than 1.96. The values of the SLP and the t values in CFA were shown in Table 2. As was shown, 16 out of 18 items of safety climate instrument met both requirements, confirming the strong condition of convergent validity for these items by the proposed scales. Two items (item 11 and item 18) had a SLP less than 0.50, however the t values of these two items were greater than 1.96, indicating that the convergent validities were also acceptable.

Naming the Factors

The first factor comprised 11 positively worded items, including item 1, 4, 5, 6, 11, 12, 13, 14, 15, 16, and 17. The stronger agreement to these items indicates better perception on organizational safety climate. Referring to the source of the instrument used in this research, the 16 items in the instrument used by Zohar and Luria (2005) were all worded positively, and they covered three themes including Active Practices (Monitoring, Enforcing), Proactive Practices (Promoting Learning, Development), and Declarative Practices (Declaring, Informing). Thus, this factor could be titled as ***Active and Declarative Practice***, which focused on measuring employees' perception on top management's active and declarative practices, such as monitoring, enforcing, training, and declaring. The second factor comprised 7 negatively worded items, including item 2, 3, 7, 8, 9, 10, and 18. The stronger disagreement (raw score) resulted in better perception on organizational safety climate. As Zohar (2008) suggested, the safety climate instrument should include the items assessing the top management's committed priorities on safety, by referring to the situations that present competing operational demands involving safety (e.g., safety vs. speed, flow, schedules, profitability). Therefore, this factor could be titled as ***Safety Priority***, which focused on assessing the true priority of safety committed by top management, by comparing safety with competing goals, such as schedule, liquidity, profitability, promotion, and authorization.

Difference in Mean of Item's Scores between the Two Factors

The scores of the 18 items were shown in Table 2. The Independent T test was applied to examine the difference in mean of item's scores between the two factors, e.g. active and declarative practice and safety priority. The result shown in Table 3 revealed that, the mean of item's scores of "Active and Declarative Practice" was significantly larger than that of "Safety Priority".

Table 3 Independent T Test

Factor Title		Active and Declarative Practice	Safety Priority
Mean of item's scores	Mean	3.967	3.40
	S. D.	0.15	0.397
	T Value	4.30	
	Sig.(2–tailed)	0.001	

Larger mean of item's scores manifests more positive perception on active and declarative practices than on safety priority on the part of top management. Top management has excellent performance, in declaring safety as the primary goal of company, asking everyone to pay close attention on work safety, and providing relatively sufficient resources (e.g. time and money) in safety training, safety inspection and personal protection equipment. However, the true priority of safety committed by top management is not as high as they declare. It is probably that top management will reduce safety inputs or loosen safety restrictions, when there is a collision between safety and competing demands, such as schedule, liquidity, profitability, promotion, and authorization. The result discloses a serious problem in safety management in construction in China that safety is not truly perceived as the first priority by top management, although it seems, by their performance, that top management indeed pays much attention on safety.

DISCUSSIONS AND IMPLICATIONS

Applying the instrument measuring organizational safety climate, this research revealed the top management's commitment on safety, in a construction company in China. The instrument developed in this research was proved to be able to evaluate the true safety priority committed by top management as well as their active and declarative practice. By conducting surveys using this instrument and comparing the results with companies of excellent safety perfomance, construction organizations could be able to diagnose its deficiencies in practices and especially values on safety of the top management. Thus they could be aware of the necessity to improve the safety performance by indoctrinating top management with safety values.

The interviews in a couple of China's construction organizations indicate that the top management believes they have provided sufficient safety resources and have devoted themselves into safety management. They usually ascribe accidents to the poor safety awareness of workers. However, this research found a different causation. It reveals that the top management has not realized the true priority of safety. Facing the rigorous punishment on managerial responsibilities of fatal accidents, the incentive of the top management in enacting safety management is to avoid responsibilities in case of fatal accidents. The reality disclosed in this research shows that the top management, in construction organizations in China, should reach a more ethical motivation for their safety management, which is a sincere concern about the life safety of workers.

There is yet not enough evidence to prove that, whether the low perception on top management's true safety priority is unique in construction organizations in China, or is universal in various industries and regions. Future research may concern the verification of the factor structure in this paper, and focus on evaluating the true safety priority of the top management.

CONCLUSION

The 18–item instrument of organizational safety climate in this paper was modified, by involving negatively phased items and industry specific items, from the 16–item instrument used by Zohar and Luria (2005) for specially measuring organization-level safety climate. The two-factor structure, extracted by EFA and confirmed by CFA, was composed of "Active and Declarative Practice", comprising 11 positively worded items, and "Safety Priority", comprising 7 negatively worded items.

Significantly higher level of perception, on organizational safety climate factor “Active and Declarative Practice”, than on the factor “Safety Priority” was found, indicating deficient commitment on true priority of safety of top management, although they enact laudable active and declarative practice on safety. The incentives of safety management enacted by top management should be their sincere concerns on workers’ life safety, rather than their attempts to avoid managerial responsibilities on fatal accidents.

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GROUP SAFETY CLIMATE IN THE CONSTRUCTION INDUSTRY: AN ANALYSIS OF STRENGTH AND LEVEL

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ABSTRACT

Much safety climate research has focused on the organization as the unit of analysis. However, using the organization as the level of analysis can mask important sub-unit differences. Workgroups in the Australian construction industry have been found to demonstrate significant within group homogeneity and between-group variation in safety climate. In particular, subcontracted work groups are reported to develop unique and variable safety climates. A typology of group-level safety climates is developed, based on the combination of climate level and climate strength. The safety climate of nine subcontracted workgroups engaged at a large hospital construction project are analysed according to this typology. Most subcontractors demonstrated 'strongly supportive' perceptions of their company's organizational safety response and supervisors' safety response (i.e. demonstrating high level and high strength). However, in some instances, the organizational safety response (OSR) and supervisors' safety response (SSR) were perceived to be low in level but high in strength. These groups were classified as possessing an 'obstructing' safety climate for these dimensions. The level of subcontractors' OSR and SSR were significantly inversely correlated with the subcontractors' injury rates. Safety climate strength was not significantly related to injury rates.

Keywords

Group level safety climate, subcontracted workgroups, Supervisors' safety response, Climate strength, Climate level

GROUP SAFETY CLIMATE IN THE CONSTRUCTION INDUSTRY: AN ANALYSIS OF STRENGTH AND LEVEL

Introduction

The construction industry's poor OHS performance

Construction is one of Australia's highest risk industries. In 2002 – 2003 construction workers were more than twice as likely to be killed at work compared to the average worker in all Australian industries. Further, 2006 figures indicate that construction has consistently been Australia's third most dangerous industry, surpassed only by transport and storage and agriculture for the past three years, with a rise of 9% in the number of recorded fatalities in 2006-07 (ASCC, 2008). Data from the National Online Statistics Interactive (NOSI) system show that in the financial year period 2003-2007, there were 184 compensated fatalities in the construction industry (an average of 46 compensated fatalities per year). Preliminary data show that, in the 2006-2007 financial year, the incidence rate for fatal injuries in the Australian construction industry was 7.8 per 100,000 employees. This rate was only surpassed by the transport and storage industry (10.8). In 2006–07 there were 14,120 serious workers' compensation claims in the construction industry, representing 11% of these claims across all industries. This equates to 39 employees a day sustaining a serious work-related injury or disease requiring one week or more off work (ASCC, 2008). Despite technological developments and the implementation of robust occupational health and safety (OHS) management systems, the construction industry's chronic level of fatalities, serious injury and ill-health appears resistant to change. This has led researchers and practitioners to focus on organizational and social factors, such as safety climate, to induce positive change to the industry's poor OHS performance.

Safety climate

There is some debate about the distinction between safety culture and climate. Shannon & Norman (2009) suggest culture consists of the underlying values, beliefs and assumptions concerning OHS which shape 'the way we do things around here' (p.327). Safety climate, on the other hand refers to perceptions of what is actually done, thus it is the check of whether the behaviour of people in the organization matches the rhetoric. Neal and Griffin (2006: pp 946-947) define safety climate as 'individual perceptions of the policies, procedures and practices relating to safety in the workplace.' The development of shared perceptions about the priority placed upon safety within the work environment is believed to inform workers' role behaviour through expectations they form about how certain behaviours will be rewarded and supported in an organization (Zohar & Luria, 2005).

Cooper and Phillips (2004) comment upon the importance of examining the ability of safety climate to predict OHS outcomes. Griffin and Neal (2000) and Neal and Griffin (2002) report safety climate to be positively related to both self-reported compliance with safety procedures and self-reported voluntary participation in safety-related activities. In the offshore oil industry, Tharaldsen, Olsen and Rundmo (2008) report a significant inverse correlation between safety climate perceptions and accident rates while Mearns, Whitaker and Flin (2003) likewise show favourable safety climate scores are associated with offshore installations returning a lower proportion of self-reported accidents. Varonen and Mattila (2000) similarly report that perceptions of the prevailing attitude towards OHS within an organization were inversely correlated with the accident rate in wood processing companies. Another Australian study in the health sector reported that safety climate levels measured at one point in time predicted higher levels of OHS motivation and self-reported OHS-related behaviour at a future point in time (Neal and Griffin, 2006). In a recent meta-analysis of safety climate studies, Clarke (2006) identified a consistent relationship between safety climate and performance in prospective studies (i.e. those in which safety performance is monitored some time after the prevailing safety climate is measured), concluding that this 'effect' is generalizable across occupational settings (Clarke, 2006).

Safety climate in construction

Early studies of safety climate in construction combined perceptions of management commitment and workers' involvement in OHS (Dedobbeleer & Beland, 1991). Research has revealed a significant positive association between safety climate and various aspects of OHS performance in the construction industry (Gillen, Baltz, Gassel, Kirsch & Vaccaro, 2002). Siu, Phillips & Leung (2004) tested a Safety Attitude Survey, which combined items about workers' perceptions of themselves, their colleagues, management, company safety officers and supervisors. Their analysis revealed that aggregated safety attitude scores were directly related to self-reported occupational injury rates and indirectly related to self-reported accident rates via reported levels of psychological distress. Zhou, Fang & Wang (2008) report that two climate dimensions (management commitment and workmates' influence) exert significantly greater influence on self-reported safety behaviour than workers' personal experiences of training and safety. In a lagged, two-wave study of Swedish construction workers, Poussette, Larsson, and Törner (2008) report that safety climate scores at one point in time (time 1) significantly predicted self-reported safety behaviours seven months later (after controlling for safety behaviour at time 1).

Muti-level safety climates

Most researchers have measured safety climate at the level of the organization. However, Zohar (2000) proposes two levels of safety climate: (i) that arising from the formal organization-wide policies and procedures established by top management; and (ii) that arising from the safety practices associated with the implementation of company policies and procedures within workgroups. Zohar tested this proposition in a manufacturing context and confirmed that workgroup members develop a shared set of perceptions of supervisory safety practices, and discriminate between perceptions of the organization's safety climate and the workgroup safety climate. Zohar suggests that group-level safety climates relate to patterns of supervisory safety practices, or ways in which organization level policies are implemented within each workgroup or sub-unit.

Zohar and Tenne-Gazit (2008) describe how, in the measurement of safety climate, individual climate scores are aggregated to the unit of analysis of theoretical interest. This can be the entire organization or organizational sub-units, such as workgroups. The findings highlight the importance of clearly specifying the unit of analysis of theoretical interest in safety climate research. Safety climate researchers have often incorporated co-worker safety stewardship and supervisory safety leadership in their survey design. For example, Lu and Shang (2005) incorporate both perceptions of co-worker safety and perceptions of supervisors' safety leadership in a safety climate survey of container terminal operators in Taiwan. However, these researchers have aggregated these scores to the level of the entire organization. With regard to supervisory and co-worker facets of safety climate, the workgroup is a more appropriate unit of analysis. Attempts to aggregate scores for these dimensions at the organization level are likely to mask important between-group differences (Tharaldsen, J. E., Olsen, E. and Rundmo, T. ,2008; Glendon & Litherland, 2001; Findley, M., Smith, S., Gorski, J. & O'Neil, M., 2007),)

Safety climate in the context of subcontracting

Recent research by Lingard, Cooke and Blismas (2009) has demonstrated that workgroups develop unique and distinct group safety climates in an Australian public sector road construction and maintenance organization. However, the employees in this organization were all directly employed. Subcontracting is a key feature of the Australian construction industry, which is known to present significant challenges in the management of OHS. Construction subcontractors are often engaged in complex relationships both horizontally (i.e. when multiple subcontractors are engaged by a principal contractor) and vertically (i.e. in the case of pyramid of multi-layered subcontracting). In this context, workers involved in subcontracted companies are only loosely connected with the principal contractor and relatively isolated from their own company, which could impact upon the development and impact of safety climate (Melia, Mearns, Silva & Lima, 2008). Facets of group safety climate have been linked to subcontractors' safety behaviour. For example, Choudhry and Fang (2008) report that when co-workers' and supervisors' are perceived to be unsupportive of safe behaviour, subcontracted construction workers are more likely to adopt unsafe work practices. The implication of subcontracting for the development and impact of safety climates within the construction industry is not well understood. The research reported in this paper examines the extent to which subcontracted workgroups in the Australian construction industry exhibit distinct and unique safety climates.

Safety climate properties

Zohar and Luria (2004) suggest climate can be described in terms of two parameters: (i) its strength; and (ii) its level. Safety climate strength refers to the degree of consensus concerning climate perceptions within members of a group and can range from weak to strong. A strong safety climate is one in which there is very high consensus between members about the priority placed upon safety by management, while a weak safety climate is where there is a low level of consensus concerning management commitment to safety. The level of safety climate refers to the relative priority placed upon safety within a work group as perceived by members of that group. The level of the safety climate can be expressed as either high (i.e., perceptions of a highly level of managerial support for safety) or low (i.e. perceptions of low managerial support for safety). Thus, it is possible for a safety climate that is supportive of safety to be either weak or strong depending upon the degree of 'sharedness' of this perception among workers in the same organization or workgroup.

Figure 1 suggests four theoretically distinct types of safety climate positioned according to their strength and level. These are:

(i) An indifferent safety climate (weak strength and low level);

(ii) An obstructive safety climate (strong strength and low level);

(iii) A contradictory climate (weak strength and high level); and

(iv) A strongly supportive climate (strong strength and high level).

In an indifferent climate, management are perceived to be low in commitment to and ambivalent towards OHS. A characteristic of this type of safety climate is a low level of consensus as to the relative priority placed upon OHS, as managers do not actively communicate their OHS expectations. By contrast, an obstructive climate is characterised by a high level of consensus that management prioritises other facets of work performance, such as production above OHS. The theory suggests that contradictory climates develop when mixed messages concerning the importance of OHS are delivered by managers or when managers' actions are inconsistent with rhetoric regarding OHS. In these circumstances, a low level of consensus about the relative priority of OHS exists, despite a perception that managers at least, pay 'lip service' to OHS. Finally, in strongly supportive safety climate, managers are perceived to consistently prioritise OHS and demonstrate a high level of commitment to OHS, which does not vary according to circumstances.

Aims and objectives

This paper presents an argument for the analysis of safety climate in the construction industry at the level of the subcontracted workgroup (as opposed to the principal contractor organization). Data supporting the validity of group-level climates in the construction industry is presented. The paper also examines two distinct properties of safety climate: (i) the level; and (ii) the strength of the safety climate. A framework for positioning group-level safety climates in a two-dimensional grid representing these two properties is described. Data collected from subcontractors working at a large construction project is plotted on these two-dimensional safety climate grids.

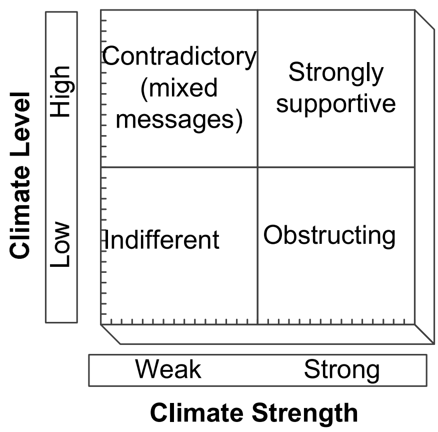

Figure 1: Safety climate types

RESEARCH METHODS

Data collection

Data were collected from directly employed and subcontracted workers at a hospital construction project in Melbourne. The surveys were administered using the 'TurningPoint' automated response system with 'KeyPad' hand held devices. The advantages of this system over paper based survey administration include the completeness of data and minimisation of human error in data entry. Participants were invited into the site office during normal work hours to participate in the survey. Participation was voluntary and participants were advised that their responses would be anonymous.

Subcontractors' Organizational Safety Response (OSR) was measured using items were taken from the HSE's Safety Climate Tool (2002). Consistent with Zohar and Luria (2005), the survey measured perceptions of management commitment to OHS as the core meaning of safety climate. Example items are "I feel that at [company name] management are concerned about my health and safety" and "[Company name's] management only bother to look at health and safety after there has been an accident" (reversed score). *Supervisors' Safety Response* (SSR) was measured using an eleven-item group safety climate scale developed by Zohar (2000). Example items are "Whenever pressure builds up, my supervisor wants us to work faster, rather than by the safe work procedures" (reverse scored), and "My immediate supervisor often talks to me about health and safety." *Co-workers' Safety Response* (CSR) was measured using items from the UK Health and Safety Executive (HSE) safety climate survey (HSE 2002). Example items are "My workmates encourage others to be safe" and "Workmates in my crew sometimes pressure me to work unsafely" (reverse scored) (HSE 2002). Participants were asked to rate all of the statements in the survey on a five point scale, ranging from 'strongly disagree' (1) to 'strongly agree' (5).

Data analysis
The internal consistency reliability of the safety climate components was assessed using Cronbach's alpha. Consistent with Zohar (2000), between-group differences in safety climate were explored by conducting a one way analysis of variance (ANOVA). Within-group homogeneity of safety climate perceptions was examined by calculating the inter-rater agreement (IRA). The IRA is used to measure the interchangeability or the absolute consensus in scores between group members. It estimates whether responses from one participant are 'similar' to the responses provided by others in the same workgroup, thus reflecting the degree of 'sharedness' in group climate scores (James, Demaree and Wolf. 1993). According to this test, within-group consensus (i.e. an acceptable level of consistency between the safety climate perceptions of different workers within the same group, in this case the subcontractor) is deemed to exist if $r_{wg(j)}$, the variance of random response ratings from multiply participants is 70% or greater. A value of 0.70 is representative of this figure. To adequately reflect team dynamics and protect participants' anonymity, subcontractors with less than three workers at the project were excluded from the analysis.

RESULTS

The sample
One hundred and thirty six surveys were completed. Table 1 shows the characteristics of the sample. The majority of respondents (N=114, 83.3%) were employed by nine different subcontractors working at the construction project. These subcontractors varied in the numbers of workers engaged at the project and thus the numbers of respondents also varied considerably by subcontractor, ranging from thirty three respondents employed by subcontractor 6 to four respondents employed by subcontractors 2 and 5.

		N	%
Status	Principal contractor	22	16.2
	Subcontractor	114	83.8
Occupation	Administrator	3	2.2
	Construction worker	98	72.1
	Foremen	10	7.4
	Graduate engineer	3	2.2
	Leading hand	13	9.6
	Manager	5	3.5
	Safety	1	0.7
	Student	2	1.5
	Missing data	1	0.7

Employer	Subcontractor 1 (SC 1	17	12.5
	Subcontractor 2 (SC 2)	4	2.9
	Subcontractor 3 (SC 3)	7	5.1
	Subcontractor 4 (SC 4)	7	5.1
	Subcontractor 5 (SC 5)	4	2.9
	Subcontractor 6 (SC 6)	33	24.3
	Subcontractor 7 (SC 7)	20	14.7
	Subcontractor 8 (SC 8)	11	8.1
	Subcontractor 9 (SC 9)	11	8.1
	Principal contractor	22	16.2

Table 1: Characteristics of the sample

Table 2 shows descriptive statistics for the three variables included in the analysis. Cronbach's alpha coefficients were > 0.7 for all three variables, indicating acceptable internal consistency reliability.

	Mean	Standard deviation	Cronbach alpha
Subcontractors' OSR	3.2	0.71	0.89
Subcontractors' SSR	3.1	0.77	0.90
Subcontractors' CSR	3.6	0.79	0.84

Table 2: Descriptive statistics for subcontractor safety climate dimensions

Subcontractors' safety climate

The existence of unique subcontractor safety climates engaged at the construction project was determined on the basis of two criteria established by Zohar (2000). These are:

(ii) Between-group variance (i.e. whether safety climates differ significantly between subcontractors working at the same construction project); and

(ii) Within-group homogeneity (i.e. whether workers employed by a single subcontractor share similar perceptions of the safety climate).

One way analyses of variance were conducted to test for significant variation in mean safety climate scores between subcontractors engaged at the projects. Significant between-group variance was found for both perceptions of the subcontractors' OSR and SSR. No significant between-group variance was found for perceptions of subcontractors' CSR.

Table 3 shows the inter-rater agreement scores for each subcontractor for the three aspects of of subcontractors' safety climate. With the exception of one subcontractor (SC 5), there was a high level of inter-rater agreement concerning safety climate in subcontracted work groups.

Subcontractor	*Subcontractors' OSR*	*Subcontractors' SSR*	*Subcontractor's CSR*
SC 1	0.82	0.82	0.86
SC 2	0.93	0.93	0.97
SC 3	0.97	0.97	0.93
SC 4	0.96	0.96	0.95
SC 5	0.00	0.00	0.00
SC 6	0.83	0.83	0.86
SC 7	0.95	0.95	0.91
SC 8	0.77	0.77	0.79
SC 9	0.84	0.84	0.82

Table 3: Inter-rater agreement scores for group-level safety climate dimensions

Strength and level of subcontractors' safety climate perceptions
A series of quadrant charts was plotted to position subcontractors' safety climate in the two dimensional schema described above. For the purposes of these plots, the safety climate level (the mean score for each subcontractors) was plotted against the vertical axis whereas safety climate strength (the inter-group agreement score for each subcontractor) was plotted against the horizontal axis. The midpoint on the vertical axis was the midpoint in the survey scale (i.e., 3). The midpoint on the horizontal axis was 0.5 as climate strength can vary between 0 and 1.0. The results are shown in Figures 2 to 4.

Figure 2 shows the quadrant plot for subcontracted workers' perceptions of their own organization's *Organizational Safety Response*. Five of the nine subcontractors working at the hospital construction project were located within the 'Strongly Supportive' quadrant, indicating a high degree of consensus among workers of those subcontracting organizations that their respective organizations are strongly committed to OHS. One subcontractor was positioned at the border between the 'Strongly Supportive' and the 'Obstructing' quadrants, indicating high within-group consensus concerning an organizational ambivalence to OHS within this subcontractor. Two of the subcontractors fell into the 'Obstructing' quadrant, indicating that there was a high degree of consensus that OHS is not always a high priority for the management of these subcontractors. Finally, one subcontractor was located in the 'Contradictory' quadrant, indicating that workers, on average, perceived their organization to be committed to OHS but that there was very low group consensus within this subcontractor, that is, workers engaged by this subcontractor did not share similar perceptions of their own company's safety management.

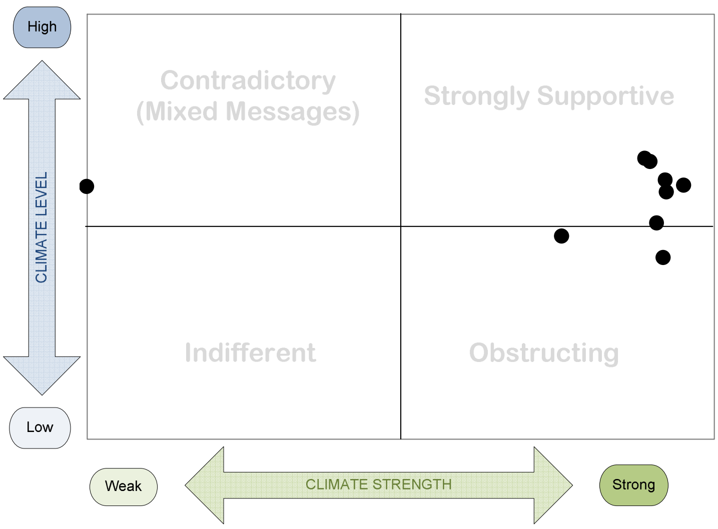

Figure 2: Strength and level of subcontractors' OSR

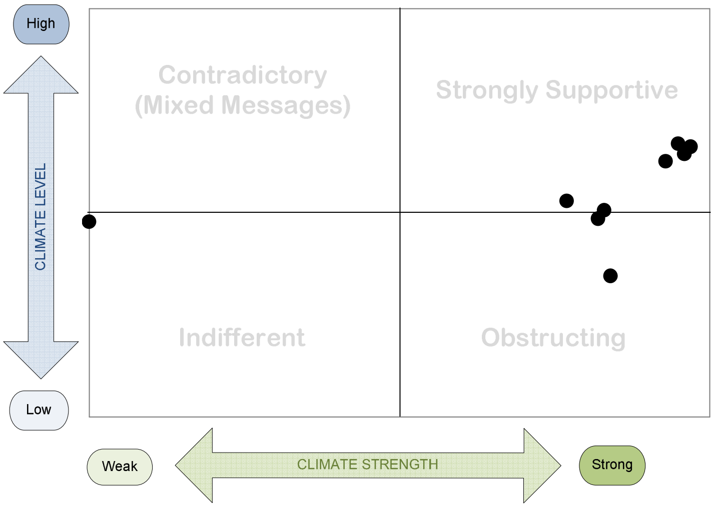

Figure 3: Strength and level of subcontractors' SSR

Figure 3 shows the quadrant plot for subcontracted workers' perceptions of their own organization's *Supervisory Safety Response*. Most subcontractors at the hospital construction project fell into the 'Strongly Supportive' quadrant for this aspect of safety climate, indicating a high level of agreement within subcontractors that workers perceived their company supervisor to prioritise OHS highly relative to other objectives. However, one subcontractor clearly fell into the 'Obstructing' quadrant, indicating that there was a high degree of consensus about this supervisor's safety-related behaviour but that the supervisor was perceived to be somewhat lacking in support for OHS. Two subcontractors were positioned at the border between the 'Strongly Supportive' and the 'Obstructing' quadrants, indicating high within-group consensus that the supervisor was ambivalent in his commitment in relation to OHS. Finally, one subcontractor was located in the 'Indifferent' quadrant, indicating that workers, on average, perceived their supervisor as being relatively low in commitment to OHS but that group consensus within this subcontractor was low, that is, workers engaged by this subcontractor did not share similar perceptions of their own company *Supervisor's Safety Response*.

Figure 4 shows the quadrant plot for subcontracted workers' perceptions of their *Co-workers' Safety Response*. All but one subcontractor fell into the 'Strongly Supportive' quadrant, indicating that workers considered that their co-workers to be concerned about OHS and also indicating a high level of within group agreement about this concern (See Figure 22). One subcontractor fell into the 'Contradictory' quadrant, indicating that workers, on average, perceived their co-workers to be concerned about OHS but having a low level of consensus about this concern, that is, workers engaged by this subcontractor did not share similar perceptions of their co-workers' level of concern for OHS.

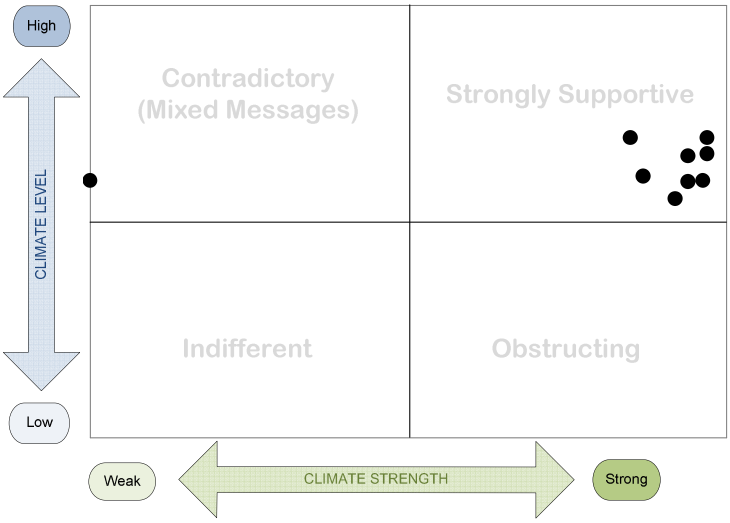

Figure 4: Strength and level of subcontractors' CSR

DISCUSSION

Group-level climates

All three safety climate dimensions indicated high levels of within-group homogeneity, indicating that workers employed by a single subcontractor share consistent perceptions of their own OSR, SSR and CSR. The analyses of variance revealed significant between-subcontractor differences in perceptions of the OSR and SSR. However, no significant between-subcontractor difference was found for perceptions of CSR. The conditions established by Zohar for group-level safety climate were satisfied for two of the three safety climate dimensions measured (i.e., subcontractors' OSR and SSR). This lends further validity to the concept of group-level safety climate in the construction industry and also extends previous analysis by examining the extent to which distinct and unique safety climates exist within subcontracted workgroups. Group-level safety climates are likely to be particularly significant when work teams enjoy a high level of autonomy and work is de-centralised and non-routine, as in the construction industry. Given the characteristics of construction work, which is undertaken within small workgroups, and in which members exercise considerable discretion in the interpretation of organizational safety policy and procedures, the safety climate of subcontracted workgroups is likely to exert greater influence on OHS performance than in other organizational contexts.

In the construction context, the variation in subcontractors' safety climates revealed in this analysis raise important questions for principal contractors concerning the alignment of subcontractors' safety climates with the principal contractor's organizational commitment to OHS. In revealing significant variance in workers perceptions of subcontractors' ORS and SSR, the results raise the possibility that some subcontractors will be perceived by their workers as being significantly different in their commitment to OHS than the principal contractor. As perceptions of the subcontractors' safety climate are likely to be the more proximal, direct influence on workers' OHS behaviour, this could undermine the principal contractors' OHS management efforts and impact upon the attainment of project OHS goals.

In the present research, group perceptions of subcontractors' OSR and SSR were both inversely significantly correlated with the subcontractors' lost time injury (LTI) and medical treatment injury (MTI) rate for the twelve months prior to administration of the survey, providing preliminary evidence of a link between safety climate (level) and subcontractors' OHS performance. The correlation between subcontractors' mean OSR score and the LTI/MTI rate was $r=-.578$, ($p=.000$) and the correlation between subcontractors' mean SSR was $r=-.313$ ($p=.001$).

The results also have important implications for safety climate research. The existence of distinct and unique safety climates within subcontracted workgroups highlights the need to carefully specify the unit of analysis in safety climate research in the construction industry. Attempts to link perceptions of the principal contractors' organizational safety climate with on-site OHS performance might mask significant differences between subcontractors.

The theoretical model for positioning workgroup safety climate in a two dimensional grid recognises that both safety climate level and safety climate strength are likely to be important in shaping safety-related behaviours (Zohar 2002). Strategies to promote 'strongly supportive' safety climates within subcontracted workgroups are recommended.

CONCLUSIONS

The results of the research lend further support to the existence of group-level safety climates within the Australian construction industry. First, the results have shown that workgroup members develop uniform perceptions concerning safety within their subcontracted workgroups; and second, perceptions of subcontractors' OSR and SSR vary between workgroups, resulting in significantly different safety climate perceptions between members of different subcontracted workgroups (i.e. between group variance).

Limitations and future research

Owing to the small number of subcontracted workgroups in the analysis (n=9), it was not possible to investigate whether the position of a workgroup's safety climate in the four quadrant model was related to OHS performance. Future research should investigate the two-dimensional models' ability to predict subcontracted workgroups' OHS performance in the construction industry. It is recommended that prospective research designs be employed in future research. It is hoped that the current study will encourage researchers to conduct further studies of a similar design in order to replicate and extend the results.

Acknowledgement

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AN INVESTIGATION OF SAFETY CLIMATE WITHIN A LARGE UK MAIN CONTRACTING CONSTRUCTION ORGANISATION

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ABSTRACT
A positive health and safety culture is a key component in enabling a safe and secure working environment. Whilst effective safety management systems are vital in achieving and maintaining excellence in health and safety, they must be viewed as dynamic processes and practices that are facilitated and enabled by factors such as peoples' behaviour, attitudes and perceptions. The influence of the human element on construction health and safety cannot be understated.

This study considers employee attitudes and perceptions regarding health and safety within a large UK main contracting organization. Experience of working for the main contracting organization across a number of regions of the UK led one of the authors to ask the question – 'why is health and safety culture so variable on construction sites in different UK regions across the same organization -particularly when management systems, policies and practices are the same across the organization's construction sites?'

Support of the main contracting organization has enabled all employees (700) within three UK regions to be anonymously surveyed regarding attitudes and perceptions towards health and safety. 180 respondents across the four regions have provided insight into the organization's safety climate and responses have informed the identification of structured themes and categories.

The survey data and its analysis goes some way to answering the initial research question, it also serves to facilitate the main contracting organization's discussion and consideration of activities and strategies to further enable the achievement and maintenance of a positive health and safety culture.

Keywords
Safety climate, Survey, Main contractor

INTRODUCTION – CONTEXT OF THE RESEARCH

This exploratory investigation is grounded in one of the author's experiences of working for a main contracting construction organisation, across a number of different regions within the UK. This experience led to the question 'why is health and safety culture so variable on construction sites in various UK regions across the same organisation - particularly when management systems, policies and prescribed practices are the same across the organisation's construction sites?'

The aim of the research study was to undertake an exploratory investigation of views and opinions regarding construction site health and safety within the case study context of the organisation of the author's experience. The study was concerned with investigating and comparing employees' health and safety related views and opinions across a number (4) of the organisation's commercial regions within the UK.

The starting point for the research was a review of literature regarding models of safety culture and their constituent components or facets. Development or testing of a model of safety culture was not the aim of the research (or this paper). It was recognised though that it was necessary to accept and utilise a model or framework of understanding regarding safety culture in order to more clearly inform understanding of the nature of the contribution that employees' views and opinions make to an organisations' safety culture. Furthermore understanding of a model of safety culture was necessary for determining suitable research methods.

Cooper (2000) offers a reciprocal model for safety culture. This is illustrated in figure 1.

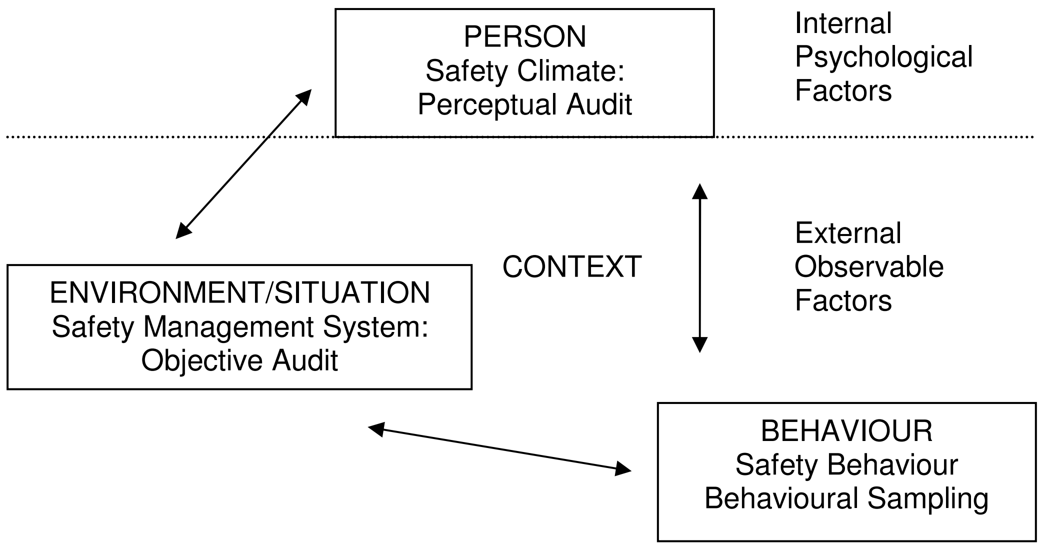

Figure 1: Cooper's Reciprocal Model for Safety Culture (Cooper, 2000)

Based on this model, Choudhry et al (2007) present a conceptual model of safety culture that facilitates the measuring of safety culture within construction site environments. Here 'situational', 'behavioural' and 'safety climate' components or aspects of safety culture are measured by application of a variety of tools including audit, survey, focus group and document analysis. In this model, behaviours are measured through a behaviour based safety programme, safety management systems are measured by safety audits and the safety climate of employees' views and perceptions are measured by survey questionnaire. This is the research challenge laid down by Choudhry et al (2000) - to establish and measure safety culture of organisations.

AIM

Any investigative measure of safety culture that does not encompass investigation of all three components or aspects of the model can be considered an inadequate and insufficient investigation of safety culture. Whilst this study is grounded in the models of culture presented by Cooper (2000), Choudhry et al (2007), it does not purport to be a study of safety culture.

The aim of this research study concerns 'safety climate' and focuses upon investigating and comparing employees' health and safety related views and opinions across 4 of the organisation's commercial regions within the UK. The safety climate focus concerns 'what people think and perceive' with regards to health and safety. As such, this research study seeks to determine a 'snapshot' of safety climate within 4 distinct regions of a UK main contracting organisation and furthermore consider the comparability of findings across the different regions of the organisation. The study does not attempt or strive to develop grounded theory, test a hypothesis or examine the relationship of safety climate with situational or behavioural aspects of safety culture. Furthermore the findings of this study should not be considered as 'typical' or transferable, nor do they represent the organisation's safety culture.

METHODOLOGY

In developing the survey relevant themes were identified and some 45 questions were drawn up after reference to climate literate (Budworth 1997; Fin et al. 2000, HSE 2005). The HSE (2001) identifies 11 'core safety climate item sets' from a study of a number of safety climate questionnaires. These 11 'item sets' are:

1. Training and competence
2. Job security and Job satisfaction
3. Pressure for production
4. Communications
5. Perceptions of personal involvement in health & safety
6. Accidents/ incidents/ near misses
7. Perception of organisational/ management commitment to health & safety - General
8. Perception of organisational/ management commitment to health & safety - Specific
9. Merits of the health & safety procedures/ instructions/ rules
10. Rule breaking
11. Workforce view on the state of safety / culture

The draft list of 45 questions was revisited and distilled down to facilitate a concise survey of 10 questions. The questionnaire was developed online using 'Survey Monkey' to facilitate both its production and the collation or responses. A request to complete the survey was distributed via an email with a web link to the survey embedded within the email. With suitable permission, the email was dispatched via the case study organisation's intranet, to *all employees* of the four distinct regions. Assurances were provided regarding respondent anonymity, this was assisted by the fact that surveys were completed via an online website that did not register details over and above those completed within the anonymous survey. Respondent wishing to offer themselves for a follow up interview or discussion were able to declare themselves and their contact details on the survey.

SAMPLING STRATEGY

No sampling of employees within the 4 regions was carried out for this study. Instead the survey was administered to *all* employees within the 4 regions. As such a total of 700 employees received the email invitation to complete the survey. The 700 employees included all personnel and job roles within the 4 regions, including inter alia: directors, quantity surveyors, construction managers, office staff, HR managers and IT professionals.

A stated period of one week was allowed to complete the survey. After this time the on-line survey was closed and the data collated. A total of 180 surveys were completed (26% response rate).

Nominal and ordinal scaling was applied in the analysis of the survey data. This facilitated the categorisation of respondents and the comparison of views and responses given by categorised respondents – for example the views of site managers regarding such matters as the reporting of near misses could be compared region by region. Nominal and ordinal analysis enabled respondents to be categorised and cross-compared with regards to their views and attitudes expressed within the survey.

RESULTS OF THE SURVEY

Figure 2 shows the percentage of respondents by their role in the organisation. The greatest response was from the Quantity Surveyors, who made up around a quarter of the data. This was followed by Construction Managers at 17%, with Project Managers, Engineers and members of the design team with an even response rate at just over 10%. A small percentage of those who responded were company directors, with the remaining 20% of the data coming from people with other roles such as HR, IT, Admin, Planning and Accounts.

The participation in the survey by people in various roles shows a commitment to safety throughout the company, from directors, to designers, through to site management and site administrative staff.

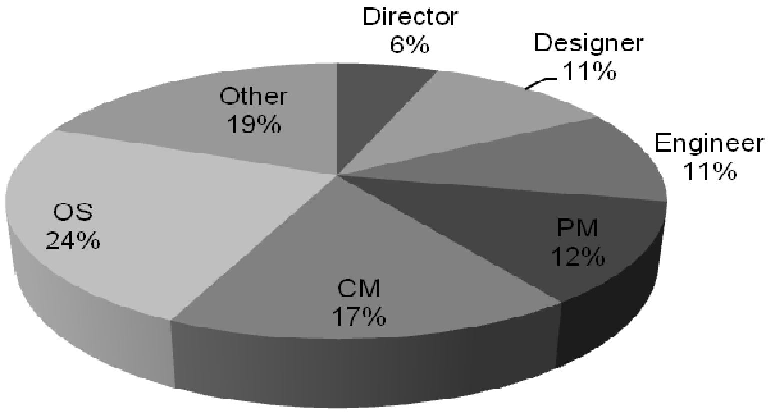

Figure 2 Respondents by Job Role

Figure 3 highlights the percentage of respondents to the survey by the length of time they have worked in the industry. The weighting of experience within the company would be assumed to be evenly spread from looking at the pie chart below. There are roughly a quarter of respondents to each of the 4 experience bands, with those in the industry between 10-15years slightly shading it with 31% of the response.

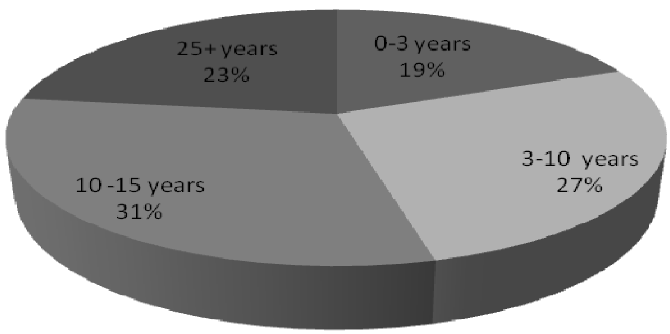

Figure 3 Industry Experience of Respondents

Figure 4 shows the percentage of respondents by the region in which they are based. Just under one half of the respondents to the survey were based within the North-West region. Yorkshire, Midlands and North-East each had between 15% and 20% of total respondents. The greater response from the North-West region could be explained by the fact that the Organisations Head-Office is based in this region. As such the region has a larger no of company staff in the roles directors, HR and IT.

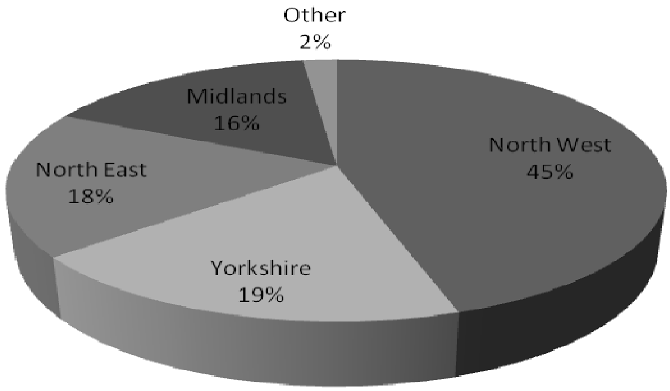

Figure 4 Respondents by Region

Employees were asked 'how do you rate the importance of Health and Safety, Time, Cost and Quality on your site?' Figure 5 presents the organisation-wide responses to this question.

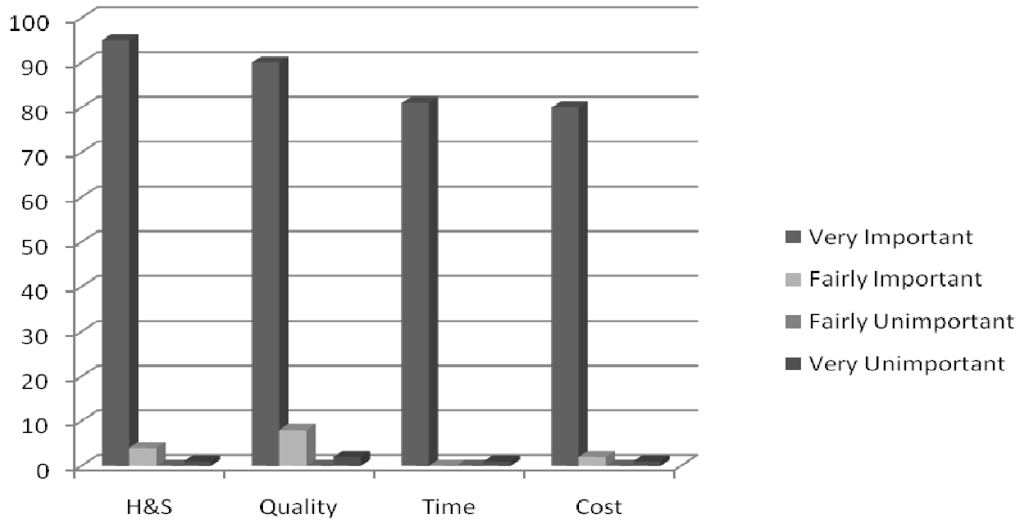

Figure 5 Respondents' views (by percentage) regarding the Importance of Key Project Indicators

95% of respondents (171) rated health and safety as 'very important'. It is interesting to note that 100% of all Directors and Project Managers ranked health and safety as 'very important'. In addition to this 100% of all directors surveyed also ranked time, cost and quality as being 'very important'.

No significant difference can be ascertained in the views and opinions expressed when categorised by role, or length of time served within the industry. When considered by region a very slightly lower 'importance score' is ascribed by respondents within the Midlands region for all four project indicators, as indicated in table 1. Here, on this scale '4' was considered to be 'very important' and '1' 'very unimportant'.

Table 1 Perceived Importance of Key Project Control Indicators by Region (mean average/4)				
	North west region	North East region	Midlands region	Yorkshire region
Health & Safety	3.99	3.97	3.83	3.94
Quality	3.91	3.94	3.61	3.94
Time	3.83	3.85	3.71	3.79
Cost	3.79	3.82	3.75	3.82

VIEWS REGARDING SENIOR MANAGEMENT

On the topic of senior management, employees were asked to give a view regarding the extent to which they agreed with the following statements: 'senior management actively promote health and safety'; 'senior management have a strong visible presence on site'; senior management readily act upon safety suggestions from the workforce'. Figure 6 presents a bar chart of the results graphically.

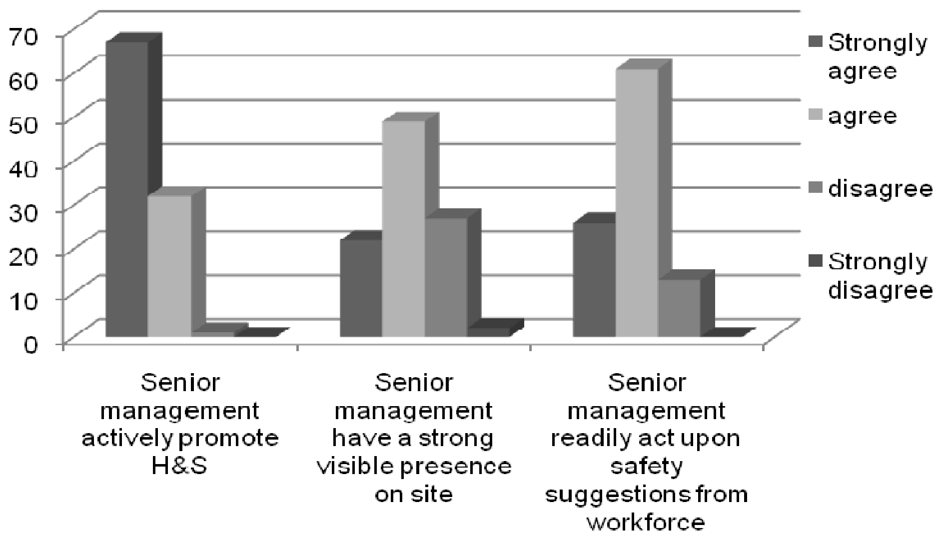

Figure 6 Perceptions regarding Senior Management Role in Safety Culture (by Percentage of All Responses)

With regards to senior managements input into safety culture, the general consensus is positive, as shown in figure 6. As the chart shows almost 100% either strongly agree or agree that senior management readily promote Health and Safety.

However when asked if senior management have a strong presence on site, almost 30% of those surveyed disagreed. This percentage is reflected in all of the job roles that were surveyed, with the exception of the organisations directors. 100% of directors surveyed either agreed or strongly agreed that senior management have a strong presence on site, as well as readily acting on safety suggestions from the workforce. This is a possibly a bias if they consider themselves under the umbrella of senior management, or an ignorance in seeing that there is no room for improvement and current practices are best they could be.

When analysing the results by region, almost half of those surveyed in the Midlands and the North West disagreed that senior management had a strong presence on site. These responses were significantly lower than the other two regions, as indicated in Table 2.

Table 2 Perception of Senior Management (SM) Role in Safety Culture by Region (mean average/4)				
	North west region	North East region	Midlands region	Yorkshire region
S.M. actively promote H&S	3..63	3.82	3.76	3.56
S.M. have a strong visible presence on site	2.75	3.21	2.69	3.15
S.M readily act upon safety suggestions from workforce	3.06	3.30	3.10	3.18

With regard to the responses and the experience held by each respondent, it would appear that those with over 25 years of industry experience are the most positive about senior managers' input into safety culture. This could be because, having been in the industry over 25 years respondents were are themselves senior managers, or had evidence considerable health and safety changes and input from senior management over that time.

VIEWS REGARDING ACCIDENTS AND INCIDENTS ON SITE

On the issue of accidents and incidents on site, employees were asked to give their view regarding the extent to which they agreed with the following statements: 'incidents and near misses are always reported'; there is an open door policy with regards to discussing safety on site'; and 'most efforts to make the workplace safer happen as the result of an accident'.
Figure 7 presents a graphical summary of responses.

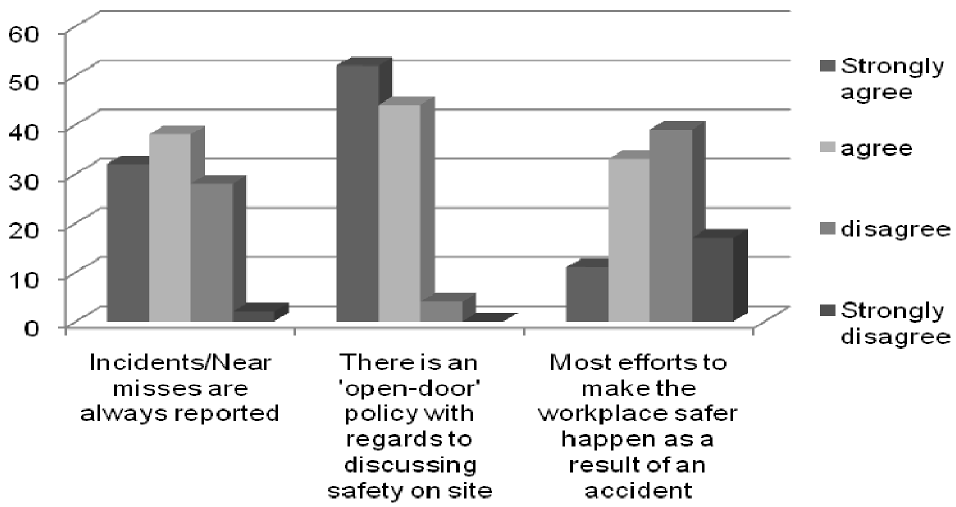

Figure 7 Perceptions Regarding Incident Reporting, Openness and Safety Improvements (by Percentage of All Responses)

Figure 7 indicates that around one third of all respondents disagree that accidents and incidents and near misses are always reported. When analysing respondents by region, around half of those surveyed in the Midlands disagree that near misses and accidents are always reported. This is greater than in any other region. This reflects the opinion of site based staff - Project Managers, Construction Managers and Engineers, where 50% of those surveyed also disagree that near misses and incidents are always reported. This is double that thought by those in office based roles. It would be fair to assume that site based staff are more aware of the reporting culture on site as they are directly involved in responding to reported incidents, unlike those in office based roles.

It has also been observed that those fairly new to the industry are more positive about the reporting culture than those who have a lot of experience in the industry. It is possible that those new to the industry are naive in thinking that people are very proactive in their approach to reporting. It may also be because those new to the industry are very keen and adaptable and possibly the most likely to report incidents themselves.

With regards to the organisation having an ‘Open Door Policy’ to safety, almost 100% of those surveyed either agreed or strongly agreed that there was an open door policy with regards to discussing safety and safety issues on site.

Figure 7 also shows that around half of those surveyed agreed most of the efforts to make the workplace safer happen as a result of an accident, and around half disagreed. On a regional level two thirds of those surveyed in the North-East and the Midlands, as apposed to only half those in the North-West and Yorkshire, either disagreed of strongly disagreed that efforts to improve safety are as a result of an accident. This could imply that the North-East and Midlands are slightly more proactive than the North-West and Yorkshire regions.

VIEWS CONCERNING SAFETY TRAINING

With regard to safety training, survey respondents stated the extent to which they agreed that: ‘the company has put sufficient resources into ensuring (my) safety’; .and ‘safety training within the company has changed the way I think and behave’.

Figure 8 summarises the responses.

Figure 8 Perceptions regarding Safety Training (Percentage of All Responses)

Figure 8 indicates that 96% of those surveyed either strongly agree or agree that the organisation has put sufficient resources into their safety training. There is no significant difference in the overall perception and agreement regarding safety training across the four regions. It is worth noting that an organisation-wide ‘Safety Training Matrix’ is applied across the regions.

Responses indicate that the longer a person has been in the industry the more they are inclined to disagree that the organisation has put sufficient resources into their safety training.

Maybe the organisation invests more time and money into the training of those relatively new to the industry as apposed to those with 25 years experience? Training is possibly delivered in an equitable manner to all with perception of sufficiency decreasing with sufficiency? These are questions worthy of further investigation. It would be wrong to assume that such an organisation does not value the training of those who have been in the industry a long time, or to presume that long serving personnel are viewed as having less to learn and less to gain from training than those new to the industry.

With regards to the effectiveness of safety training, around 90% of those surveyed either agreed or strongly agreed, that the organisations safety training had had an impact in changing their attitudes and behaviours on site. This is an early indication that the behavioural safety campaigns delivered by the organisation have had a desired effect. When analysing the results further, the only notable statistic was again that 100% of the directors surveyed agreed that the safety training within the organisation had changed their attitude and behaviour. This would suggest a strong belief by all directors of the organisation that the behavioural safety campaign is the way forward and that they are fully behind the campaign and prepared to lead by example on this.

CO-WORKERS AND HEALTH AND SAFETY

Figure 9 summarises respondents' agreement with the statements: 'my co-workers demonstrate a positive health and safety attitude and behaviour'; and 'I am also responsible for the health and safety of my co-workers.

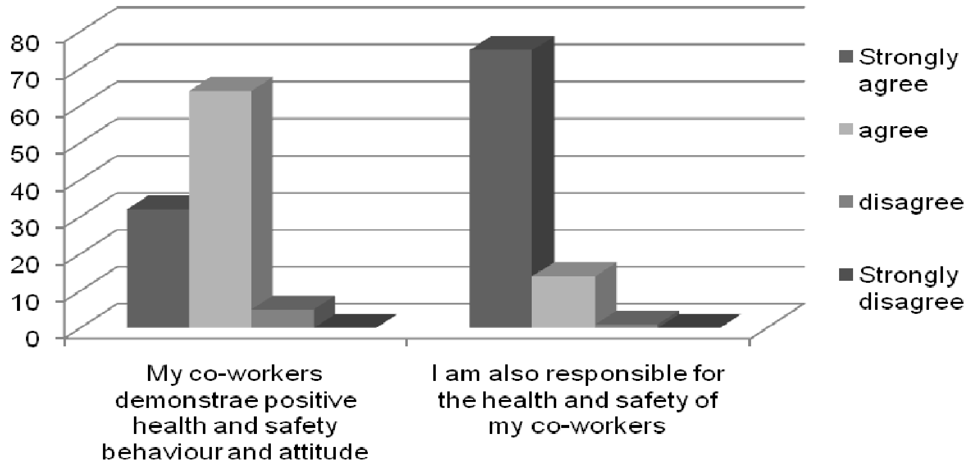

Figure 9 Perceptions regarding Co-workers and Health and Safety (By Percentage of All Responses)

Over 95% of those surveyed either strongly agreed or agreed that their co-workers demonstrated a positive Health and Safety behaviour and attitude. Once again there is no significant variance between the level of agreement and regional placement. There does however, appear to be a slight trend that would suggest that those who are relatively new to the industry agree more strongly that their co-workers demonstrate a positive health and safety attitude, in comparison to those with more experience. When studying the results by job role, again it the directors of the organisation who agree the most strongly that their co-workers have a positive health and safety attitude. The chart also shows that almost 100% of those surveyed agreed that they are responsible for the health and safety of their co-workers, 75% strongly agreeing. This suggests that the organisation has achieved an ownership with regards to health and safety, with everyone believing they have a responsibility to not only themselves but to everyone else, to act in a safe manner.

PERCEPTION OF PERSONAL SAFETY ON SITE
When asked 'How safe do you feel on your site?' the responses were overwhelmingly positive.

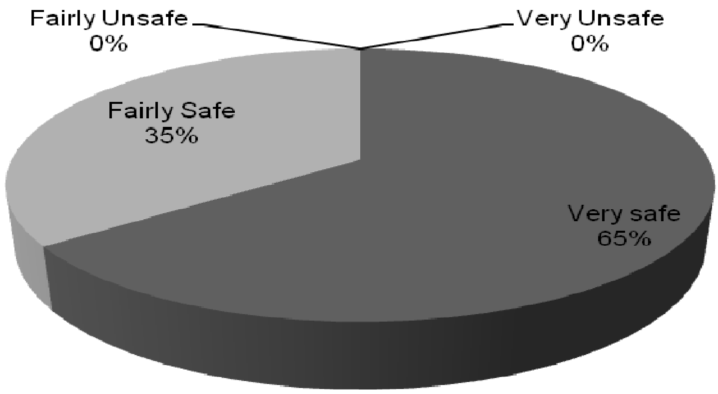

Figure 11 Perception of personal safety on site

65% of respondents stated that they felt 'very safe' on site, whilst 35% responded that they felt 'fairly safe'. It is apparent that respondents Clearly everyone goes to work and feels they are operating in a safe environment. From analysing the results further, there seems to be little to no difference in results between regions and considering the amount of experience of the respondents. When analysing the results by role within the organisation, it is again the directors whom are the most positive, with 91% of the surveyed directors strongly agreeing that the company's construction sites are very safe.

CONCLUDING SUMMARY
This study was intended as a singular case study investigation of a large UK-based main contracting organisation. Primarily the study served to explore safety climate differences within four of the organisation's different regions of UK operation. The exploratory findings of this study should not be inferred or generalised beyond this singular context.

The survey results do not indicate that there are significant differences in the attitudes and perceptions of employees from the four different regions of the case study organisation. Whilst interviews revealed that there is little communication between regional divisions, all four regions responded very similar in respect of the survey. This suggests a similar 'temperature' (Budworth 1997) of safety climate across the four investigated regions of the case study organisation.

This paper has sought to answer an experientially-grounded question– 'why is health and safety culture so variable on construction sites in different UK regions across the same organisation - particularly when management systems, policies and practices are the same across the organisation's construction sites? The results of the survey infer that differences in safety culture across the organisation's regions are not due to the safety climate attitudes and views held by the organisation's own staff at a regional level.

It could be suggested that significant variance in safety climate (and culture) occurs at an individual site level, rather than at a regional levels within the same organisation. This would provide an interesting further study. On individual sites, safety climate and culture is subject to influence from a variety of subcontractors, to name but one factor. Interestingly it was suggested in a number of follow-up interviews that there was a perceived noticeable difference (in safety culture) in having a supply chain approach and using repeated sub-contractors. Supply chain familiarity, it was suggested could contribute positively towards the maintenance of a positive culture. It was also stated that the safety culture can become challenged when the supply chain involve their own sub-contractors. Competency and attitude to work is then beyond the direct influence of the main contracting organisation. Further investigation of these aspects may provide worthwhile insight and findings.

Interestingly, this safety climate study indicates that those relatively new to the industry are generally more positive in their opinions and views. This positivity with regards to safety was also expressed by the case study organisation's company directors - who were most positive in agreeing of the importance of safety.

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CONSULTATION, ORGANISATIONAL MATURITY AND INFLUENTIAL DECISION MAKING AT THE WORKPLACE: HAS THE CONSTRUCTION INDUSTRY THE MATURITY TO ALLOW OHS REPRESENTATIVES REAL INFLUENCE IN THE OHS DECISION MAKING PROCESS?

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ABSTRACT

The consultation process is regarded as one of the major mechanisms for communicating and exchanging information and ideas between workers and management. The OHS representative is considered to be one of the major conduits for this information exchange to occur.

The construction industry is acknowledged as one of the most hazardous and dangerous industries in the world. In part, to overcome such problems, the concept of utilizing the knowledge and skill of those who are carrying out the work, via the process of consultation, has become a major component in the battle to counteract these hazards and dangers.

It is also recognized that the concept of strategic, upstream safety is pivotal in designing out and eliminating many of the hazards and risks that can occur during the building and construction phase.

Using data collected from the author's current research project, this presentation will give an insight into some of the initial findings of how consultation is conducted over OHS issues between the OHS representative and senior management of five different construction companies, deemed to have reached different levels of organizational maturity, and the array of OHS issues that are typically being addressed.

Keywords: Construction industry; Consultation; Organisational maturity; OHS representatives.

INTRODUCTION

The construction industry is acknowledged and renowned for its high risk and hazardous nature and has one of the highest injury and fatality rates across all industries (Australian Safety and Compensation Council 2008, 2005 a&b; Loosemore and Andonakis 2007; WorkSafe Victoria 2006; Cameron, Hare, Duff and Maloney 2006; Australian Safety and Compensation Council 2005a; Behm 2005; Walters, Nichols, Connor, Tasiran and Cam 2005; Hager 2001; Lin and Mills 2001; Hopkins 1995;). Both statistically and in real terms, it remains one of the most hazardous industries throughout the world (Loosemore and Andonakis 2007; WorkSafe Victoria 2006; Cameron et al. 2006; Australian Safety and Compensation Council [ASCC] 2005a; Lingard and Rowlinson 2005; Behm 2005; Walters et al. 2005; Australian Bureau of Statistics 2002; Cole 2002; Hager 2001; Lin and Mills 2001; Hopkins 1995).

There is an overall consensus that worker involvement in OHS via the process of consultation, is vital to OHS success (Cameron et al. 2006; Johnstone 2005; Worksafe 2005; Cooling 2005; Walters et al. 2005; Lingard and Rowlinson 2005; Wilkinson, Dundon, Marchinton and Ackers 2004; Page 2002; Hart 2002; WorkCover Corporation S.A. 2001; Blewett 2001, 2001a; Frick, Jensen, Quinlan and Wilthagen 2000; Health and Safety Executive [HSE] 2000; Fuller 1999; Haines and Wilson 1998; Committee on Health and Safety at Work 1972). In its most basic and fundamental terms, OHS success equates to the prevention of fatalities and serious injury and disease occurring at the workplace, which is the embodiment of the OHS philosophy. In hazardous industries like the construction industry, such OHS success is imperative.

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But is the presence and prominence given to the consultation process under both the OHS and industrial relations legislative framework, sufficiently adequate to support the philosophical underpinnings upon which the concept of consultation is established upon (Walters 2006; Johnstone 2005; Shearn 2004, Gollan 2003; Sargeant 2001)? This question is based on the concept that legislation by itself does not necessarily guarantee that the quality, richness and depth of consultation will occur[†]. According to Quinlan and Mayhew (2000):

> 'Knowledge of OHS legislation does not equate to compliance or even a willingness to try to comply' (p.194).

EFFECTIVE AND MEANINGFUL CONSULTATION

It is generally accepted both in Australia and internationally, that the effectiveness of the consultation process relies upon a set of common foundations and preconditions; issues such as trust, respect, support, a willingness to listen, honesty, integrity, sharing of information, sharing of power, adequate time; both in terms of the timing of consultation and time given for consultation, adequate resources, sincerity, security, inclusiveness and relevant training and commitment, are all considered to be required in one form or another if successful and meaningful consultation is to occur.

Such issues or principles, while not generally mandatory under any type of constitutional rule (which for the purposes of the research specifically referred to the OHS Act 2004 [Vic]) are arguably morally and ethically required under what Emmet (1966) described as constitutive rules of morality. Such rules or principles were claimed by Emmet as being necessary if a practice was to be considered moral or ethical and which, when enacted upon would enable a constitutional rule to be applied effectively. For the purposes of the research, the issues of trust, honesty, commitment and respect were eclectically selected to best represent both the constitutive principles of 'moral relativism' as described by Emmet (1966) and the principles upon which effective and meaningful consultation are broadly based upon.

Emmet (1966) believed that constitutive principles were primarily concerned with moral and ethical considerations and were influenced by people's ethical and moral beliefs and their cultural ways of life. Transposing this into an organisational and workplace context, the culture of the organisation becomes pivotal in determining how the issues required for meaningful and effective consultation are applied. This approach is consistent with the cultural concept of occupational health and safety, which supports the paradigms of social and cultural relations at the workplace (Hvid 2001). A useful model that espouses the social and cultural relations paradigms is the Hudson evolutionary safety culture model (Hudson 2003a).

HUDSON'S EVOLUTIONARY SAFETY CULTURE MODEL

The Hudson model is based upon an evolutionary process of organisational and cultural maturity, set out in a framework or scale of five maturity levels. Commencing from the bottom of the scale and working towards the top, the levels of the model are pathological, reactive, calculative, proactive and generative (see Figure 1). According to Hudson (2003a), the notions of organisational culture and the subsequent understanding of both safety culture and safety management, will differ according to the levels of cultural maturity that an organisation achieves.

Hudson (2001a) argued that true safety cultures are characterised by good communication and consultation between management and workers, which he believed not only enhanced levels of OHS but also elevated morale and productivity.

[†] Without meaningful consultation occurring, there is a risk that the knowledge and skills possessed by workers and their OHS representatives will not be fully utilized (Walters 2006, Walters et al. 2005). According to Smith (2001), the underutilization of knowledge means valuable human and knowledge resources are lost and wasted.

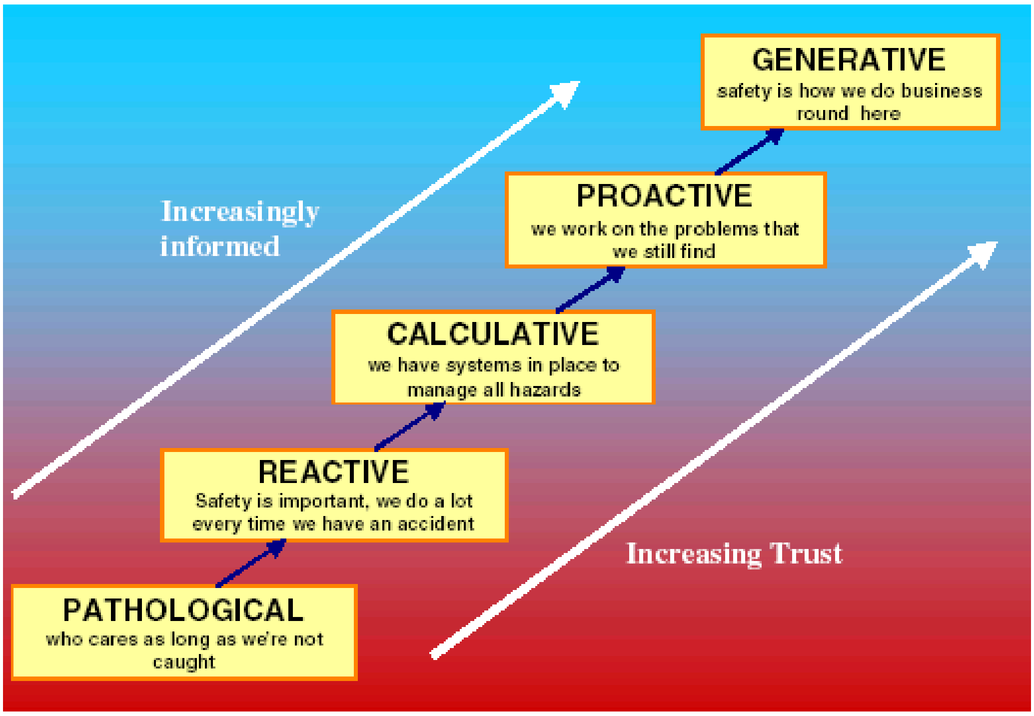

Figure 1: The Hudson evolutionary safety culture model Source: Hudson (2003a)).

The research

As the project was primarily designed as a qualitative piece of research, constructionism was chosen as a suitable and relevant epistemology (Crotty 1998). The theoretical perspective that laid behind the choice of the methodology for the project was that of interpretivism and within this interpretative theoretical perspective, it was decided that such symbols and interpretations were best viewed within a symbolic interaction approach. The research methodology utilized for the project was ethnography, with the methods of data collection being by a variety of methods and sources consistent with the case study methods and approaches of Genzek (2003), Yin (1998) and Sechrest et al. (1996).

The data collection phase consisted of a mixture of semi structured interviews with both project or site managers and the OHS representatives from each company, non participant observations (which included observations on site safety walks, OHS committee meetings and site safety tool box meetings) and a review and analysis of site and company OHS documentation. The data collection phase was managed over a period of approximately twelve months. The OHS documentation included company occupational health and safety management systems (OHSMS), site and company OHS policies, minutes from site or project safety walks, including copies of items listed or identified for rectification and copies of minutes of the site or project OHS committee meetings.

The selection of the companies for the case studies initially involved an appropriate number of construction companies, whose primary source of engagement within the construction industry was work carried out within the commercial and industrial sector of the Victorian construction industry[‡], being purposefully selected as potential participants. From this initial pool, twenty companies were again purposefully selected to be the basis of an expert panel selection process. This process required each panel member to allocate each of the twenty companies into one of each of the five levels or tiers that make up the framework of Hudson's model. Each company was unidentifiable to the panel members save for a number allocated to each company. The researcher provided each panel member with a dossier of information about each company based upon eight

[‡] The commercial and industrial sector of the industry is acknowledged as having greater potential for incurring major hazards and risks, and where consultation is seen as a vital element in the attempt to reduce and control such hazards and risks (WorkSafe Vic 2007, 2005).

observable OHS measures that were specifically tailored to the construction industry. This process was based upon a similar approach conducted by Parker, Lawrie and Hudson (2006).

The panel of experts were selected due to their familiarity and knowledge of research methods and their familiarity, expertise and experience in both the construction industry and in the field of occupational health and safety. A similar selection process for selecting and using an expert panel was implemented by Behm (2005) in his research linking construction industry fatalities and the concept of safe design. The use of an expert panel and purposive sampling allowed for the selection of unique informative cases, the selection of a specialised population and the identification of the particular types of cases for in-depth investigation (Neuman 2003); all of which were the requirements for the research.

After the companies were chosen and agreed to participate, each company was asked to nominate a project or site which they thought would most accurately reflect their companies approach and philosophy towards the process of consultation.

See Figure 2 for a diagrammatical overview of the sample selection process for the case studies.

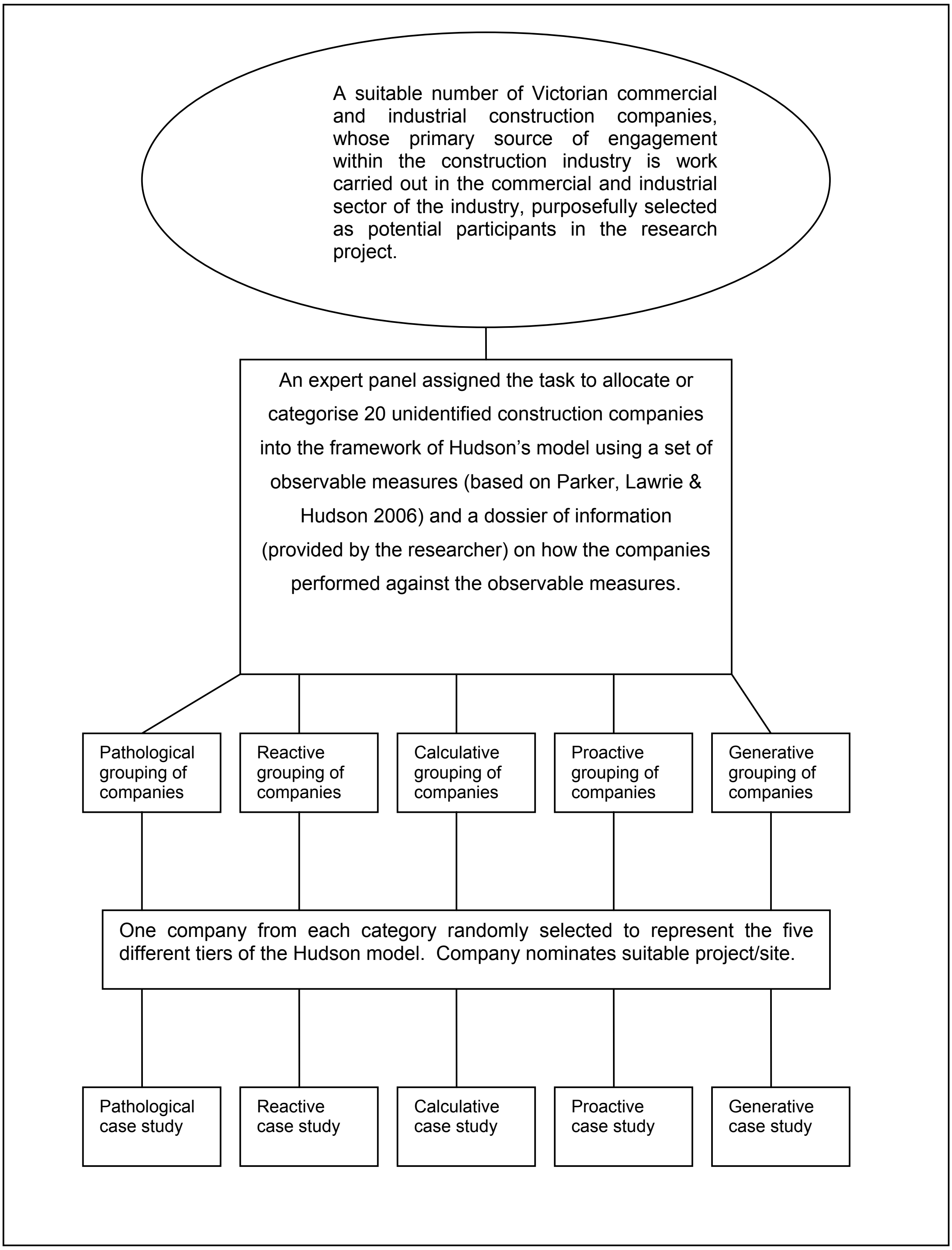

Figure 2: Diagrammatic overview of sample selections for case study.

DATA SUMMARY

The data revealed that in terms of consultation and the overall approach or at least belief in the concepts of the chosen constitutive principles (i.e. trust, honesty, commitment and respect) all participants, both management and OHS representatives, truly believed in the value and worth of both the process of consultation and the constitutive principles. However the application of the principles by the participants often became blurred and confused; especially by those companies at the lower echelon of the Hudson model. This lead to the OHS reps taking what appeared to be more of a subordinate or secondary role in terms of the OHS decision making process. Indeed all the OHS reps from all of the companies played no part in any type of strategic OHS decision making process or forums such as the company OHSMS or any of the OHS policies incorporated within the system.

The great majority of the OHS issues that the OHS reps were consulted over consisted of what Lunt et al. (2008) described as day to day trouble shooting issues; which while important in their own right, are not what most scribes would describe as strategic or high level and influential OHS decision making forums or processes.

What was also evident was that the only company who did not appear adverse to the OHS rep inviting officials of the trade union that the OHS rep was a member of onto site, to assist and provide OHS advice to the OHS rep, at least not without first gaining permission from the management, was the deemed Generative Company. Indeed the project manager of the Pathological Company believed that such trade union assistance was simply an alias for future industrial relations issues, and he believed he had a legal right not to allow officials of the trade union onto his project. The Generative Company was the only company who gave their OHS representative the autonomy to chair the site OHS committee meetings, to take charge of and lead the site safety walks and was the only company to provide their OHS rep with his own computer with access to the internet, allowing him unhindered and unrestricted use of the equipment. Such availability and use of the computer is an invaluable tool in today's electronic medium in terms of researching OHS issues or verifying and confirming OHS advice and or information.

In summary, the consultation approach or focus of the companies appeared to ensue along the following lines:

Pathological Company: Consultation over very basic day to day issues, with the OHS rep appearing to play a secondary role in the OHS decision making process over such issues. The OHS rep had no role in any strategic or high level OHS making forum; either on site or within the organisation as a whole. Consultation appeared to occur more at the behest of management rather than in a true consultative manner. The relationship between the project manager and the OHS rep appeared honest and respectful, although very heavily weighted in the managers' sphere of influence and approval.

Reactive Company: The consultation appeared to be based on basic day to day troubleshooting issues. While there was an apparent sharing and input by the OHS rep into the solutions to do with these OHS issues, the OHS rep appeared to play no part in any high level or strategic OHS decision making process within the organisation. While the relationship between site manager and OHS rep appeared very trusting, honest and harmonious, the site manager appeared to be very much in charge of the final OHS decision making process.

Calculative Company: Day to day trouble shooting issues appeared very much the focus of consultation. Project management did however inform the OHS rep of upcoming works and events that may impact upon levels of OHS and which would be considered to be influential in terms of the site layout and works to be carried out on site. The project manager and the OHS rep appeared to have a very honest and open relationship, with the project manager making time to have one on one discussions over OHS issues with the rep. Final OHS decisions appeared to be focused on managerial approval; however the project manager actively listened and appeared to strongly consider and welcomed the OHS reps' opinions and points of view. However there was no involvement by the OHS rep in the company OHSMS.

Proactive Company: The majority of issues over which consultation occurred appeared to be day to day or troubleshooting and reactive issues, although some issues could be described as influential in terms of works to be carried out on the site. The OHS rep was kept informed of upcoming and future works that may impact upon levels of OHS on the site; however the final decisions over strategic or high level OHS issues appeared to be at the behest of the site manager. The OHS rep played no role in the OHSMS of the company or other high level or strategic OHS decision making forums.

<u>Generative Company</u>: Majority of the consultation appeared to be around day to day troubleshooting issues; however the OHS rep did have limited input into certain influential long term site OHS issues. The OHS rep of the Generative Company was the only rep out of the five OHS reps that was given the autonomy to chair the OHS committee meetings, site safety tool box meetings and to lead the site safety walks, however he had no influence or input into the company OHSMS. There appeared to be a very trusting, honest and respectful relationship between the site manager and the OHS rep, with both parties appearing to be genuinely committed to the process of meaningful and effective consultation.

CONCLUSION

Collins (1994) described industrial democracy, employee involvement and consultation in terms of '…a continuum to help express the fluidity of the concept as a whole…' (p.17). This continuum demonstrated different levels or stages where workers had virtually no input or influence over decision making, right through to where workers had equal control to that of management.

Davis and Lansbury (1996) claimed that the term industrial democracy has been gradually replaced by terms such as employee participation and consultation in the terminology of industrial relations. They argued that the concern should not be over the terms or labels used to describe the process, but rather should focus on the amount of influence employees could exert on the decision making process. This, they suggested, was best gauged in the degree of influence the employee or employee representative had and the sorts of issues they were capable of influencing.

Frick et al. (2000) claimed that while most voluntary OHS management systems may include recommendations to consult with workers, typically the consultation process in such management systems entails very little if any sharing of decision making power. Walters (2003) held a similar position and argued that despite all the rhetoric that effective consultation supports and reinforces the notion of OHS management systems, systems which in turn should lead to increased levels of OHS performance, he believed that the majority of OHS management systems are generally managerialist, rather than truly participative. According to Saksvik and Quinlan (2003), workers and their OHS representatives have had a very limited role via consultation, both in the design and the improvement of systematic occupational health and safety management.

According to Lunt et al. (2008), past research specifically targeted at the construction industry has indicated that the type of involvement or engagement that the majority of construction workers, including OHS reps, have within the industry is more focused

> '… on surface/reactive issues … . In other words the workforce has little influence on safety management systems, which are generally formulated without their input.' (p.27).

The data from the research project appears to support and reinforce the above viewpoints. All the OHS representatives who took part in the project only appeared to deal with and were primarily only consulted over day to day troubleshooting and reactive issues. They appeared to have no input or influence into either their company OHS management system or other strategic OHS decision making forums on their projects; either as individuals or via their site OHS committee. Walters (2003) acknowledged the arrangements of joint health and safety committees both in Australia and the UK, but he also questioned their role and indeed their influence to undertake more strategic roles in keeping health and safety performance and arrangements under review; rather than simply being used to address the day to day issues at a workplace; a role that all the OHS committees observed in this research appeared to do almost exclusively.

Walters (2003) believed that there was overwhelming evidence that proved that in order for meaningful and effective consultation to occur, the OHS rep not only required adequate training and information, but the opportunity to openly and freely investigate and communicate with their members and have the correct and proper channels to engage in dialogue with management over problems and changes planned for the workplace. Walters (2003) argued that this process and indeed the ability of the OHS rep to autonomously represent their members effectively, is dependent upon strong trade union support.

The evidence from the data collected in this research project seemed to suggest that the majority of companies, other than the Generative Company, were wary of trade unions entering their workplace and engaging with the OHS rep and other workers on the site over OHS issues. In addressing the concerns of the pathological project manager that OHS issues may be used as an agenda item to further delve into the general realm of industrial relation matters, Saksvik and Quinlan (2003) argued that there is a *'… longstanding, artificial and historically contingent separation … between industrial relations and OHS found in most industrialized countries…'* (p.43); a separation which they argued is based purely on ideological grounds.

Saksvik and Quinlan (2003) claimed that worker involvement has been significantly undermined by inadequate enforcement and the erosion of collective industrial relation laws. They further believed that the involvement of workers in OHS is still very much problematic, with only trade unions providing any long term and effective logistical support to many formal OHS participatory mechanisms and providing a channel for worker representation and meaningful negations over OHS issues. According to Saksvik and Quinlan (2003), the decline in union density and collective employment regulation over the past twenty years has lessened the participation and co-operation between the parties. While the full effect that this may have had on levels of OHS in the workplace is yet to be fully and critically assessed, there is enough evidence to suggest that there are fewer effective workplace OHS committees and OHS representatives, and that the lessening importance of tripartite collaboration has reduced the influence and role that workers have been able to play in terms of vetting OHS management systems and other strategic OHS decision making forums (Saksvik and Quinlan 2003).

In terms of worker and OHS rep involvement in more upstream and strategic OHS issues, data collected from this project appears consistent with the general literature overview of low worker involvement in such processes and forums. This is arguably a great pity, as the knowledge and skills of workers is potentially being underutilized. According to Rooke and Clark (2005), there is a vast reservoir of unrecognized knowledge and skills possessed by workers in the construction industry which, if it continues, will ultimately be to the detriment of the industry; especially in terms of levels of OHS.

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PICTORIAL AIDS FOR COMMUNICATING HEALTH AND SAFETY

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ABSTRACT

Approximately 8% of the UK construction workforce is from overseas. Recent studies show several barriers for migrant workers including language and communication difficulties. This has obvious implications for the management of health and safety. This paper discusses the effectiveness of pictorial aids for communicating hazards and controls on construction sites. A lexicon of 118 critical H&S terms was developed through content analysis of worker induction guidance. A pictorial inventory of images was developed, tailored to the lexicon. The images were tested for comprehension amongst 50 migrant workers. A threshold of 85% (43) correct interpretations of each image was set. Demographic data was also collected. Only 23 images failed and were altered before re-testing to satisfactory levels. Workers from European countries (n: 42) identified more images correctly (m: 102) than workers from African and Indian origin (n: 8; m: 87). 50% of workers had less than 5 year's construction experience. Those with less than 5 years experience scored less (m: 95) than those with more experience (m: 105). Pictorial aids can communicate simple hazards and controls. However, only experienced workers (with prior knowledge) scored higher. Therefore, if a concept is new to the worker, understanding will be low. This highlights the importance of prior training. Furthermore, cultural differences may distort comprehension. However, the images should supplement existing communication methods, not substitute them. The images developed are now in industry guidance for site managers.

Keywords: Communication, Images, Pictorial

INTRODUCTION

Researchers investigating migrant workers in UK construction estimate that there were approximately 88,000 non-UK workers in the industry in 2003, with most employed on short-term contracts (HSE 2006b: App A3). More recent sources estimate the figure to be around 8% of manual workers (CCA 2009). This figure is dominated by Eastern Europeans; with 70% from Poland (ibid). Migrant worker deaths in construction have also climbed in recent years to 17% of the industry total (n:12) for 2007/08 (ibid). Based on these figures, migrant worker fatalities are twice the expected number.

Research investigating worker engagement in construction (HSE 2006a, HSE 2006b), has found that the language and communication difficulties of non-English speaking workers in the industry is a growing problem, with obvious implications for, amongst other things, worker engagement and the management of health and safety. These studies have made recommendations for a detailed study of methods of communicating with non-English speaking workers to ascertain how these language barriers can be overcome.

Strategies adopted by construction companies to overcome these barriers include: bringing workers - who speak the same language - together in small groups with an English speaking leader (in some cases identified by a uniquely coloured hard-hat) to act as an interpreter; `buddy' systems where a foreign worker is paired with a colleague of the same nationality who can speak English; using external translators; providing English language courses; translating risk assessments or method statements into the worker's own language; and pictorial methods of communication.

Using workers as interpreters can have drawbacks, for example when that person is not available. Providing English language courses can be expensive but are considered the best long-term investment. English for Speakers of Other Languages (ESOL) courses are available for specific vocations, including construction. These invariably include material on health and safety which incorporates a glossary of terms and some pictures or diagrams (see Cottom 2005: Section 4). The Health and Safety Executive (HSE) have recently translated some of their guides into foreign languages to aid the communication of risk assessments and method statements; though this approach may hinder the integration of foreign workers as it can discourage learning of English. This conclusion is also supported by a recent Government Research Report (CoIC 2007).

Pictorial methods are usually found on safety signs and posters. However, their application to direct communication of health and safety information has received little attention. This paper discusses the effectiveness of pictorial aids for communicating hazards and controls on construction sites. The following section explores work done in this area, followed by results from recent research completed by the authors.

USE OF IMAGES

Recent attempts to develop images to tackle communication problems on construction sites include: development by The Irish Health and Safety Authority (HSA) of `pictograms' for the communication of health and safety messages (HSA, 2008); images of do's and don'ts `the silent book' (NCC2000); and the "Trojan Horse" project (HSE 2005). However, these have not been developed in line with any recognised standards. Instead they have been produced in an `ad-hoc' manner in response to particular local needs. Despite this, academic research has shown that hazard communication is done best with the combination of text and well-designed pictorial symbols (Kalsher et al 1996; Wilkinson et al 1997; Young et al 1995).

Even with well designed images, the competence of the worker needs to be established. Interviews with a sample of migrant workers have found that most had not received any training (HSE 2006b). Further, in cases where training had taken place, no attempt had been made to establish whether this was understood by the workers. Research conducted in the USA found that providing training to non-English speaking construction workers did not actually result in reduced accident rates amongst these workers (Halverson 2003). Therefore, testing understanding may be an important requirement. This is certainly a fundamental factor in most theoretical models of communication (Schramm 1965; Rogers & Kincaid 1981; Wogalter et al 1999). Testing pictograms and safety phrases for comprehensibility is covered by the United Nations document "Globally Harmonised System" (GHS) of Classification and Labelling of Chemicals (UN 2005). Halverson's research results may also be explained by the influence of 'culture'. Whatever the influences at play, merely providing training will not guarantee improved safety behaviour.

However, developing methods of effective communication is an essential starting point and logic suggests that core 'safety critical' words and phrases and supporting pictorial materials would be highly advantageous tools with which industry could begin to address the problem of effective engagement of migrant workers. Similar recommendations have been made with regard to construction specific training for second language speakers (Schellekens & Smith 2004).

To date, only extremely limited lists of H&S words and phrases exist in ESOL teaching materials. Likewise, examples of pictorial methods of communication are fragmented with little or no evidence of their suitability or impact (the Trojan Horse project being the only exception). In addition to this, unrecognised cultural barriers may exist. For example, caricatures and cartoons may be regarded as belittling and different cultures can interpret the same sign differently.

METHODS

The authors wanted to develop a suite of validated images to help communicate generic information such as the main hazards to expect on a construction site, simple site rules and safety procedures. The UK Construction Skills Council commissioned the authors to develop materials for this purpose, which included the development of images for use during site induction training. This type of induction training is intended to cover site specific hazards as opposed to a general induction into the employer's organisation.

The objectives of the study were:

1. To develop a lexicon of critical H&S terms;
2. To develop a pictorial inventory of H&S images based on the lexicon;
3. To develop communication materials based on the lexicon/images;
4. To pilot the materials via industry stakeholders
5. To test the materials for comprehension with migrant workers;
6. To develop guidance, incorporating the materials

A lexicon of critical H&S terms was created, which focused on terms relating to higher risk and most frequently encountered construction hazards. Information that needs to be communicated by law was also included, e.g. emergency procedures. However, the list was limited to hazards encountered by general operatives due to the time constraints on the project. Specialist work, such as asbestos was also beyond the scope of the lexicon. This resulted in the following definition of "Occupational Safety and Health (OSH) Critical Hazards" for the purpose of the study:

Safety hazards that feature in most fatal and major accidents or are most common on construction sites, health hazards resulting in most lost time and in all cases those hazards most likely to be encountered by 'general operatives'.

HSE accident statistics were used to identify high risk activities. These consisted of:

1. Fatal accident statistics;
2. Major accident statistics; and
3. Lost days through ill health statistics.

Supplementary HSE reports and publications were also used. This included the publication "The absolutely essential health and safety toolkit for the smaller construction contractor" which lists "some of the hazards most commonly found on construction sites" (HSE 2004).

Documents required for content analysis were obtained in electronic format to aid the process. Three main types of documents obtained were: CITB-ConstructionSkills documents (e.g. tool-box-talks); HSE's website; and Contractors' in-house worker guidance (Method Statements/Risk Assessments/Tool-Box-Talks).

The content analysis consisted of the following steps:

1. Read the page or section, then re-read line by line;
2. Line by line labelling of text as "activity" "hazard" "risk" or "control";
3. Creating a row on a spreadsheet showing the activity, hazard, risk, and control, along with a reference number indicating the source document and page/section;
4. Manually re-reading the rows to consolidate duplicate items;
5. Checking for "saturation" (no more new rows being created from the analysis).

Duplicate items were minimised during analysis by using the "search" function. If two similar activities were identified they were consolidated. Invariably, this resulted in the same hazard accumulating additional risks (consequences) and multiple controls. Note that the controls identified from the guidance were those relating to the workers' own span of control. Therefore, principles of prevention such as "combat at source" and "design out the hazard" were not present in the 'worker guidance' analysed. An extract from the "hazard-risk-control" database is shown in Table 1 below. The source documents have been referenced; in this extract the issue of correct ladder angle has been identified in four documents.

RAW DATA		ANALYSIS					
Item	**Ref**	**Text**	**Activity**	**Sub-activity**	**Hazard**	**Risk**	**Controls**
88	CSTBT24	Ladders should be set on a firm base and lean at the **correct angle which is one unit out to four units up.**	work at height	ladders	ladder at wrong angle	fall	ladder at one-out four-up angle
	HSE INDG405	Ladder angle **75o** – **1 in 4** rule (1 unit out for every 4 units up)	work at height	ladders	-	-	-
	CSTBT29	Make sure the ladder is at the correct angle, **one unit out to four units up.**	work at height	scaffold	-	-	-
	CSTBT30	Ladders must be rested at the correct angle (**1 unit out for 4 units up)**.	work at height	ladders	-	-	-

Table 1: Extract from Hazard-Risk-Control database.

The content analysis stopped when no more new rows (or very few) were created from the next document to be analysed. This is known in research terms as “saturation”, but can be described in general terms as “the law of diminishing returns”.

A review of current H&S images was conducted to support the lexicon (essentially a safety-critical word-list). The sources of images were:

- AEM Pictorial Database (AEM 2008)
- BS 5499 graphical symbols and signs (BSi 2002)
- CIRIA C662 CDM 2007 Construction work sector guidance for designers (CIRIA 2007)
- HSENI Universal Safety Book for Migrant Workers (HSENI 2008)
- HSE Getting to grips with manual handling: a short guide (HSE 2008a)
- HSE Asbestos kills protect yourself! (HSE 2008b)
- NCC Construction The Silent Book (NCC2000)
- Haskell’s Safety Alert System (Angelo 2004)

These were used to create a single database of 557 generic images using categories: activities/hazards/risks/controls. Annotation of the images allowed categorisation and mapping to the lexicon database. Microsoft Excel/Access software was used to enable annotation and categorisation of images. This software allowed analysis of both text and images in one environment to reduce the potential problem of incompatibility. This also facilitated quick and easy retrieval of images and subsequent mapping to text (see Figure 1 – images mapped to item in Table 1).

Figure 1: Extract from Hazard-Risk-Control database (images).

The original images used for analyses were not included in the materials developed to avoid issues of copyright. Instead, new images were developed from the originals using Adobe Illustrator software (Figure 1). When no original image existed to mach a phrase similar themed images were used, as a point of reference, to guide the development of the new ones.

This database was used to develop various materials, including a suite of 118 induction training images (see examples shown in Figure 2). These were chosen from the main database by searching the terms covered in generic industry guidance for induction training.

Figure 2: Example images for induction training.

The main categories, developed from industry guidance for induction training, are as follows:

1. Site details
2. Site security
3. Site layout
4. Site entry
5. Emergency
6. Fire equipment
7. First aid
8. Accidents
9. Welfare
10. Risk Assessment / Method Statement
11. Work equipment
12. Alcohol/drugs
13. Smoking
14. Personal items
15. Concerns
16. Discipline

The induction images were validated via industry experts (two workshops of 12). This resulted in 40 alterations to the images. These were then tested for comprehension amongst 50 migrant workers; the minimum international standard for statistically significant comprehension testing (UN 2005). A threshold of 85% (43) correct interpretations of each image (among the 50 workers) was set. This acceptance figure was based on USA guidance (ANSI 1998) as no official threshold is given in UK standards.

Three sites were chosen from the contractors within the workshop membership for worker comprehension testing. They were purposefully chosen to achieve a stratified sample covering two dimensions:

- Large, medium and small projects; and
- Equal geographical distribution.

To achieve this, the three sites were:

- A regional contractor's site in Stirling (Scotland);
- A national contractor's site in London (South England); and
- A multinational contractor's site in Manchester (North England).

On the day of the site visits the site management team were asked to randomly choose workers of between four and six groups (plus the site interpreter) to be interviewed. This selection process was more of a choice of convenience, dictated by work patterns, weather and availability, which is expected during real-world research. The site interpreter explained the reason for the interview and obtained the answers to the demographic questions.

The images were then presented to the workers. These were printed on A4 landscape, six images to a page (image size 60mm x 60mm). Guidance on the presentation of images states that it is best to present one image per page. However, this had to be balanced against the volume of images to be tested and the overwhelming number of pages this would have produced. This could have prevented workers from participating.

The testing consisted of asking the simple open question "what does this mean?" occasionally, the question was "what would you do if you saw this image?" Group interviews were necessary due to time constraints. However, having only one interpreter meant that only one individual could answer at a time (via the interpreter). This presented the potential problem of copy answers from other members of the interview group, once they had heard the first answer. Therefore, a different member of the group was asked to respond first for each image. The answers were recorded against a copy of the images for later analysis.

Analysis of the results consisted of aligning the following categories to answers (United Nations 2005, BSi 2007):

1: correct
2: partially correct (some element correct but not all of it)
3: incorrect
4: total opposite
5: don't know

FINDINGS

Demographic data for the sample of workers are shown in Table 2. This shows nationality; age; occupation; experience (in years); time in the UK (in years); and a language score based on the interpreter's assessment of the workers ability to understand and speak English (explained later).

Factor	Divisions					Total
NATIONALITY	Europe	India	Africa	-	-	
Number	42	5	3			50
AGE	16-25	26-35	>35	-	-	
Number	13	29	8			50
OCCUPATION	Woodwork	Labourer	Concrete	Brick/Block	Other	
Number	17	13	5	3	12	50
EXPERIENCE	≤ 2 years	>2 : ≤ 4	> 4 : < 12	≥ 12 years	-	
Number	11	13	12	14	-	50
TIME IN UK	≤ 1.5 years	> 1.5 : ≤ 2	> 2 : ≤ 3	> 3 : < 5	≥ 5 years	
Number	9	11	11	10	9	50
ALTE	≤ Level 1	Level 2	Level 3	Level 4	Level 5	
Number	18	8	9	9	6	50

Table 2: Demographic data.

The workers were mostly Eastern European: Polish; Lithuanian; Romanian; and Czech. These are the dominant migrant populations in UK construction. The remainder were African (Nigeria and Ghana) and Indian. The majority of workers were aged 26-35. The eight workers over 35 years consisted of four under 40 and three under 50. The oldest was 53. Woodworkers and labourers made up the majority of the occupations. Those labelled as ‘other’ included steel fixers, lift engineers, window fitters a banks-man and a roofer. The length of experience (in construction) was uniformly spread among the sample as was their time in the UK.

The workers were also assessed on their English Language ability. This was done using the Association of Language Trainers in Europe (ALTE): language “can-do” statements for work environments. The interpreter used these can-do statements as a guide to assess the workers’ level from lowest (zero) to highest (five). This assessment tool has already been validated and provided a readymade instrument to measure language ability.

Although the purpose of the site testing was to validate the images, the above data allowed cross reference to test scores for assessment of demographic factors on ability to understand the meaning of the images. Average scores (from a maximum of 118) were cross-tabulated to each of the above categories.

European workers scored an average of 102.4 correct answers, whereas non-European workers (African and Indian) scored an average of 86.6. Age and experience factors were (as expected) closely aligned. Average scores increased slightly then dipped, as did experience (see Tables 3 and 4). Those aged 26 and over had an average score of 101.6. Those under 26 had an average of 95. Similarly, the combined average of the two lowest experience groups was 95.1 with the higher experienced groups returning an average of 104.7.

Age	16-25	26-35	>35
Number	13	29	8
Mean Score	95	101.69	101.25

Table 3: Age.

Experience (years)	≤ 2	>2 : ≤ 4	> 4 : < 12	≥ 12
Number	11	13	12	14
Mean Score	94.09	95.15	105.17	104.29

Table 4: Experience.

Experience (years)	≤ 2	>2 : ≤ 4	> 4 : < 12	≥ 12
European				
Number	9	9	11	13
Mean Score	98	97.22	106.64	105.46
Non-European				
Number	2	4	1	1
Mean Score	76.5	90.5	89	89

Table 5: Experience per nationality .

The categories ‘occupation’, ‘time in the UK’ and ‘language ability’ returned no patterns. The only exception was the concrete workers, who had a lower than average score of 85. However, they were all Indian, therefore, nationality was the true issue. Since both ‘experience’ and ‘nationality’ influenced understanding, a cross-tabulation was performed showing mean scores based on experience sub-divided between European and non-European workers. The numbers at this level of analysis are very low, especially non-European workers. However, non-European workers with 2 years experience or less had the lowest scores (m: 76.5), whilst European workers with 4 years experience or less had lower averages than those with more than 4 years experience.

DISCUSSION AND CONCLUSIONS

A total of 118 induction images were created. Of these, 103 were correctly understood by at least 85% of the migrant workers who tested them for comprehensibility. European workers understood more images than workers from Africa and India. This could be due to harmonisation of safety signs (on which most of the images were based) between UK and other European countries. However, this finding also shows how cultural differences can impact on workers’ ability to understand images and raises questions of possible cultural or technological differences affecting comprehension.

The experience of the workers also influenced comprehension. Those with more experience may have been exposed to more training, hazardous activities etc. therefore, were probably better able to match the images to their memories of site rules, hazards and safe procedures. Whilst the current body of knowledge on this subject acknowledges the impact of cultural differences, the cognitive understanding of the receiver has had little attention. There was also some evidence that experience influenced both European and non-European workers and is potentially the most dominant factor. It was also interesting to see that the level of English understanding did not influence the worker’s ability to understand the images.

The study has found that pictorial aids can communicate simple hazards and controls relating to site induction training. However, only experienced workers (with prior knowledge) fully understood the images. Therefore, if a concept is new to the worker understanding will be low. This highlights the importance of prior training. However, this limitation could also mean that the level of comprehension (of the images) can be used as a measure of knowledge and understanding of safe methods of working. However, the images should supplement existing communication methods, not substitute them.

The sample of 50 workers satisfied the requirements of this study but full statistical analysis of demographic factors could not be performed satisfactorily. Therefore, future research with larger sample sizes could help reinforce the findings. Further, the use of group interviews presented methodological problems when individual interviews would have been more suitable to prevent group influences. This problem was partially addressed by rotating the sequencing of interviewees’ answers. However, this limitation is acknowledged.

Despite the limitations of the methods used, they can be used by academics and industry practitioners alike to test either existing images or newly developed ones. Simply assuming that clip art, safety posters or commercially developed images will automatically communicate safety information is erroneous. Whereas testing for comprehension amongst workers will give some level of confidence that they actually work.

The images developed are now in industry guidance for site managers, as part of the Construction Skills publication "Construction Site Safety" (GE 700).

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CHALLENGES TO EFFECTIVE OHS CONSULTATION ON LARGE CIVIL CONSTRUCTION PROJECTS

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ABSTRACT

Major construction sites place a heavy emphasis on OHS management systems which generally take the form of documented policies and procedures. However, these do not always capture the hazards associated with the many non-routine jobs on constantly changing sites. Data for this project was gathered from focus groups comprised of individuals who attended 4-day OHS Consultation courses for OHS representatives and OHS committee members. Some in-depth interviews were also conducted to further explore worker perceptions. Workers often perceive that management place more emphasis on getting paperwork correct, rather than listening to their ongoing health and safety problems. The heavy reliance on paperwork silences the many workers who struggle with literacy. The boss vs. worker struggle often means that workers are reluctant to speak up with their real safety concerns. The constant drive to keep costs to a minimum creates a message that OHS is not as important as profits and can result in cutting corners. Many subcontractors make minimum safety efforts and many of the OHS representatives do not have the skills or confidence to bring their concerns to managers who are perceived to care little about answering the hard questions. Workers notice what managers pay attention to rather than what they say or what the procedures/documents say. Eight real examples of difficulties with making OHS consultation effective are explored. Recommendations are made for improved training for OHS committee members, and the importance of site supervisors to have good people management and leadership skills is discussed.

Keywords: Consultation, Management commitment, OHS representation

INTRODUCTION

In this paper I discuss the challenges to effective OHS consultation and, thereby, effective management of OHS on large civil construction projects. I firstly provide some background information to help us understand the context of OHS in the construction industry and then review some literature that discusses the management of OHS and in particular, OHS consultation. I follow this with an outline of the methodology used for this research and then present a discussion of the findings. Finally I offer some recommendations and implications to consider for the improvement of OHS consultation in the construction industry.

BACKGROUND

The construction industry is a high-risk industry (Stromm, 2001) with a high incidence of workplace deaths, injuries and diseases (WorkCover NSW, 2001) and a poor safety record (Blockley, 1996). According to Worker's Compensation statistics, the construction industry in Australia has the highest number of work-related fatalities (ASCC, 2009) and the fourth highest incidence of employment injuries (ASCC 2009) of all industries. The incidence of injury in the construction industry throughout Australia is 50% higher than the all industry rate (Breslin, 2004). Despite this high toll these statistics do not accurately portray the real picture in the industry (Mitchell and Boufous, 2005) because workers compensation data does not include sole trader subcontractors who constitute a large proportion of workers in the industry (Wadick, 2007), and does not accurately reflect the number who suffer permanent or fatal work related diseases (Cowley, 2006).

LITERATURE REVIEW

The Robens report (Robens, 1972) heralded the modern approach to OHS by providing for a statutory duty of care requiring all employers to provide safe workplaces and stressed the importance of consultation with workers. This is exemplified by modern legislation in Australia that requires all employers to consult with workers about health and safety matters and to use a risk management approach to managing OHS hazards. Much OHS literature takes a technical rational (Williams, 1993, Labisch, 1985, Ineson and Thom, 1985, Senge, 1996, Dwyer, 2000) approach to managing OHS as many professionals see the issues as largely technical: exposure limits, ergonomics, guarding and so on, that is, industrial hygiene rather than industrial relations (Hopkins, 1993). However, successful OHS outcomes require more than this, they require the engagement of the workers because employment relations remain a major factor behind health and safety at work (Frick and Wren, 2000). OHS legislation ignores organisational factors such as power structures, incentive payments, and production pressures that encourage hazardous practices (Johnstone and Quinlan, 1993). Legislation requiring a safe workplace and OHS consultation opens up the possibilities for new practices of safety, but they do not ensure them because knowledge of consultation itself is not enough to act, there needs to be a 'capacity to act' (Senge, 1996). Legislation has merely opened a discussion and given permission, it has not shown how.

Research demonstrates that OHS consultation can lead to better OHS outcomes (Walters and Frick, 2000), although the effectiveness of OHS reps in not always clear (Nichols, 1997). Consultation and worker participation pave the way for a new paradigm for OHS designed to give workers a real voice in negotiating working conditions and OHS, but it does not automatically result in improved health and safety (Dwyer: 2000). Workers and OHS reps need to be assertive in exercising these rights (Johnstone, 2004) and the effectiveness of such participation will depend on how they can formulate and speak up for their views (Walters and Frick, 2000).

In the following sections I explore what I think are some significant factors that impinge on the success of OHS consultation contributing to better OHS outcomes.

Society, culture and schooling

Firstly we all come from a culture within which we live and are socialised. In western societies children go to school for up to 13 years. Conventional schooling does not really prepare people for democratic learning (Caspary, 1996). Here they learn the lessons that they must do what they are told or they will get into trouble, that their opinions are not really valued, and that their best defence is to not make waves and be perceived as a trouble maker. The pedagogic practices of the school classroom and administration make possible both what can be said and what can be done (Walkerdine, 1984); students learn to be combative and resistant (Caspary, 1996). This does not give us a good grounding in speaking up, and it is difficult for workers to believe that they now can speak up with impunity.

History of labour relations

Historically in workplaces there has been an underlying tension between liberal economic principles of capitalism, the obligations of governments to protect peoples, and the workers clamouring for a better deal. Workplaces in the western world are safer now than in the early days of the industrial revolution, but the tension still exists; neo-liberalism is a powerful influence and costs and "bottom line" thinking still underpin our economic system. In the capitalist system of production there is a fundamental underlying conflict of interest between profit and safety (Creighton and Gunningham, 1985, Hopkins, 1993). Industry's main goal is profit, and the workers main goal is survival. After 200 years of OHS regulation there is still a high incidence of workplace injury and disease because employees and employers have conflicting interests (Nichols and Tucker, 2000), yet this conflict is ignored in much OHS literature (Nichols and Tucker, 2000)

OHS has not been seen as an industrial relations matter for bargaining, which was often limited to hours, wages and conditions. Once governments enacted OHS legislation (for example, the factory acts from the early 1800's), it further reinforced that OHS was a matter for governments to control (Quinlan, 1993). Pre the 1970's, OHS had been excluded from the realms of collective negotiation and consultation between labour and capital, which suggests there is no history of the modern requirements to consult. Traditionally, workers have not been encouraged to speak up – they have the knowledge, and they have views, but can/will they express them? They have been dissuaded in the past from speaking up; will they now trust that they can? Employers cannot suddenly create trust through a policy when they have not engendered trust through their actions (Covey, 1989).

OHS consultation, then, is situated in the labour relations context, which moves OHS into the arena of a social construct (Walters and Frick, 2000). Based on the many stories that I hear in my courses, management is making the mistake of thinking that they can separate OHS consultation from the effects of the local industrial relations at each particular workplace. They are inseparable.

From the beginning of the industrial revolution the *worker versus boss* struggle has been spoken into existence through years of mistrust and abuse, and this constrains workers willingness to speak up. The employers still have the power, or management prerogative, to tell the workers what to do, and the workers still rely on the employer to give them a job. The modern push for OHS consultation overtly empowers workers but it can almost be perceived as little more than a 'sham' (Gunningham, 1985) because there is still no real shared authority or decision making. Coupled with this is the modern decline in trade unions (Dwyer, 2000; Walters and Frick, 2000), which traditionally have been the main voice of labour in challenging unrelenting demands on their bodies.

OHS is liability driven

Duty of care requires all persons concerned in the management of an organisation to ensure a safe workplace as far as is reasonably practicable. The onus of proof has been thrust onto the duty holders and this is sometimes breeding a liability culture in which improved OHS outcomes are being subsumed by the perceived need for an auditable paperwork trail. This has been termed 'degenerate OHS activity' by Yossi Berger (1999) and can result in a 'paper tiger' (Frick and Wren, 2000) in which having the paperwork correct becomes reified as more important than actual health and safety.

One can perceive two strands of OHS operating at many workplaces: the management needs to protect themselves from liability so they insist on comprehensive paperwork systems, and workers need to keep their jobs and protect themselves from injury so they develop their own systems of work based on their knowledge of how to do the work within the tensions created by job security versus their own safety (Milles, 1985). Industry's main goal is profit, and the workers main goal is survival. While official policies espouse consultation, workers know that the covert/shadow side of the organisation is where the real values-in-use operate (Egan, 1994) and these do not allow workers to question the system that privileges profits over their health and safety. Workers are dependent on the employer for their job which introduces the harsh reality of a power differential (Williams, 1993, Boyle, 1993, Carson, 1985).

Despite this potentially underlying tension and conflict, consultation can help both management and workers satisfy their needs. It can help management pursue their goal of duty of care by hearing what workers have to say about what is actually happening at the workplace, and it can protect the separate interests of the workers by giving them a voice.

Undermining of workers' opinions

Some actions of management undermine workers and send out messages that their opinions are not really valued, despite the rhetoric of their consultation policy and procedures. For example I regularly hear stories from workers that they consider their opinions not valued because very often their concerns are not listened to, or their reports fall on deaf ears as they disappear into a "black hole". One new employee at a large construction site told me that even though he was told at the induction that he should report all hazards and near misses, when he constantly reported them he was warned by his foreman that 'these will go on your record', indicating that when the next job starts he may be overlooked if he kept this up. Very quickly workers learn what is safe to say and what is unsafe because they have no authority to re-locate control over the processes of production, which is at the heart of the matter (Creighton and Gunningham, 1985), and management always has the final say (Gunningham, 1985). Hence, this version of worker participation (that is with no effective decision making power beyond the right to be consulted) is unlikely to bring about the degree of safety that workers require because of the inherent conflict between health and safety and production pressures (Gunningham, 1985).

Frontline supervisors

Recent research commissioned by WorkSafe Victoria found that one in three supervisors say senior management is not serious about safety and another 9% dismiss the importance of safety in their workplace, demonstrating that the company does not care about safety (Stathis, 2009). This is despite the fact that research suggests that management commitment is of primary importance for improving safety (McKenna, 2006, Walters and Frick, 2000). Management prerogative allows management to punish workers but not vice-versa. While this punishment tends to reduce unwanted behaviours, it does so at the price of also reducing desired behaviours. For example, on a large construction site management would send offending employees who exceeded the site speed limit back for an OHS re-induction to the site. Symbolically this is treated by workers as a sign to not rock the boat, which can be generalized to not making suggestions for fear of victimisation. Imagine if the organisation's response was different: for example, imagine if they critically and reflectively looked at their management practices that encouraged production and speed and tried to understand how this impacted on employees rushing.

Masculine workplace culture

The building and construction workforce historically has been and still remains predominantly male. The work is very physical and requires people to create and make tangible material articles. The workplace culture reflects both its maleness and its practical nature. The risk perception of building and construction workers and their approach to risk management is profoundly influenced by this workplace culture. In a study of maleness, Beale (2001) comments 'Risk taking is part and parcel of life as a male'. Men, especially young men, like to take risks, and a masculine culture such as the building industry may promote some risk taking as normal behaviour. In fact, risky behaviour may be seen as heroic and desirable in such a masculine world. Hence, the significance of the dangers faced daily at work can be minimised through a stoic male paradigm and may explain some reason why men may not speak up about dangers at work.

Poor quality OHS inductions and training

Inductions and training that require the workers to sit in the training room and listen to the trainer telling them the things the organisation wants them to know sets the scene for an introduction into a workplace that does not value consultation and participation when important things are discussed. These pedagogic practices reproduce the 'power structures' (Merriam and Caffarella, 1999) of society that they learned in school and are now being reinforced in the workplace. It creates the initial impression that my voice is not worthwhile, that I have nothing really to say. It adds to the weight of schooling that teaches us to be quiet, unassuming and do what we are told. Oh yes, and then at the end of the induction the trainer says 'Any questions?', and of course, very rarely anyone will ask.

METHODOLOGY

The research methodology for this project was based on a qualitative theoretical framework because it was felt that, being exploratory, a quantitative perspective may have had difficulty in allowing for attitudes to be made explicit. The qualitative approach allowed for the participants to freely express their views in their stories. Whereas positivist research stresses statistics and correlations, I am interested in how people understand their lives, what meanings they attach to their experiences, and how these influence the decisions and actions they take.

The information presented as evidence in this paper was primarily gathered from workers (5 managers and 27 employee/subcontractor construction tradespersons and/or laborers) who attended 4 separate 4-day OHS consultation training courses for members of OHS committees. This training was treated like focus groups in which the participants explored their issues within the framework of the training. The informants were from 6 different OHS committees, each committee representing the workers from a different site – 3 road building, one bridge, and two large civil works building projects. About 800 workers (almost 100% male) were employed across the 6 sites. Other data was also gathered from conducting 2 workplace inspections, reviewing OHS documents such as safe work method statements, policies, procedures and OHS committee agendas/minutes; it also included attendance at 4 OHS committee meetings. Each day after the courses I wrote summaries of the stories in my journal and attempted to make sense of them, using their own words as much as I could.

The reliability and validity of the results is strengthened by my long association with the industry. As I have worked in the construction industry for almost 20 years as a tradesperson it was very difficult for the study participants to mislead me or deceive me, or to gloss over things. I know what questions to ask to permit them to reflect deeply on their observations.

RESULTS AND DISCUSSION

In this section I give examples from my focus groups, using the words and stories of the participants to demonstrate the complexities involved in turning construction workers into OHS committee members who have the desire and ability to speak up effectively, especially when the culture and structure of the industry struggles to change enough to readily facilitate the process.

Example 1

A machine operator on a large construction site was elected by his team to represent them on the OHS committee. He reluctantly accepted – he believes in the value of a safe workplace because of several brushes with serious workplace injuries (both to him and others). He is a shy person who does not easily speak up in formal public gatherings, such as tool box talks (team safety meetings) facilitated by ‘the boss’. However, his new role invites him to speak up; he wants to speak up; he learned and practised speaking up in a safe training environment, but he struggles with speaking up at work. According to him, it’s not so much his shyness that is the barrier, but rather the teasing from his team, who (jokingly – but it still hurts and threatens to make him an outsider) call him a suck up and accuse him of colluding with the boss. They taunt him that he now gets time off work when he is out of his machine and talking. He now must see himself as verbal, as a talker, a communicator, a negotiator, an active listener and as a mediator between his team and the powerful management hierarchies. It is difficult for him to maintain his new identity of the OHS rep and still be accepted as one of the team. His new role appears to give him access to more power and control: he is invited to have an opinion, he is invited to try to influence decision making, and he trembles with the tension created by this potential.

Example 2

Another construction worker tells the researcher that he sees no hope of addressing his safety concerns because he is a ‘steelfixer’, and steel fixers get a bad back; and he has terrible RSI in his right hand and arm from repetitive use of his wire twisting pliers. He is resigned to his fate with a what can you do? attitude. He feels powerless to change as there is no obvious career path for the skilled, barely literate steel fixer. He gains his personal power from doing a good job and having *fun with my mates*. However, this person too has accepted nomination as his team’s OHS rep on the safety committee. Not only does he feel powerless to stop his work practices and tools from damaging his body, he now must use the new (to him) technology of the written word. Yet, when asked if he would help a team mate fill out a hazard report form, he said *How could I; I never have any pen and paper!* This new technology of the contemporary construction site is not his technology. His engagement with his new role may be as a fringe dweller, a peripheral participant in which he self marginalises.

Example 3

New members of the OHS committee leave the course full of enthusiasm and new ideas to implement in their workplace. How they are met at a personal level at their workplace will influence how successful they are at maintaining their enthusiasm and influencing change that results in safer workplaces. For example, some of the participants in one course were having difficulty getting the full support of management for their opinions. Part of their function is to conduct safety inspections of the workplace, and to report the results to an OHS committee meeting. The first inspection these newly trained reps conducted was subtly discouraged by middle management (the foreman), questioning the amount of time the workers would need to complete the task. Then, at the last minute, the same foreman said he was too busy to participate, and became passively uncooperative. They learned that, in their immediate boss's opinion, their role was not valued. However, their commitment sustained them over this first hurdle, and they persevered to conduct the inspection. Half way through, they encountered a senior manager, who was very supportive and stopped what he was doing to accompany them for the rest of the inspection. Now they were in a dilemma – their immediate boss was unsupportive and the big boss was supportive: how do they negotiate a safe path between the contradictory discourses? Even though the senior manager has more authority, their foreman has more direct power over them, and he can make their life a misery. They admit to me that if they want to *'survive'* they must tread very carefully. They got such a surprise that being an OHS rep was such a political process.

Example 4

There were many such stories of (both passive and active) resistance from management. A formworker who now feels empowered to request proper scaffolding is told by the boss we'll look into it, with two weeks going by with still no answer, even though this worker knows he can refuse to do dangerous work he wouldn't dare because he knows that he will be overlooked on the next job for being a troublemaker. The workers become suspicious and powerful rumours circulate through the grapevine encounters that the bosses get big bonuses if they can finish ahead of schedule and under budget. The workers feel that their bodies are being put at risk to benefit an already privileged group who are not exposed to the same risks as them. The company makes a profit at the expense of the degraded bodies of the workers. And this degradation is accelerated through safety shortcuts necessitated through poor project management. The OHS reps wonder how they can rectify this situation when they are denied any real authority or power. The OHS reps are caught now between their new found OHS knowledge and skills, the official discourse of company safety policy, management lack of support and fellow worker demands of both offering and withdrawing emotional support.

Example 5

The formworkers and steel workers lament that they are forced to walk over rocky and uneven surfaces and endure ankle and/or knee injuries to save on the cost of smoothing it out with truck loads of fine gravel. There are symbols of power involved – the bosses have smooth ground and air conditioned offices, the workers do not. The workers know their place and accept (and expect) the physical manifestations of these power imbalances that treat them like they are less important, and they do not clamour for improvements. These symbols can be thought of as techniques of domination and a subtle message that management does not value the workers' opinion. If your opinion is ignored often enough, you will stop giving it.

Example 6

The management of OHS can be seen as a technology of power where employees perceive that they are being held responsible for their own safety. So often I hear workers complain that management is transferring liability to them by getting them to sign off on inductions, safe work method statements (swms), and other forms of written knowledge. The workers often sign without actually understanding what they are signing. The extra paperwork is a symbol of power and it is being used as a form of control. In the end, the worker has signed many pieces of paper to say they know and understand something. The knowledge that they have done this erodes their confidence to speak out against practices that hurt the body. The paperwork takes on power and control. And, like in Foucault's exploration of Bentham's Panopticon, the workers become the guards and enforcers of this power as no one is permitted into their own sphere of control until they have signed the bits of paper. They are doing all this not because they believe in it, but because they and their bosses are under the gaze of the Other, and the Other is WorkCover (the statutory authority administering OHS). Getting people to sign helps them demonstrate to the Other that they have complied with legislation and is perceived to reduce their liability. However, These documents are perceived as doing very little to improve safety. For example, when I studied the swms for steel fixing there was no mention of the constant bending and repetitive use of pliers. When I asked the steelies why they don't suggest to have it included they just shrugged their shoulders because they know that under present arrangements there are no alternatives. Still, they sign.

Example 7

In this essay I am trying to describe the discord emerging in OHS consultation, especially in the construction industry. On the face of it, employers do set up OHS committees, and the OHS reps do undertake the compulsory training. However, the effectiveness of this system is undermined by several factors. OHS consultation is designed to empower workers, but it often does not because workers are often disempowered through the management practices on site. Many trade and labouring jobs on site offer limited decision making opportunities; e.g. engineers decide on the type and position of the steel that is 'placed' by the steel fixers. That is, in general, the trades/labourers do the work while management make the decisions that affects what work they do. It is very difficult to become a creative and articulate problem solver and risk manager when you are usually only expected to do as you are told.

Example 8

OHS reps often feel penalized for diligently carrying out their role, which reduces their motivation. E.g. newly elected committee reps conducted a site safety inspection and came up with a score of 68% compliance (using the in-house scoring mechanism). The supervisor was horrified because his KPI's require an average of > or = 85%, which they believe is only possible by being blind to some things. They got a roasting from the boss, who accused them of being troublemakers. He took these results and changed them to demonstrate to senior management that his target was being achieved. They believed that he compromised their safety to look good to the auditors. They became discouraged and lost belief in the system. Imagine the difference if their score was greeted with a 'terrific', and 'thank you!' response, and they were seriously invited to suggest improvements that were implemented.

Example 9

Not all employees believe in the effectiveness of one Council's risk management and risk assessment strategies. A story I was told by two employees during an audit interview illustrates this: When the risk assessment program was being rolled out to all the workgroups, the concreters came up with a residual risk score of 2 for their job, using WorkCover's matrix. They arrived at this score by combining a severity of Long Term Injury with a likelihood of Likely. This result is described by Council as unacceptable by Council's OHS management system, and a risk score of 2 results in the following treatment: 'Work activities must be suspended immediately until hazard can be eliminated or controlled or substituted for a lesser hazard'. That is, the concreters could no longer continue with that particular activity until the risk was better controlled. A manager met with the concreters, who would not budge from their score. They were told that Council cannot sanction work with that high a risk, and may have to consider contracting out the work. With this unofficial 'threat' to their jobs in mind, the concreters reluctantly moved the score to a 3. This created suspicion of the motivation of management and an example of focusing on the numbers without dealing with the real risk. When this same team is consulted about their risks in the future they will not honestly engage because they no longer believe in the process.

Example 10
On one large site the workers were told that this company values safety before profits. They were told that a proposed concrete pour was brought forward 2 days and now had to have the formwork and steel finished in time. They reacted by suggesting that this could not be done safely and requested that the pour be kept to the original schedule. They were abused by they foreman for that area who aggressively yelled at them 'JUST DO IT!' This eroded their faith in any chance of an effective consultation system.

RECOMMENDATIONS AND IMPLICATIONS

It is not simple or easy to change this situation because it is changing the tide of history. I offer the following suggestions that, if implemented, will help.

1. Train the OHS representatives in the skills of consultation. This means that the trainer needs to use a democratic and consultative approach throughout the training. The training model needs to mirror the consultation process. The trainer needs to create a safe place and space where the participants can share ideas, beliefs and attitudes with others to facilitate the social construction of meaning. The interaction among participants will simulate the workplace if they are challenged and forced to justify their suggestions and allowed to practise listening, speaking, problem solving and root cause analysis, based on the real issues of their workplace.

2. A challenge for the trainer is to teach the participants to use a different language to describe OHS problems at work so as to open up possibilities for improvement. For example, the rhetorical question 'What can you do?' implies that nothing can be done because the industry is inherently dangerous and there is no other way to do the job. The workers need to learn to reframe this into a statement such as 'Yes, it has been a dangerous industry, but, with careful consideration, we can make it safer'. This positive attitude will give them the hope and impetus to creatively consider ways of controlling hazards at the source.

3. Site supervisors need to become mentors for the emerging OHS representatives – they can nurture the skills needed to speak up, to fill out and contribute to paperwork such as reports, incident investigations, agendas, minutes and site safety inspections. Consequently, supervisors need to lead by example – by paying at least as much attention to OHS and consultation as they do to production and numbers.

4. Best practice workplaces may be able to help employees develop skills in literacy, problem solving, communication, decision making, reflective practice and public speaking. This could be done on "wet days" when workers often pass the time of waiting by playing cards or other non productive activities.

5. Site inductions may be improved by using a questioning approach to the new worker; that is, get them involved and talking. Before boring them with all the things they have heard before, ask them what they think the hazards are on this site, and how they are going to control the hazards and risks they face. Get them to ask you some questions. Make the induction a discussion, and during this discussion, demonstrate your sincerity about workplace health and safety. Ask them if they know about OHS consultation, and what they know about it. Introduce them to the site OHS representative. Let them know that you and/or the site rep want to know any concerns they have for their own or others' health and safety.

6. Senior management needs to walk regularly around the site, talk to workers and be friendly, listen to their stories. If they do report something, stop what you are doing and go and have a look, be interested, and ask them for ideas on what can be done to fix it. Let them report things verbally, and you fill out the incident/hazard report for them. Make sure you take all of these reports seriously; if you don't, they won't. When something they suggested is fixed, go back to tell them and thank them for their ideas. Use the skills of transformational leadership.

CONCLUSION

Management of OHS on construction sites is more effective when workers contribute to the making of OHS decisions through an efficient consultation process. Employers often pay lip service to these legal requirements rather than make real efforts. Construction employees are not used to being a core part of the decision making process, and often do not have the necessary knowledge, attitudes and skills. It will be very difficult to make construction sites safe if we continue to marginalise workers by not training and mentoring them adequately to be able to speak up to become part of the real decision making process.

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SUBCONTRACTING VERSUS HEALTH AND SAFETY: AN INVERSE RELATIONSHIP

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ABSTRACT

The construction industry has an unenviable reputation of being one of the worst industries in the UK in respect of health and safety (H&S) performance. Among other factors, research points to subcontractors' safety behaviour (hence subcontracting) as one of the factors influencing safety performance on construction sites. With 80% of construction work in the UK being subcontracted, clearly it has become imperative to investigate this inverse H&S-subcontracting relationship. This situation is exacerbated by the increasing complexity of construction technologies which inevitably implies that specialisation will grow and consequently there would be even more subcontracting. Through a critique of the literature on H&S and procurement in the UK, it is shown that this state of affairs is attributable inter alia to the lack of adequate resources among small contractors to enable them invest in H&S, the differences in safety cultures between main and subcontractors and the less familiarity of subcontracted personnel with the inherent safety issues of all site activities due to their specialisations. Indeed it is argued further that this is compounded by the limited time spent on site, a lack of interest in the overall project and the impact of their activities on other operations on site. Beyond creating awareness of the inverse H&S-subcontracting relationship and the key drivers of this phenomenon, critical research questions arising from this phenomenon are examined, setting the premise for research work to expound on the reasons for this relationship and also identify best practice measures to be adopted to mitigate the negative impact of subcontracting.

Keywords: Construction industry, Health and safety, Subcontracting

INTRODUCTION

Research literature indicates that subcontracting grew significantly over the 1970s and 1980s and continues to be practised in several countries (ILO, 2001). It is evident that, in spite of the numerous economic benefits, subcontracting has adverse industrial relations effects on wages, working conditions, bargaining and unions (ILO, 2001; Chiang, 2009). In highlighting the diminution of employment conditions arising from this practice, researchers have identified a parallel link to occupational health and safety and the construction industry has not been left unscathed (Ankrah, 2007; Yung, 2009). As a prelude to a wider study into the inverse subcontracting-H&S relationship, this paper begins by surveying the literature on subcontracting within and outside of the UK construction industry, the aim being to explore its evolution, the rationale for its practice and its association with adverse occupational health and safety outcomes. It then goes further to highlight from the literature the causes of the inverse subcontracting-H&S relationship within the UK construction industry and through a critique points out the scope that still exists for further research by putting forth the emerging research question.

SUBCONTRACTING

Over the last three decades labour markets of several countries including the United Kingdom have undergone significant changes. Notably, the traditional model of long term employment relation between an employer and employee has been supplemented by a variety of forms such as self employment, casual/temporary, part-time and contract/subcontract employment (ILO, 2001; Mayhew and Quinlan, 2001; LFS, 2004). The growth in 'non-standard' or 'atypical' forms of work such as subcontracting was driven by a mixture of economic priorities, technological and regulatory shifts, and increased product market uncertainty which led to management requirements for a more flexible and inexpensive workforce (Hunter *et al.*, 1993). This finding was also corroborated by Bielenski *et al*.(1993; 1999) and more recently by Chiang (2009).

In examining the rationales for the use of subcontracting, literature indicates that the main influencing factors are:

- the ability to fine-tune labour flexibility;
- the ability to rapidly meet changing product market demands;
- the ability to externalise less rewarding and dangerous activities;
- the ability to bargain down labour cost;
- to encourage quicker completion of tasks;
- the transference of financial risk; and
- the avoidance of workers' compensation cost.

(Mayhew and Quinlan, 1997; ILO, 2001; Wong and So, 2002; Chiang, 2009)

Subcontracting is a secondary arrangement to contracting out which generally is the practice where an organisation (public or private) enters into a formal agreement with another for the provision of a particular good or service, with the contractor then being considered as the supplier in the procurement process (Ascher, 1997). Subcontracting, then is defined as the process of subletting the performance of tasks which often affects the employment status of the workers doing the tasks as well as the manner in which those tasks are performed, the structure of control at the workplace and the patterns of regulation (Mayhew and Quinlan, 1997).

Subcontracting in the construction industry

Subcontracting has for some time been an integral part of the construction industry (Stinchcombe, 1959; Eccles, 1981; Lai, 2000). In construction, it usually is the subletting of the execution of a section(s) of an entire project(s) to a contractor(s) who in most cases is a specialist in those works to be executed. This generally takes the form of domestic subcontracting where a principal/main contractor appoints a subcontractor(s), or nominated subcontracting where the project client/clients' representative(s) appoints a subcontractor(s). In construction project procurement, subcontracting is also seen in management contracting (Kwakye, 1997; Harris *et al.*, 2006).
Construction employment trends in Great Britain indicate a progressive increase in self-employment from 1998 to 2007(ONS, 2008). This growth gives indication of the prevalence of subcontracting in the industry. This situation is marked to increase as construction technologies become more specialized and the organizations which carry out those technologies also specialize into subcontracting organizations. Self employment and subcontracting contribute to the proliferation of small production/employment units (Mayhew and Quinlan, 1997; ONS, 2008). Micro and small construction companies constitute over 90% of construction companies in Great Britain, and majority of them obtain work as subcontractors, therefore forming an important group in the supply chain in the UK construction sector (Kheni *et al.*, 2005; ONS, 2008;). Earlier research also indicates that 80% of construction work undertaken by UK main contractors is subcontracted ((Saad and Jones, 1998) cited in Thorpe *et al*.(2003) and Kheni *et al*. (2005)).

OCCUPATIONAL HEALTH AND SAFETY OUTCOMES OF SUBCONTRACTING

In spite of the economic benefits derived from subcontracting, the practice has negative consequences including weakening of bargaining power, non-payment of workers, under-development of human resource skills and loss of job security (ILO, 2001; Chiang, 2009).

Evidently, subcontracting also has adverse effects on occupational health and safety (ILO, 2001; Chiang, 2009). Subcontracting is typically a payment-by-results system where payment is based on the amount of work completed rather than the period of time spent on the worksite. Thus returns are enhanced by the completion of tasks in the shortest possible time, leading to subcontractors pushing themselves hard, working excessive hours, or cutting corners in regard to safety where it impedes production (Mayhew *et al.*, 1997). Pressures to complete a job quickly may be increased where intense competition amongst subcontractors drives down the price of services performed. Work intensification results as the subcontractor's profit must be derived from working harder and longer resulting in occupational health and safety (OHS) outcomes such as fatigue, stress, burn-out and failure or delays in seeking treatment for work-related injuries (Mayhew *et al.*, 1997).

Retrospective evidence from several industries in several countries indicated that there was a high incidence of injuries and fatalities among subcontractors and self-employed. Research by Harrison *et al*. (1989; 1993) in Australia linked subcontracting and self-employment to high incidence of fatalities amongst workers in the transport, communication and agriculture industries. Subsequent reports by Toscon and Windau (1994) and USBLS (1995), both in the USA; Blank *et al.* (1995), in Sweden; and Mayhew and Quinlan (1997), in Australia similarly associated subcontracting with adverse OHS outcomes in industries such as mining, agriculture and transportation.

In the UK a similar situation exists. For instance, health and safety statistics indicate that the rate of fatal injury to self-employed in the agriculture industry from 1992/93 to 2007/08 (HSE, 2007a; 2009) has been approximately twice that of employee. This suggests that the self-employed (a category embracing subcontractors) have a fatality rate of approximately twice that of employees. Evidently, this inverse subcontracting-H&S relationship pervades the construction industry world wide (ILO, 2001).

Occupational health and safety outcomes of subcontracting in the construction Industry

As previously mentioned, subcontracting results in the proliferation of small production/employing units and it is reported by McVitties *et al*.(1997) of the Canadian construction industry that SMEs have a higher frequency of injury than large firms. This is consistent with the findings of Fabiano *et al* (2004), in the Italian construction industry and Jannadi and Al-Sudairi (1998), in the Saudi Arabian construction industry. In other countries such as Spain, Malaysia, Philippine, Poland, Hong Kong and China, subcontracting has similarly been associated with adverse H&S outcomes in the construction industry (Byrne and van der Meer, 2001; ILO, 2001; Wong and So, 2002; Yung, 2009).

Statistics in the UK construction industry indicate a similar trend. Fatal accidents by employer size and site size from 2000/01 to 2007/08 indicate that there are more fatalities among micro to small contractors and small sites-which are also dominated by micro and small contractors (HSE, 2009). Although small construction companies employ 36% of the construction workforce, they account for 67% of fatalities amongst workers on construction sites (HSE, 2007b). They are therefore responsible for a disproportionately large number of fatal injuries. Although the Health and Safety Executive (HSE) does not collect data on major injuries according to the size of company or project, there is usually a close correlation between the number of fatal and major injury accidents (HSE, 2007b). Research by Mayhew and Quinlan (1997), HSL (1999), Loughborough University and UMIST (2003) and Ankrah (2007) also acknowledge the adverse H&S outcomes due to subcontracting in the UK construction industry.

Causes of the inverse subcontracting-H&S relationship in the UK construction industry

In order to redress the inverse subcontracting-H&S relationship, it is critical to understand the causative factors. Literature indicates the following enumerated factors:

1. The proliferation of smaller production/employing units which lack the resources to invest in occupational health and safety hence resulting in adverse H&S outcomes on projects where they are engaged (Mayhew and Quinlan, 1997; HSL, 1999). This is in agreement with the findings of McVitties *et al*. (1997), Champoux *et al*. (2003) and Fabiano *et al*. (2004) in their studies of firm size and occupational health and safety outcomes in other construction industries. Research by Chiang (2009) in the Hong Kong construction industry also highlighted this factor.

2. Fierce competition for contracts among subcontractors resulting in unreasonable cost minimisation in order to win contracts at the expense of due consideration to H&S (Mayhew and Quinlan, 1997; HSL, 1999; Loughborough University and UMIST, 2003). Fabiano *et al* (2004) in their study also mentioned that small firms often make the saving on safety measures one factor of competition and survival on the market.

3. Ambiguity about responsibilities and unclear work relationships arising from complex subcontracting relationships on site (Mayhew and Quinlan, 1997; HSL, 1999; Loughborough University and UMIST, 2003).

4. Inadequate communication and teamwork and the intense competition among contractors arising from fragmentation of the workforce on site (Mayhew and Quinlan, 1997; HSL, 1999; Loughborough University and UMIST, 2003).

5. Inadequate regulatory control: for instance the underperformance of the CDM 1994 and the inadequate H&S inspectors to enforce legislative requirements (Mayhew and Quinlan, 1997; HSE, 2007b; Mathiason, 2008).

6. Less familiarity of subcontract personnel with the inherent safety issues of all site activities ((Maurno, 1992) cited in (HSL, 1999), (Hill and Ainsworth, 2001)). This situation is exacerbated by the transient nature of construction projects and even more so by the brief periods spent by subcontractors on site within those transient project durations.

7. Differences in safety cultures between main contractors and subcontractors (Loughborough University and UMIST, 2003; Ankrah, 2007; Ankrah *et al.*, 2007), with Loughborough University and UMIST (2003) highlighting that subcontractors have a poor safety culture thus accounting for poor safety performance on projects where they are engaged.

The factors listed above and the sources from which they have been extracted clearly demonstrate that the inverse subcontracting-H&S relationship has been the subject of much research. More importantly, they provide an opportunity to critically evaluate the effectiveness of measures that have been developed to minimise adverse H&S outcomes within the industry in response to these underlying causative factors.

Mitigating the adverse H&S outcomes of subcontracting

From the influence network for health and safety in construction illustrated over (Figure 1) , Bomel Limited (2007) points out that the regulatory influence is the most significant environmental level influence on construction health and safety compared to the other environmental level influences such as the market (which is the driver of subcontracting).

Generally since the beginning of the 20th century, regulations have been put in place to control activities and address specific problems on construction sites (HSL, 1999). The construction regulations of 1961 and 1966 which were made under the Factories Acts of 1937, 1948 and 1961 primarily provided H&S control of activities (HSL, 1999). They however did not provide guidance on health and safety management which according to the influence network is the most significant strategy level influence (Bomel Limited, 2007). In 1974, the Health and Safety at Work etc Act (HSWA) 1974 was introduced to provide a comprehensive and integrated single piece of legislation dealing with the health and safety of people at work and the protection of the public from work activities (Hughes and Ferrett, 2008). The radical difference between the HSWA 1974 and all preceding Health and safety legislation is the emphasis the Act places on individuals and their duties rather than on the place of work (Joyce, 2001). The HSWA 1974 represents a key progression in the enhancement of H&S in that rather than the prescriptive approach which was adopted by the preceding legislations, the Act is based on principles designed to bring about a greater awareness of the problems associated with H&S issues (Joyce, 2001).The Act also established the Health and Safety Commission and Health and Safety Executive, which recently under the Legislative Reform (Health and Safety Executive) Order 2008, have been merged into a unitary body called the Health and Safety Executive. Regulatory proposals from the HSE (formerly the HSC) to the Secretary of State are enacted into law by the UK Parliament for implementation. Through this legal arrangement several construction H&S regulations among others have emerged from the HSWA 1974 all with the aim of mitigating adverse H&S outcomes on construction projects. One such key construction H&S regulation made under the HSWA 1974 which touched on the H&S issues of subcontracting as part of a broad health and safety framework, with a focus on management is the Construction (Design and Management) Regulations 1994 (CDM 1994). Prior to the CDM 1994, the H&S regulation that spearheaded H&S management at work places (including construction sites) was The Management of Health and Safety at Work Regulations 1992 which was subsequently amended under The Management of Health and Safety at Work (Amendment) Regulations 1994 and finally revoked by The Management of Health and Safety at Work Regulations 1999.

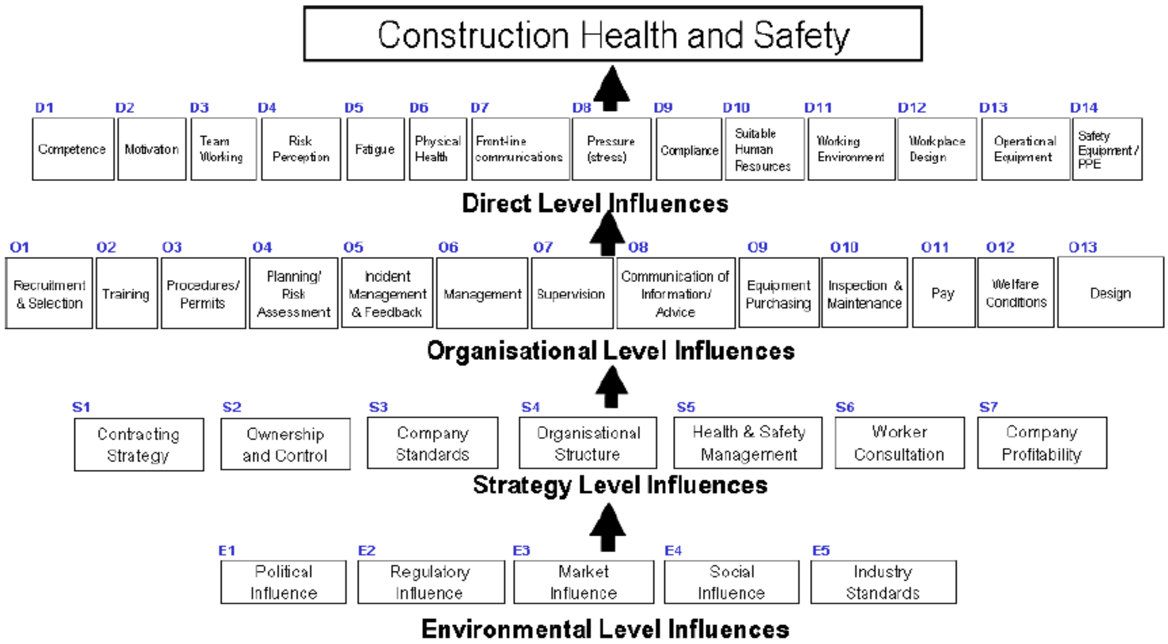


Figure 1: Influence network for health and safety in construction (Bomel Limited, 2007).

The CDM 1994 which came into force against the background of high accident incidence rates during the 1980's (the period around which subcontracting also grew significantly) provided a framework for H&S management in construction (HSE, 1996). The CDM 1994, with an emphasis on team work created specific roles for clients, planning supervisors, designers, principal contractors, and contractors with the common aim of achieving adequate levels of health and safety during construction (HSE, 1996). The CDM 1994 however underperformed in terms of competence assessment, fostering team work, and clarification of duties (Wright, 2003; HSE, 2006; Bomel Limited, 2007) all of which are issues pertinent to subcontracting and have H&S implications. Under the Construction (Design and Management) (Amendment) Regulations 2000, the CDM 1994 was amended. The amendment was however not in response to its underperformance. In 2007, the underperformance of the CDM 1994 finally yielded the Construction (Design and Management) Regulations 2007 (CDM 2007) which seeks to address the shortfalls of the CDM 1994 so as to achieve improved levels of H&S in Construction.

Also, as a complement to the regulatory framework, the HSL (1999) in a study of the impact of procurement and contracting on health and safety in the construction industry and other industries, developed a generic model for the H&S management of contractors. The model emphasizes the linkage of four main points as necessary in the management function:

- the health and safety policies of both the host employer and contractor in combination with the work method statement should form the basis for the development of a site specific framework for management;

- training needs should be clearly identified and acted on, particularly where there is unfamiliarity with the site or process and also where a contractor is being used for the first time in the host company;
- the need for empowerment of individuals, giving authority, for example, to stop unsafe acts and enforce disciplinary procedures; and
- the establishment of communication links between the host company and the contracting organisation, including the provision of a forum where contract employees may raise health and safety concerns.

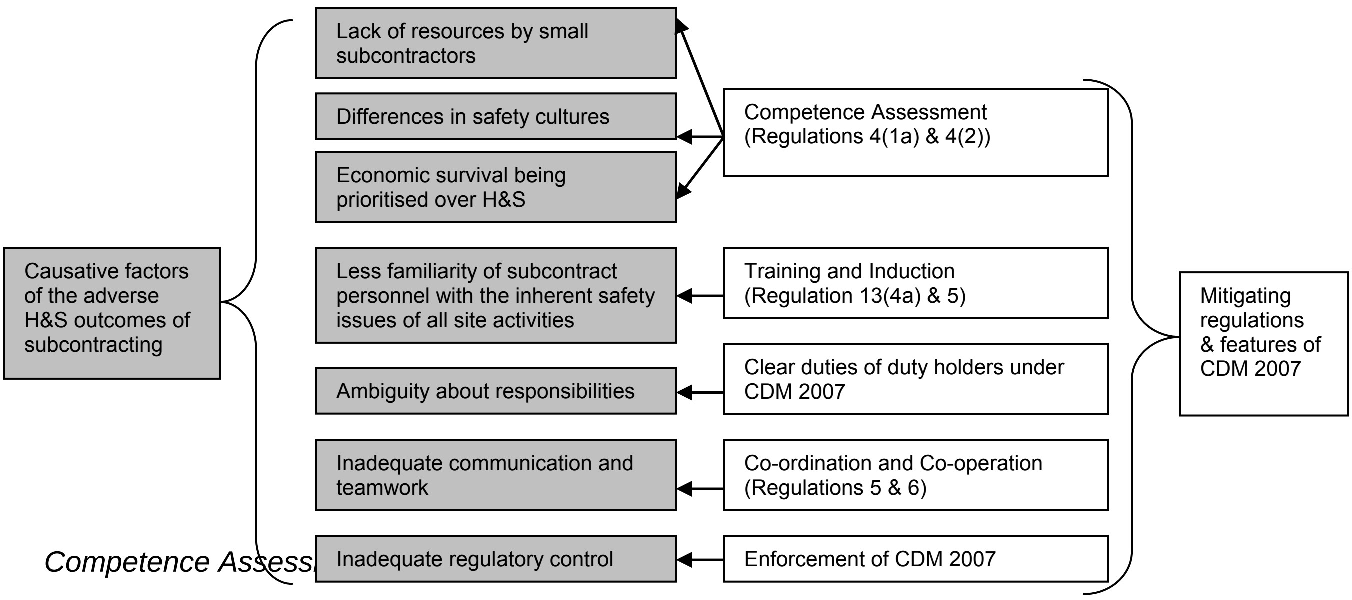
It is important to note that the CDM 2007 with its aim of integrating H&S into the management of construction projects comprehensively embodies the above requirements of the generic model (HSC, 2007). The CDM 2007 thus represents a critical mitigating force against the adverse H&S outcomes of subcontracting.

IMPLICATIONS FOR FURTHER RESEARCH

It is startling to note that in spite of all the mitigating efforts, the reports of this inverse relationship have persisted over the years (see for instance HSL (1999), HSE (2009), Ankrah *et al.* (2007) and Donaghy (2009)). Anecdotal evidence, recent statistics and research reports continue to link subcontracting to adverse H&S outcomes. Although recent statistics show improvement in construction H&S, safety experts have also been quick to point out that the improvement could be linked to the recession which has resulted in a downturn in construction activity (Hoyle, 2009). Notwithstanding this disputable improvement, it is significant to note that the 2008/09 provisional rate and number of fatal injuries for the construction industry self-employed (a category embracing subcontractors and also inundated by micro and small size construction firms) exceeds that of 2007/08, the period when the CDM 2007 came into force (HSE, 2009). The recent Donaghy report (Donaghy, 2009) on the underlying causes of construction fatal accidents has also mentioned the adverse health and safety implications of subcontracting. Although these do not necessarily point to a failure of the CDM 2007 (as a critical mitigating force), justifiably, questions regarding its practical on-site effectiveness in redressing this inverse relationship could be raised.

A fundamental research question arising from the above context is the question of the extent to which the CDM 2007 effectively addresses this inverse relationship on projects, particularly projects where complex subcontracting relationships exist and projects where the supply chain is constituted in the main by micro to SMEs. To answer this query it is crucial to identify and map out the regulatory provisions of the CDM 2007 that potentially mitigate the causative factors of the inverse relationship and also lay out an outline for evaluating the effectiveness of the identified mitigating regulatory provisions.

Mitigating regulatory provisions and features of the CDM 2007



Competence Assess

Figure 2. Mitigating regulations and features of the CDM 2007.

A critical review of the CDM 2007 reveals the following potentially mitigating regulatory provisions illustrated above in figure 2.

Formal competence assessment has long been a feature of the construction industry (The Consultancy Company, 1997). Under the CDM 2007 Regulations 4(1a) & 4(2), the requirement for competence assessment continues to be enforced. From the previously mentioned influence network (Figure 1), competence and risk perception are ranked as the most significant direct level influences on construction H&S (Bomel Limited, 2007). The workshop discussions leading to the development of the influence network revealed that competence varies widely across the industry. Size of organization and type of profession were considered to be the key differentiators, with large companies and more technical professions showing higher levels of competence on average (Bomel Limited, 2007). This implies that averagely micro and small construction companies (majority of which obtain work as subcontractors) comparatively show lower levels of competence. This is worsened by the often unregulated subcontracting chain by the principal contractor or client (jzcarpenter limited, 2006). With competence being a direct level influence on construction H&S it is only consequential that construction companies employing up to 15 workers (i.e. micro to small construction companies) account for 67% of all fatalities amongst workers on construction sites (HSE, 2007). Regulating the subcontracting chain through effective competence assessment could mitigate the causative factors of lack of resources by small subcontractors, difference in safety cultures and economic survival being priorities over H&S. Through effective competence assessment of the subcontracting chain, a form of a H&S minimum acceptable threshold requirement, relative to the needs of projects and proportionate to the risks, size and complexity of the construction works will be set. This will thus create a leveled playing field during tendering by subcontractors, where no subcontractor will have an undue competitive advantage in terms of under pricing for H&S. Through adequate pricing for H&S, subcontractors could be better placed to invest in H&S. Investing into and implementing H&S management will eventually yield improvement in their H&S cultures as H&S culture embodies H&S management (HSL, 2002; Hughes and Ferrett, 2008).

Training and Induction

CDM 2007 Regulations 13(4a) & 5 places the legal requirement on contractors to conduct the necessary training and induction for their workers. This provision in the CDM 2007 once effectively done should mitigate the causative factor of the less or unfamiliarity of subcontract personnel with the inherent H&S issues of site activities.

Co-ordination and Co-operation

Regulations 5 & 6 of the CDM 2007 impose on all duty holders including contractors the requirement for co-ordination and co-operation. Effective co-ordination and co-operation among contractors implies the need for effective communication and these together engender and enhance teamwork (Dickinson and McIntyre, 1997; Baiden, 2006). The co-ordination and co-operation requirement could therefore mitigate the problem of inadequate communication and teamwork arising from fragmentation of the workforce due to subcontracting.

Clear Duties of Contractors

The CDM 2007 delineates clear duties for contractors and other duty holders for the management of H&S throughout construction projects, from the design concept onwards (HSC, 2007).The adequacy of this feature of the CDM 2007 should potentially mitigate the causative factor of unclear H&S responsibilities arising from complex on-site subcontracting relationships.

Enforcement of CDM 2007

Following several discussions and research which revealed the underperformance of the CDM 1994, the CDM 2007 was introduced to rectify those shortfalls in order to achieve improved H&S in construction. The improvements/changes reflected in the CDM 2007 buttressed by its effective enforcement on all project sites (small and large) by the HSE inspectors and the local authorities should contribute to mitigating the adverse H&S outcomes of subcontracting.

Having outlined the potentially mitigating regulations of the CDM 2007 for each of the causative factors it is also essential to lay out an outline for evaluating the effectiveness of their on-site implementation.

Outline for evaluation of effectiveness

Figure 3 illustrates a proposed simplified outline for evaluating the effectiveness of the mitigating regulations.

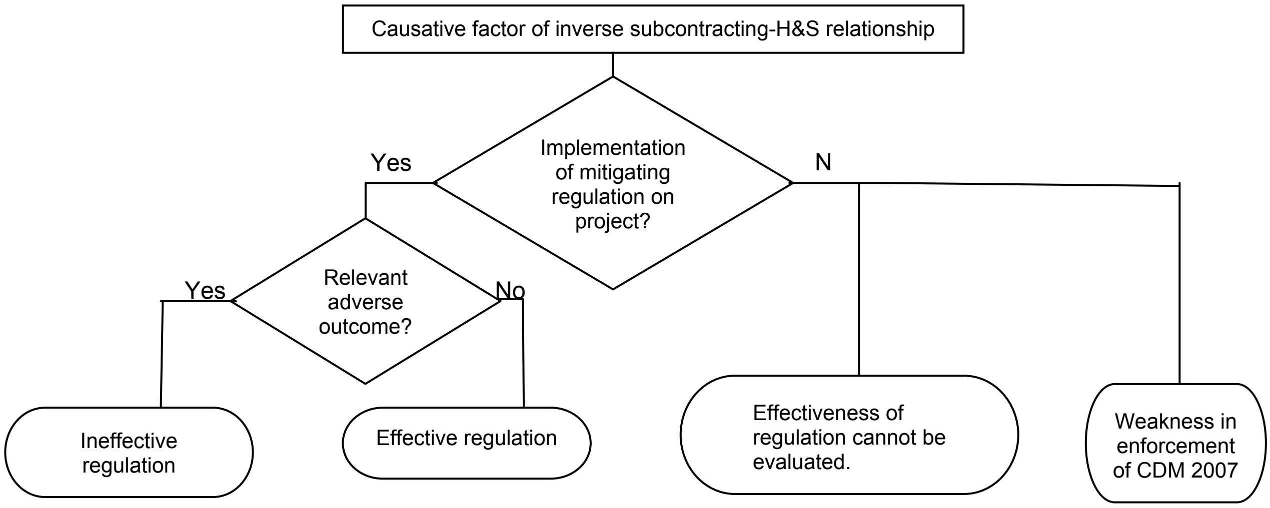


Figure 3: Outline for evaluation of effectiveness.

For each causative factor, the effectiveness of the corresponding mitigating regulation will be assessed as illustrated in the outline. The CDM 2007 Approved Code of Practice (ACOP), titled, “Managing Health and Safety in Construction”, provides practical guidelines for complying with the duties set out in the regulations. The guidelines also represent minimum requirements to be adhered to in complying with the regulations. Any adopted alternative implementation method should therefore be equally effective or better than that recommended by the ACOP as stated in the Health and Safety at Work etc Act 1974. The ACOP thus constitutes a good basis for determining whether or not a mitigating regulation is implemented or complied with. The evaluation of the on-site effectiveness of a mitigating regulation in addressing a corresponding causative factor will be based on the H&S outcomes as the ultimate aim of the CDM 2007 Regulations like other H&S regulations is to achieve improved H&S outcomes (HSC, 2007). The occurrence of a relevant adverse outcome(s) in spite of the implementation of a mitigating regulation would imply that the regulation is not adequately effective in addressing the corresponding causative factor. Conversely, the non-occurrence of a relevant adverse outcome following the implementation of a mitigating regulation would imply an effective mitigating regulation.

A mitigating regulation would be considered not implemented if the ACOP for that regulation is not complied with and also if no equivalent or better alternative method is implemented in compliance with the regulation. In such a case, the effectiveness of the mitigating regulation can not be evaluated. Such a case would also constitute a non-compliance with the CDM 2007 and that could be linked to a weakness in the enforcement of the CDM 2007. However, the non-occurrence of an adverse outcome following the non-compliance with a mitigating regulation would imply that whatever alternative method that may have been implemented could possibly be an effectively adequate mitigating measure. Such a measure would then be the subject of further investigation to establish its suitability and effectiveness as a mitigating measure. Where there is a relevant adverse H&S occurrence(s) in the case of non-compliance with a mitigating regulation, then whatever alternative method that may have been implemented would be considered ineffective. Having laid out the potentially mitigating provisions of the CDM 2007 and the evaluation outline the challenge then is to apply the outline on projects to assess the effective of the mitigating regulations of CDM 2007. Clearly, such a investigation carried out through an applied industrial research, as suggested by Gilbertson (2008) in his assessment of the CDM 2007, will be very helpful in that, even as the CDM 2007 is still in its early periods of implementation, the research will before long aid in identifying possible limitations of the CDM 2007 in addressing the H&S problems associated with subcontracting.

CONCLUSION

The consensus of research findings and statistics, identified through the review of subcontracting and H&S indicates that subcontracting results in adverse H&S outcomes: a situation which also prevails in the UK construction industry with severe ramifications. Beyond highlighting the existence of this relationship in the UK construction industry, the causes/reasons for the relationship have been put forth by researchers and efforts also made to address it. However, unfortunately, the tide has generally remained unturned as this relationship continues to linger in the UK construction industry. It will blatantly be a great disservice to the UK construction industry if it is assumed that the CDM 2007 is definitely up to its task and therefore ignore the urgency and need to conduct industrial research to assess the extent to which the CDM 2007 provisions address this relationship practically on projects. The key research question emerging from the critique is a clear indication of the knowledge gap which forms substantial justification for further industrial research to address this inverse relationship. Such research will help significantly in the quest to improve H&S performance in the UK construction industry and even beyond.

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